US 20260194986A1

(19) **United States**

(12) **Patent Application Publication**

Reisman et al.

(10) **Pub. No.: US 2026/0194986 A1**

(43) **Pub. Date: Jul. 9, 2026**

(54) **ADJUSTING VOLUME AT A PAIR OF SMART GLASSES AND CONTROLLING A USER INTERFACE OF AN APPLICATION USING MULTI-STAGE IN-AIR HAND GESTURES DETECTED VIA A WRIST-WEARABLE DEVICE, AND SYSTEMS AND METHODS OF USE THEREOF**

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(21) Appl. No.: **19/559,871**

(22) Filed: **Mar. 6, 2026**

Related U.S. Application Data

(63) Continuation of application No. 19/239,748, filed on Jun. 16, 2025, which is a continuation of application No. 18/364,396, filed on Aug. 2, 2023, now Pat. No. 12,360,608, which is a continuation-in-part of application No. 18/359,855, filed on Jul. 26, 2023, now Pat. No. 12,436,620.

(60) Provisional application No. 63/399,187, filed on Aug. 18, 2022, provisional application No. 63/399,188, filed on Aug. 18, 2022, provisional application No. 63/414,880, filed on Oct. 10, 2022, provisional application No. 63/414,884, filed on Oct. 10, 2022.

Publication Classification

(51) **Int. Cl.**

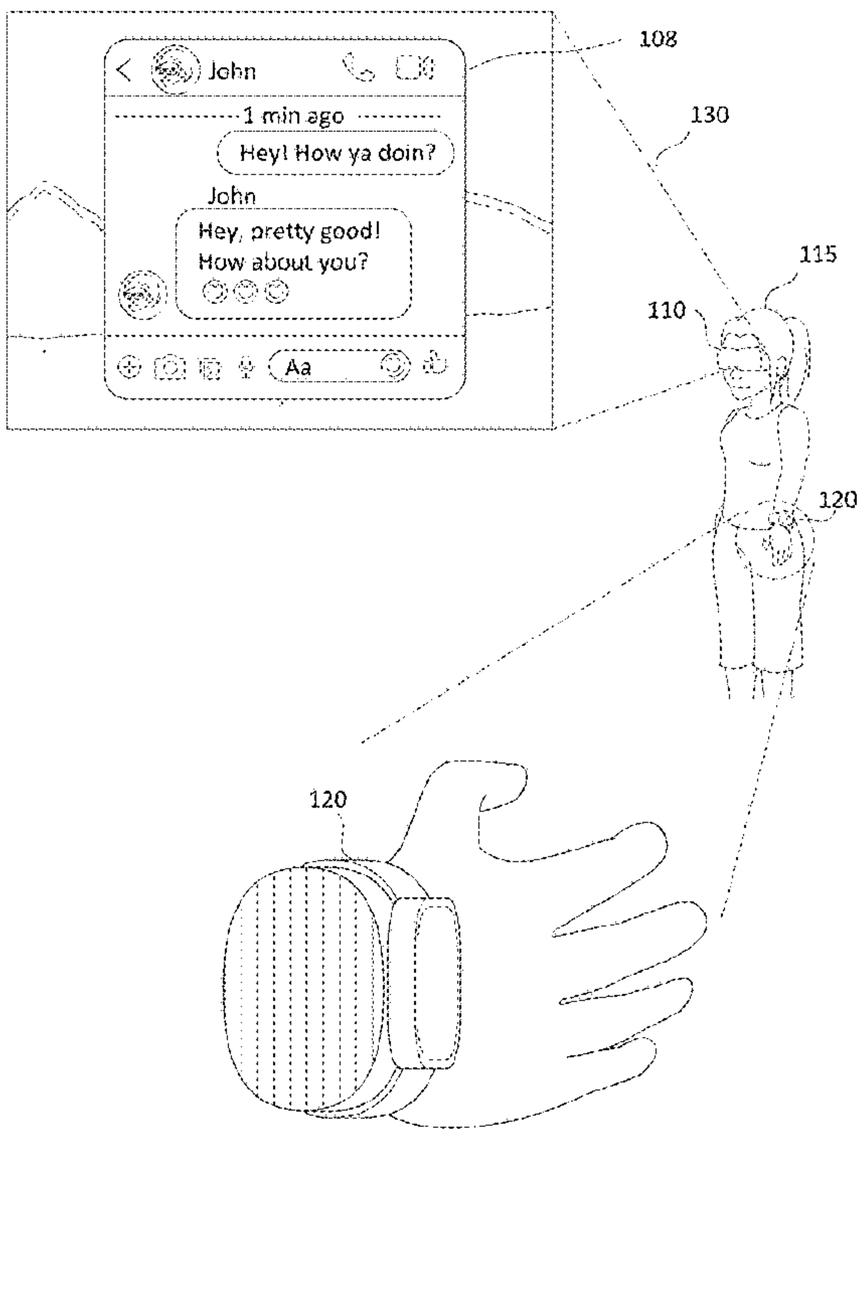
G06F 3/01	(2006.01)
G06F 3/0482	(2013.01)
G06F 3/0485	(2022.01)
G06F 3/0487	(2013.01)

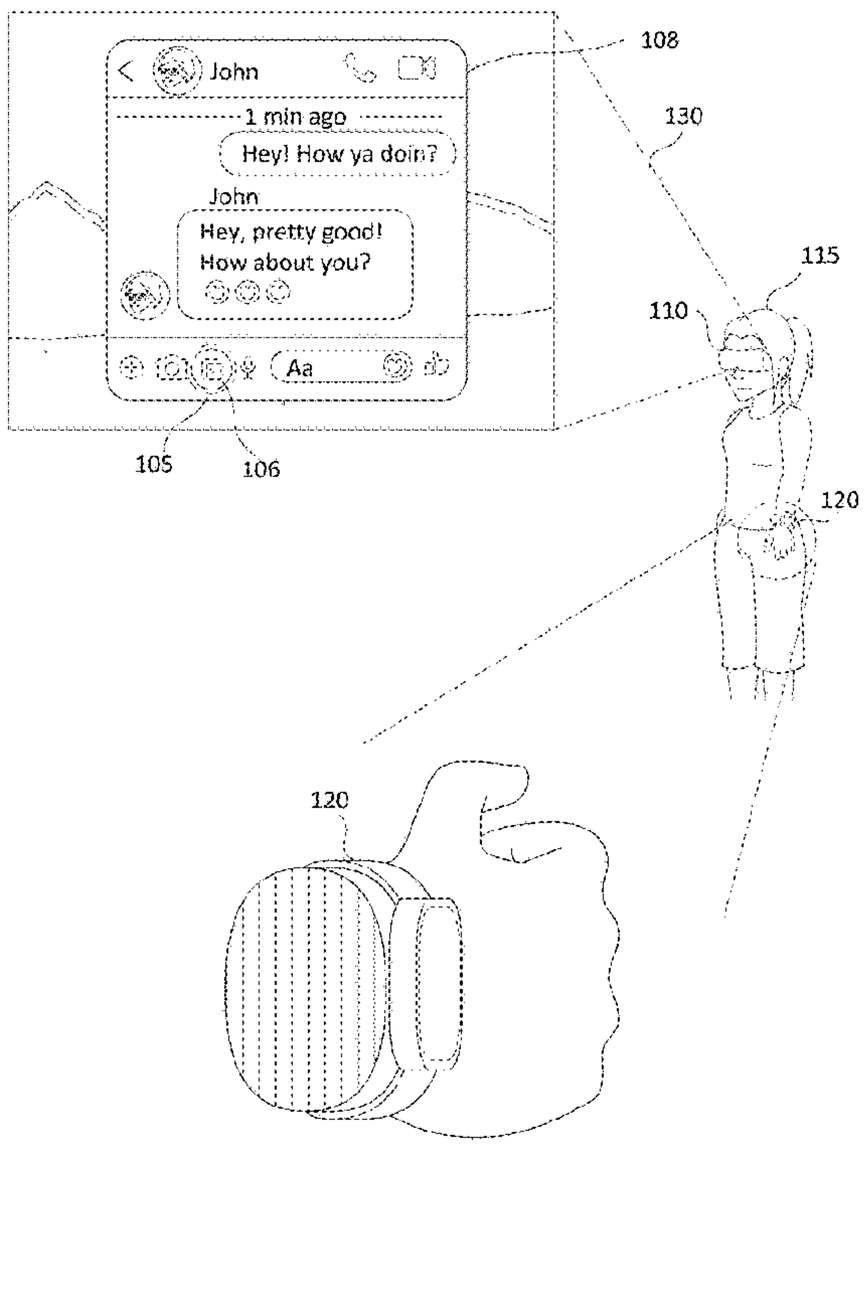
(52) **U.S. Cl.**

CPC ***G06F 3/017*** (2013.01); ***G06F 3/015*** (2013.01); ***G06F 3/0482*** (2013.01); ***G06F 3/0485*** (2013.01); ***G06F 3/0487*** (2013.01)

(57) **ABSTRACT**

A method for using a multi-stage in-air hand gesture to adjust volume at a pair of smart glasses and control a user interface of an application. The method includes causing display, at a pair of smart glasses, of a user interface for an application. The method further includes receiving data from a multi-stage in-air hand gesture from sensors of a wrist-wearable device and determining that the user is performing a pinch gesture for a threshold amount of time and a wrist-rotation gesture in a first rotational direction while the pinch gesture is maintained, and based on this determination, increasing a volume for speaker output at the pair of smart glasses. The method further includes determining the user is performing another pinch gesture for less than the threshold amount of time, and in response causing performance of an operation at the user interface for the application while maintaining the increased volume.





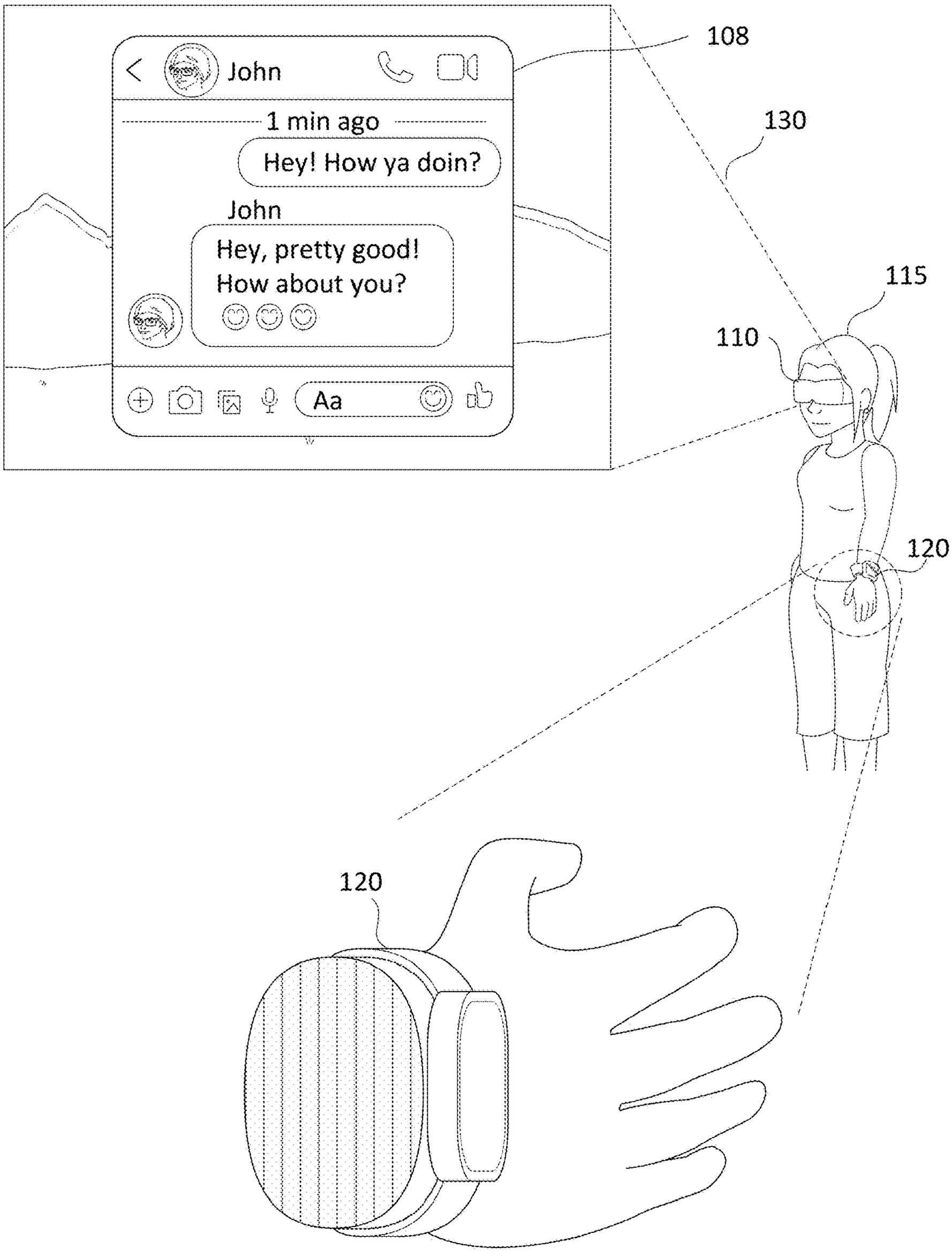

John
1 min ago
Hey! How ya doin?
John
Hey, pretty good!
How about you?
Aa
108
130
115
110
120
120

FIG. 1A

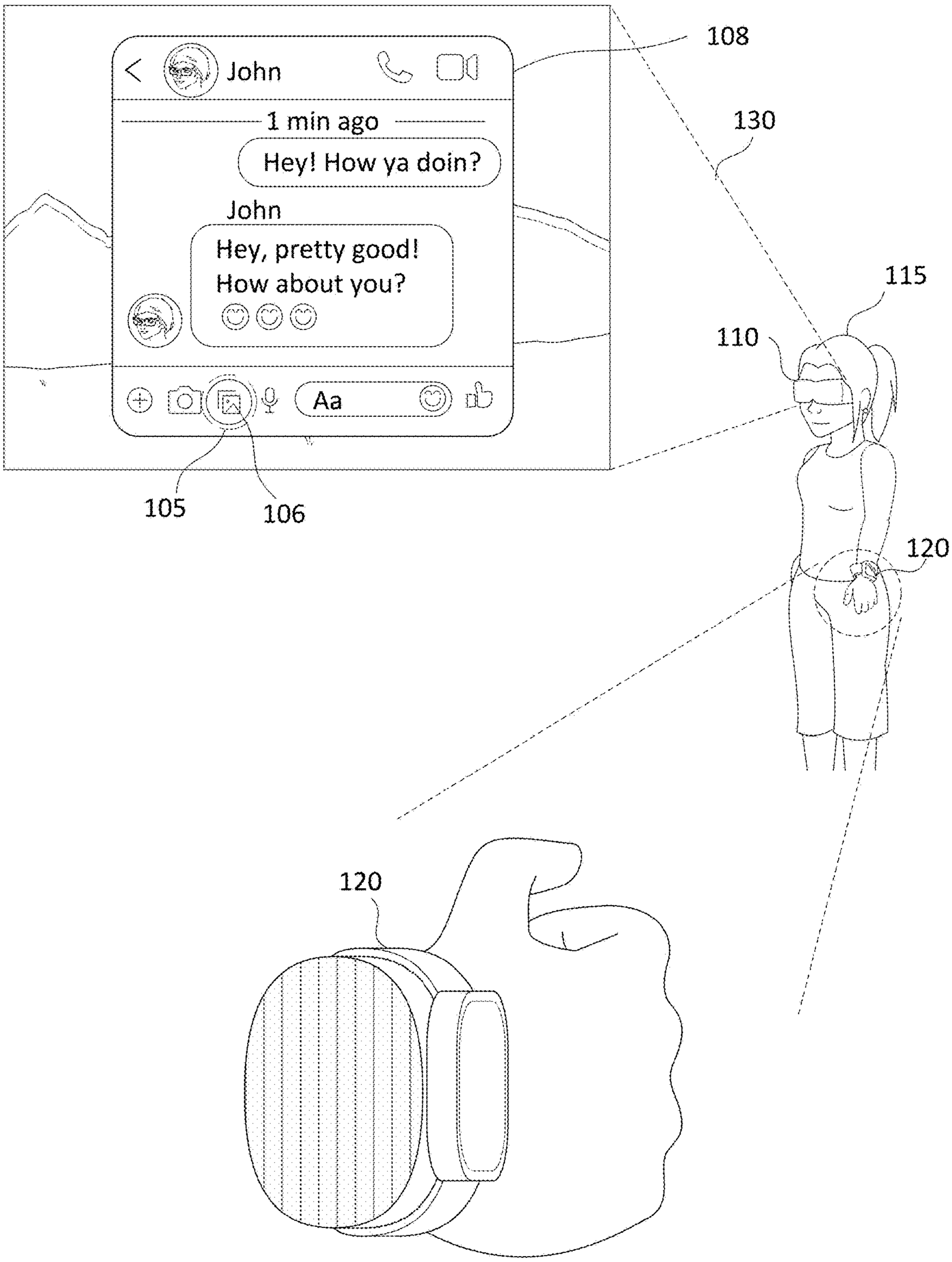

John
1 min ago
Hey! How ya doin?
John
Hey, pretty good!
How about you?
Aa
105
106
108
130
115
110
120
120

FIG. 1B

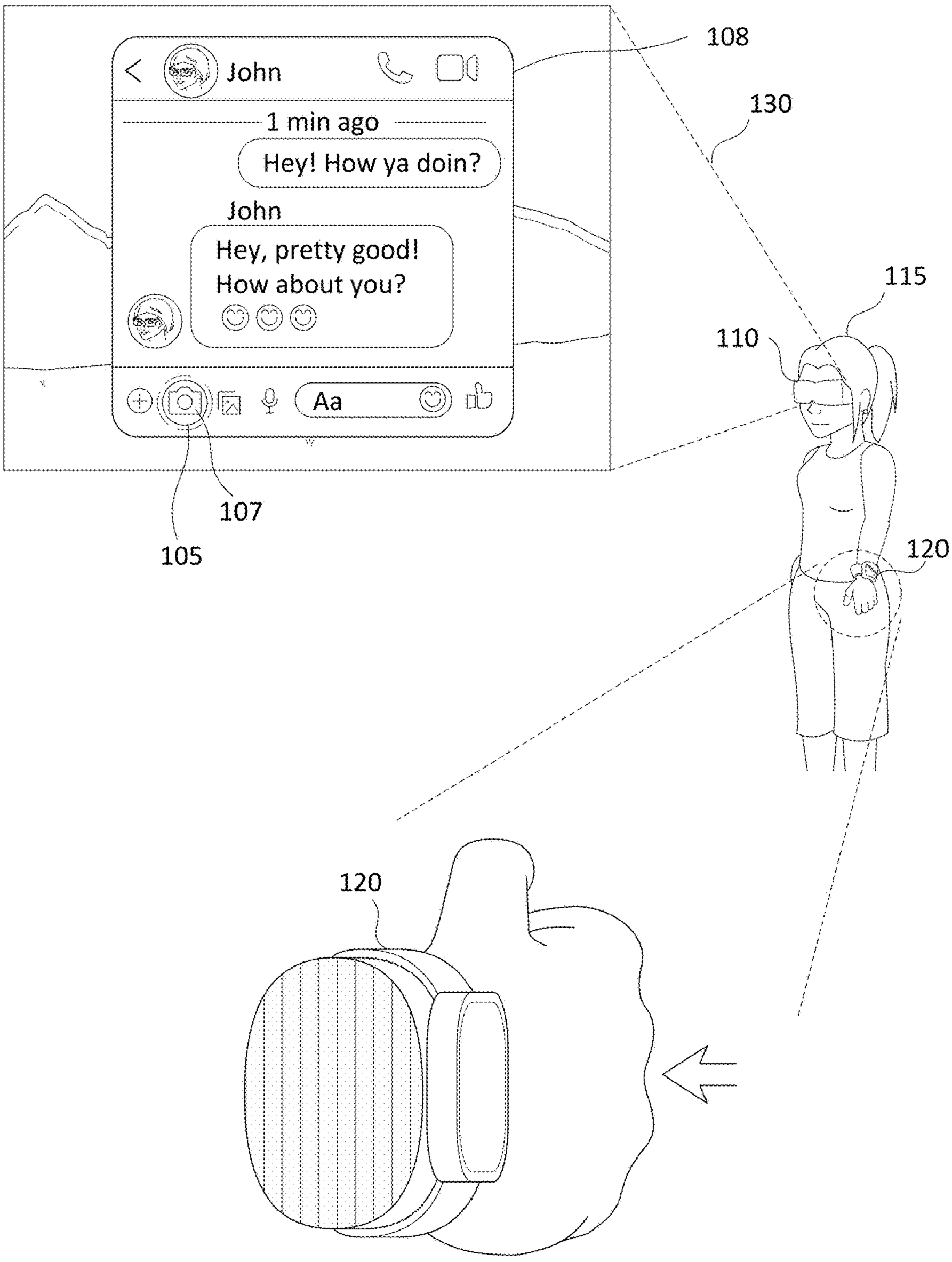

John
1 min ago
Hey! How ya doin?
John
Hey, pretty good!
How about you?
Aa
108
130
115
110
120
120
107
105

FIG. 1C

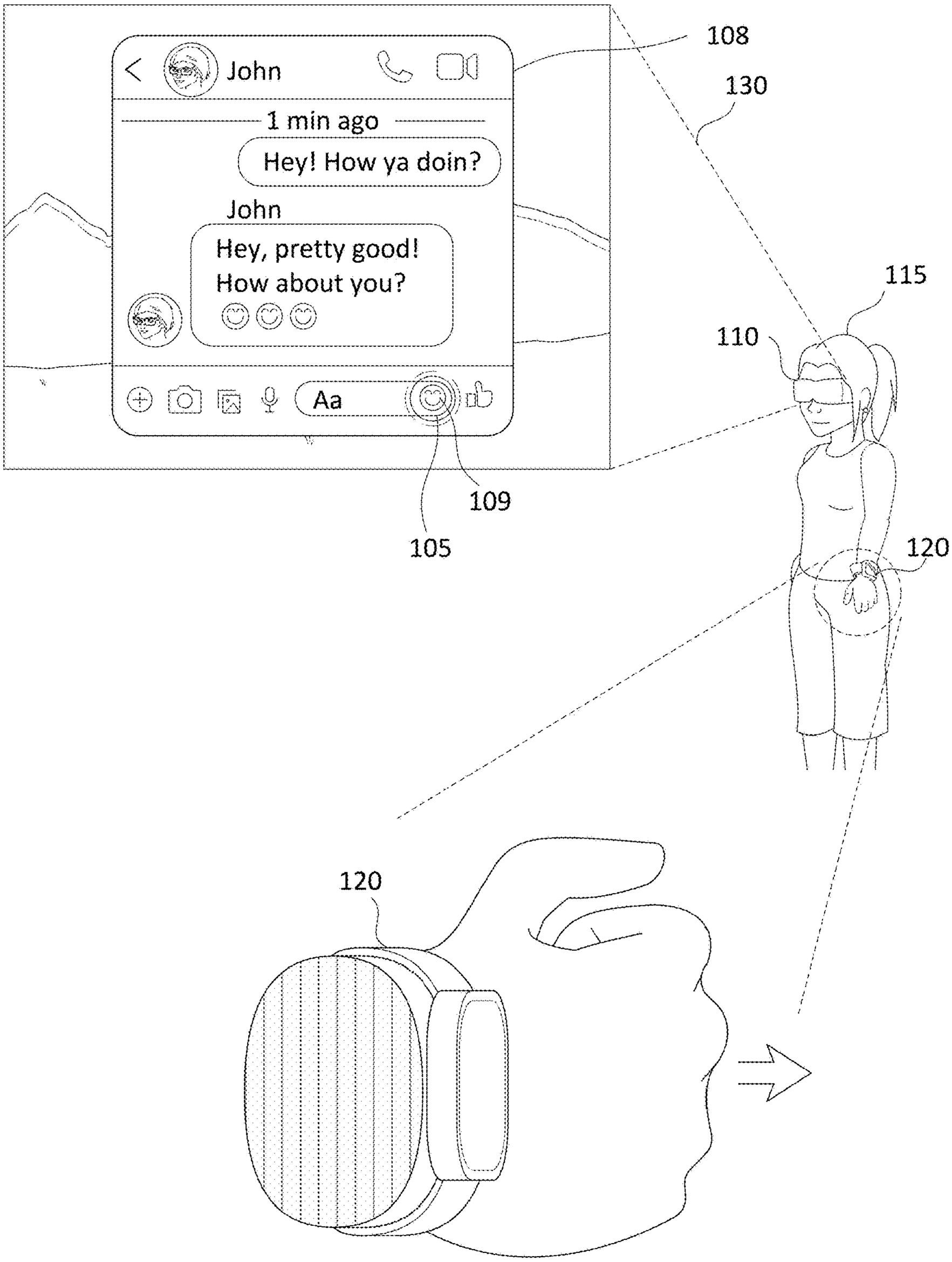

John
1 min ago
Hey! How ya doin?
John
Hey, pretty good!
How about you?
Aa
108
130
115
110
120
109
105
120

FIG. 1D

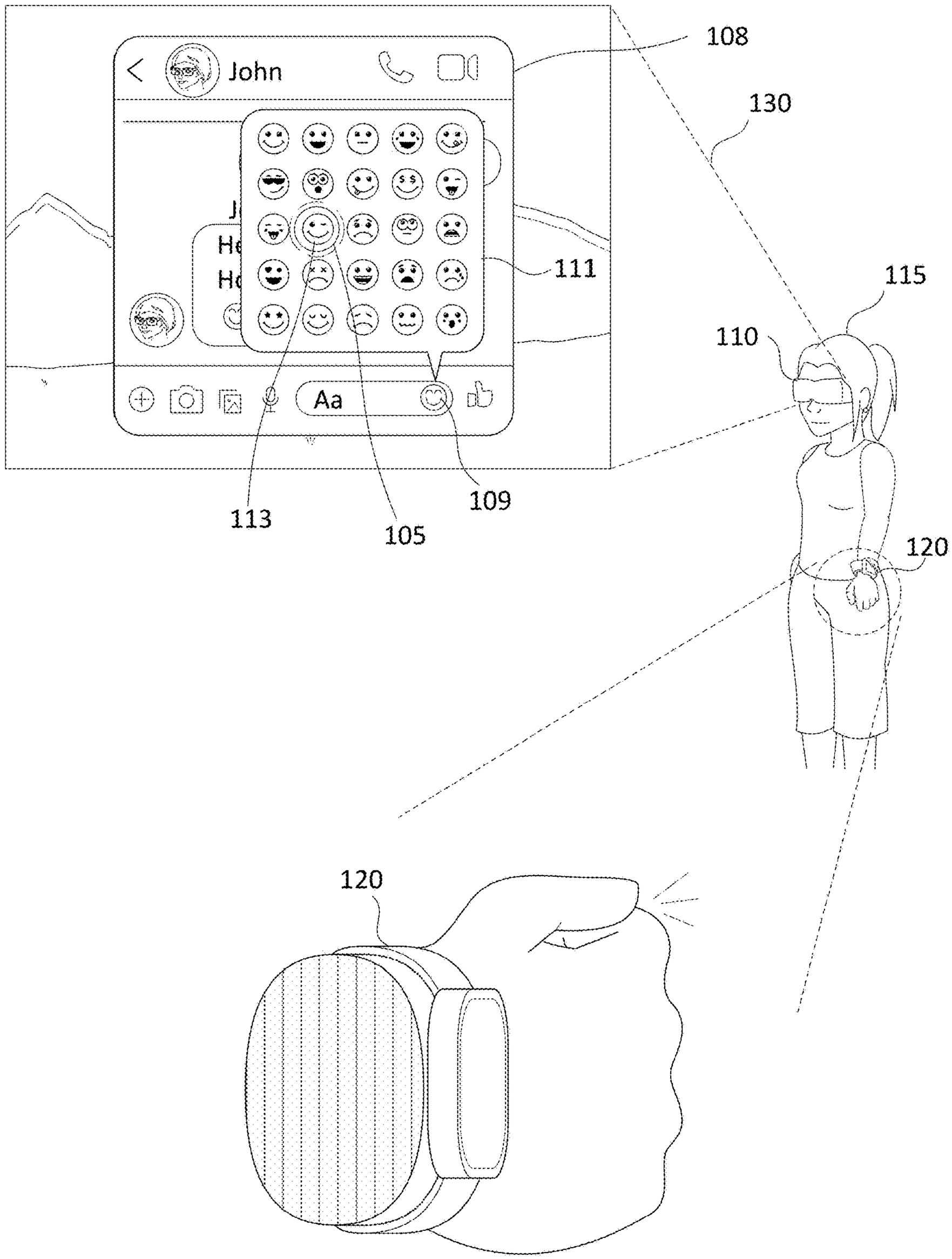


FIG. 1E

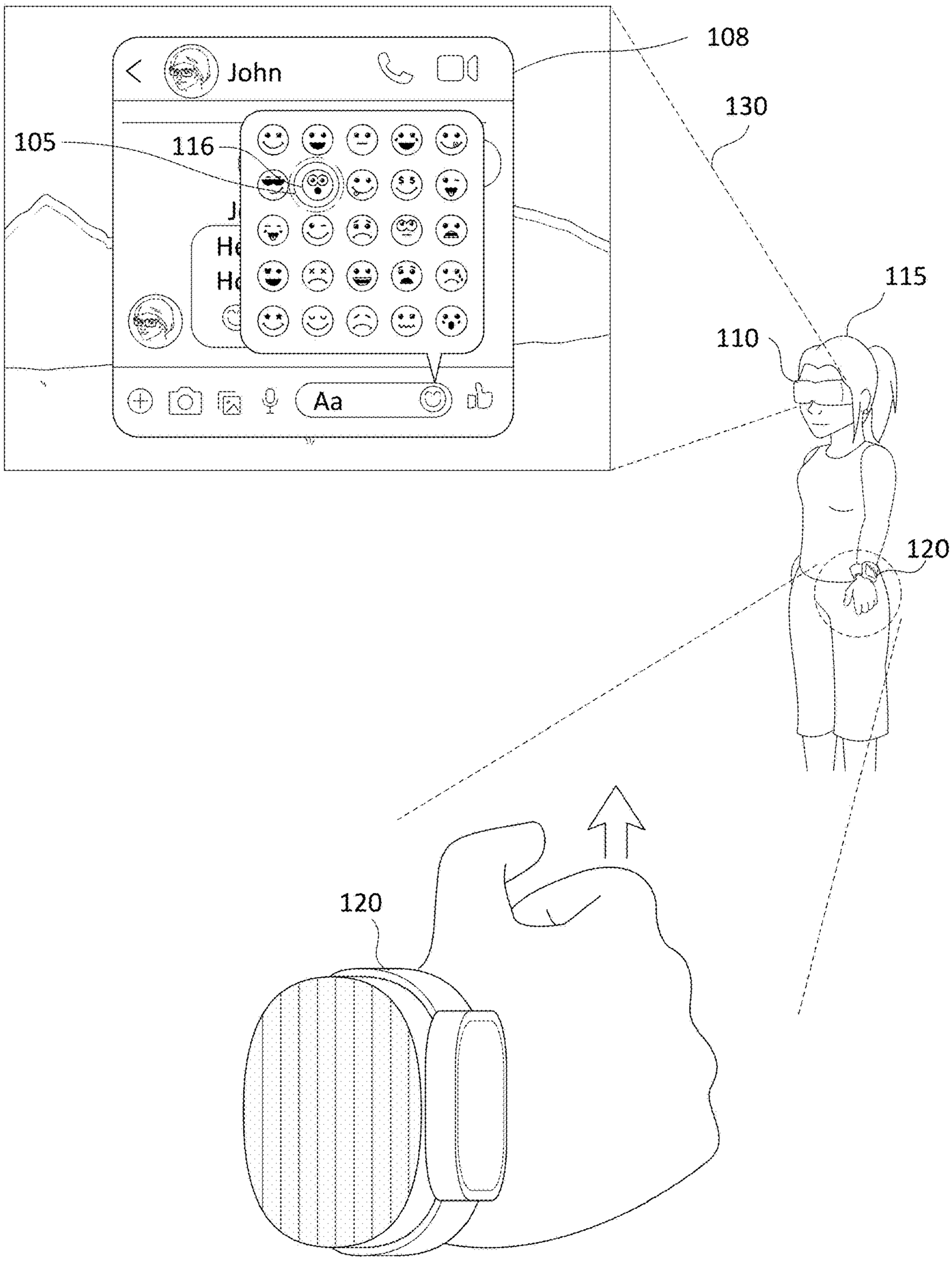


FIG. 1F

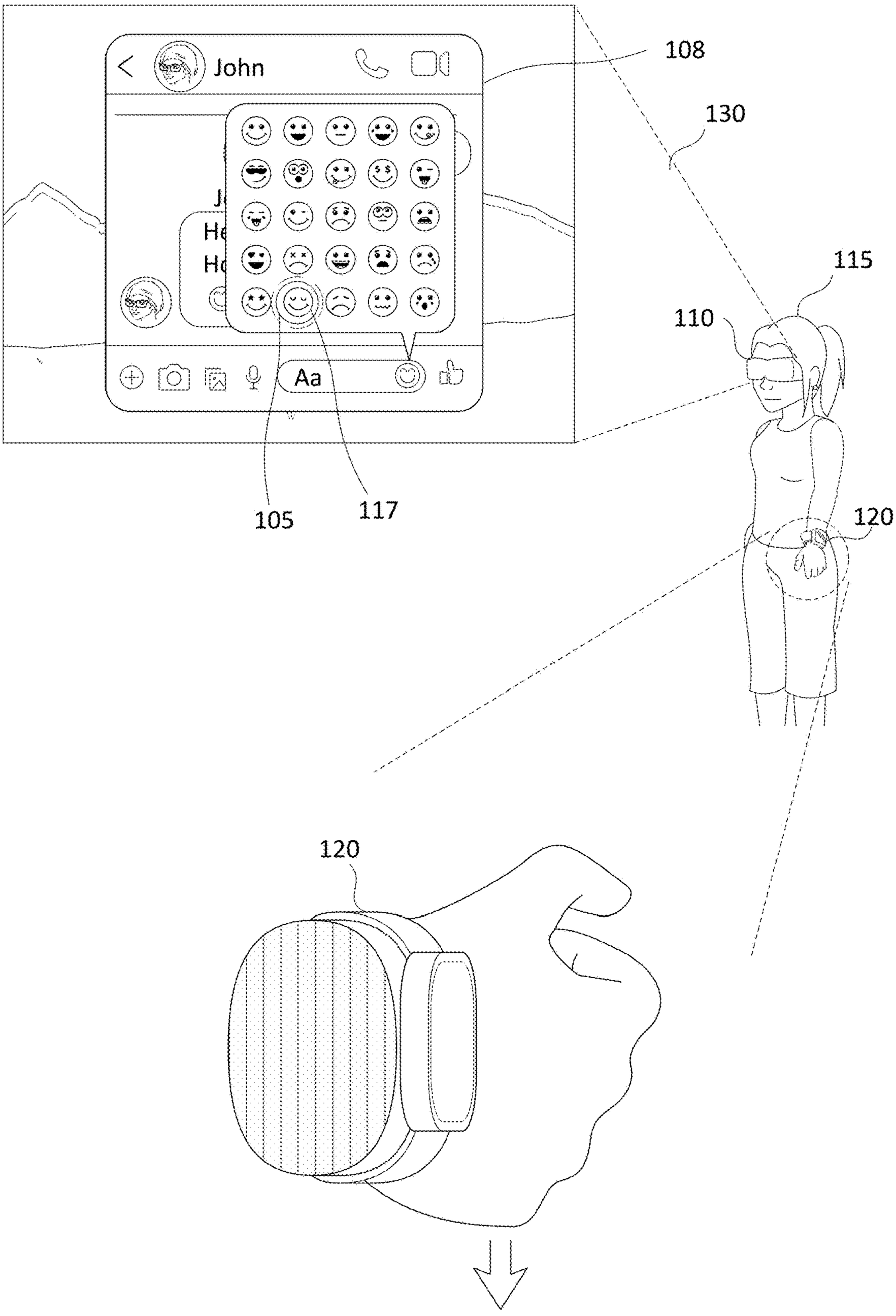


FIG. 1G

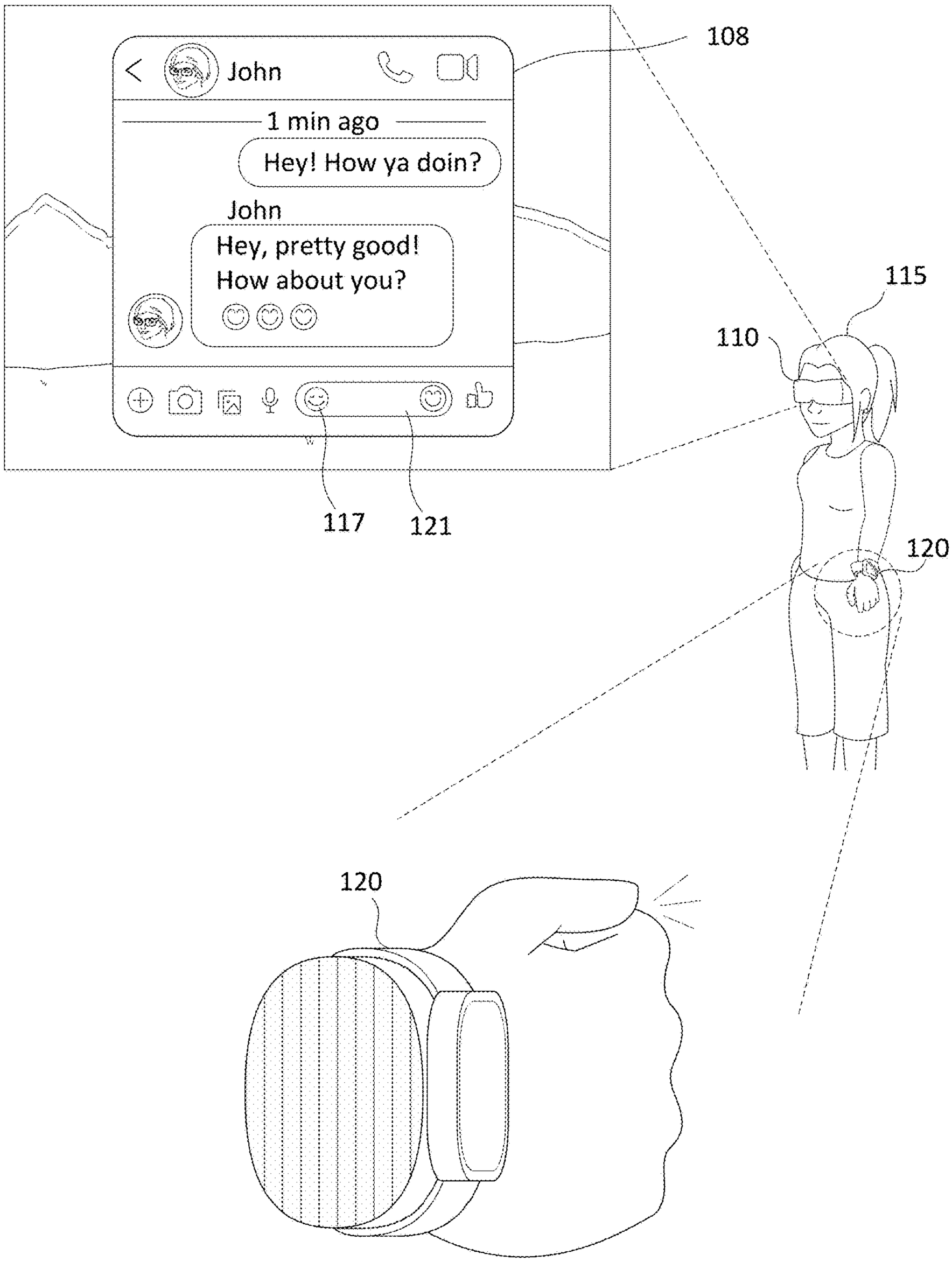

John
1 min ago
Hey! How ya doin?
John
Hey, pretty good!
How about you?
108
115
110
120
117
121
120

FIG. 1H

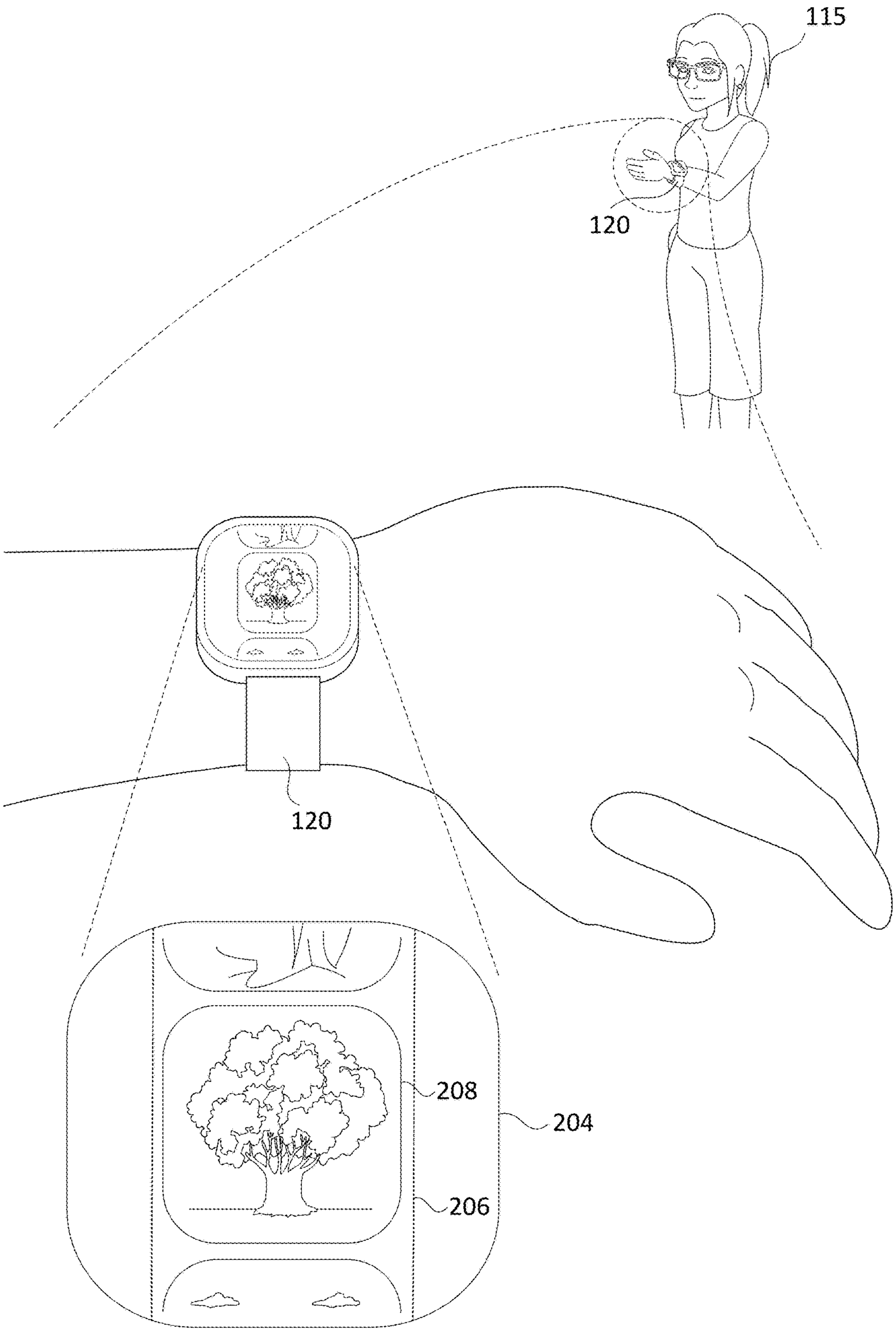


FIG. 2A

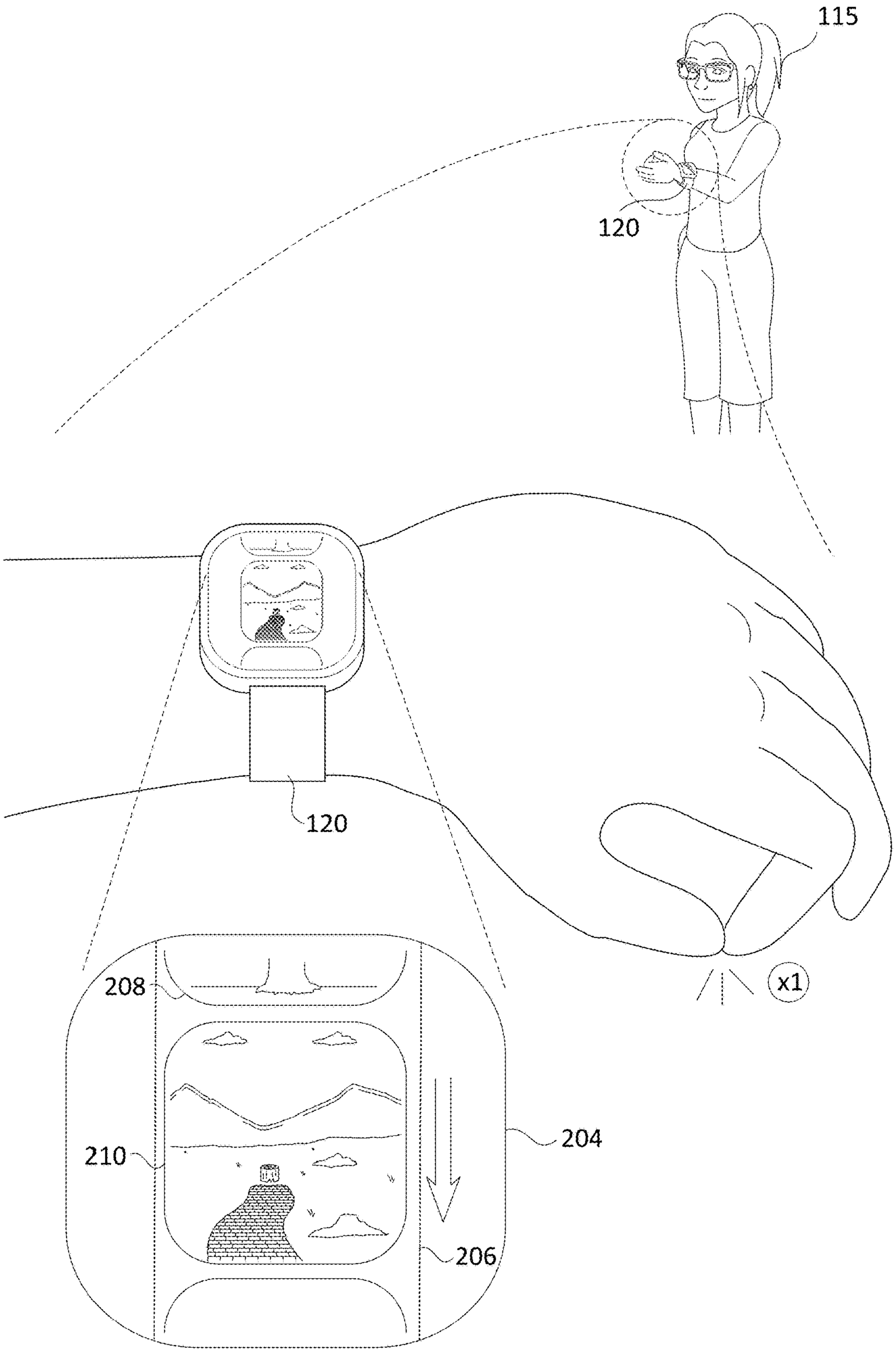


FIG. 2B

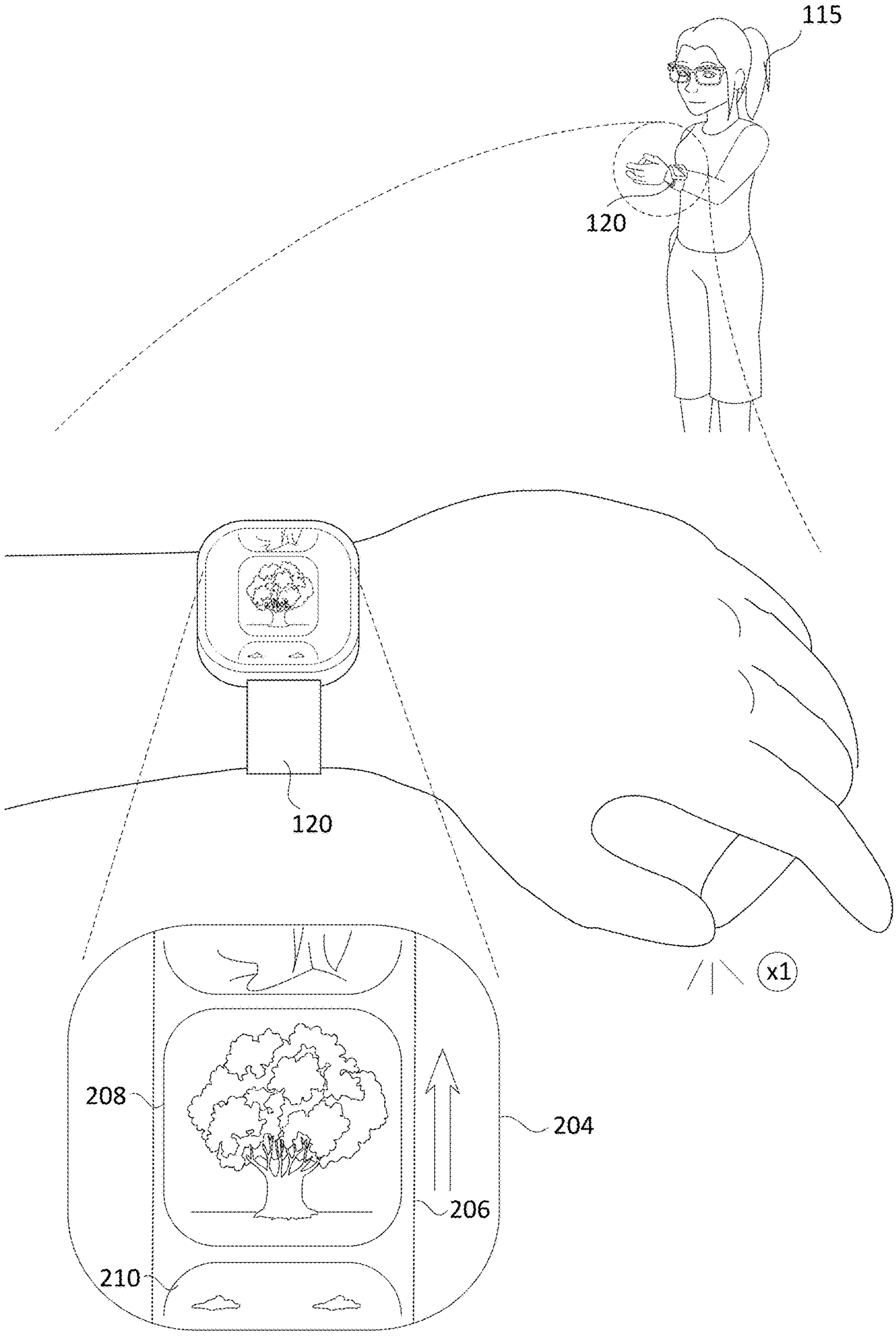


FIG. 2C

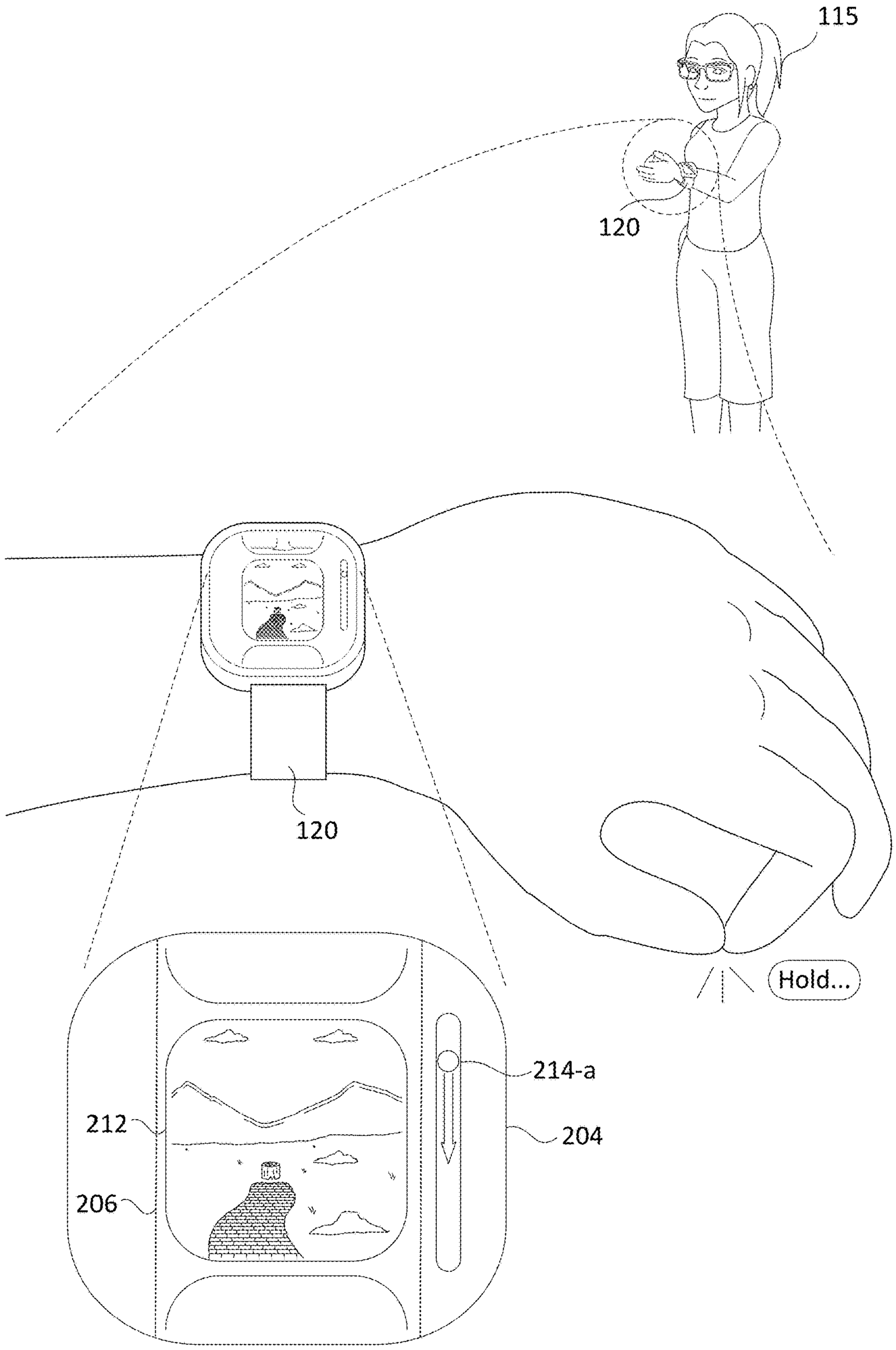


FIG. 2D

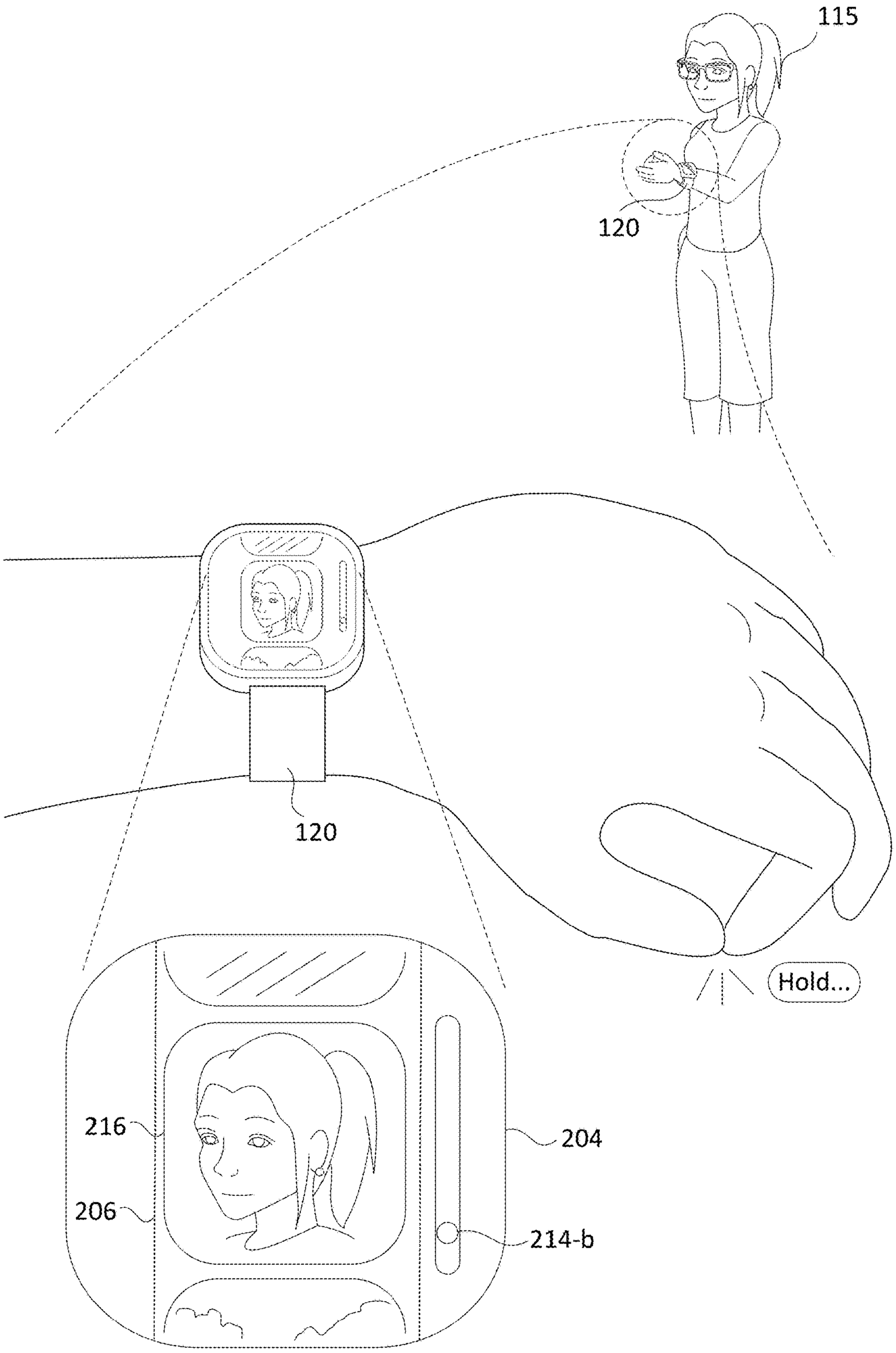


FIG. 2E

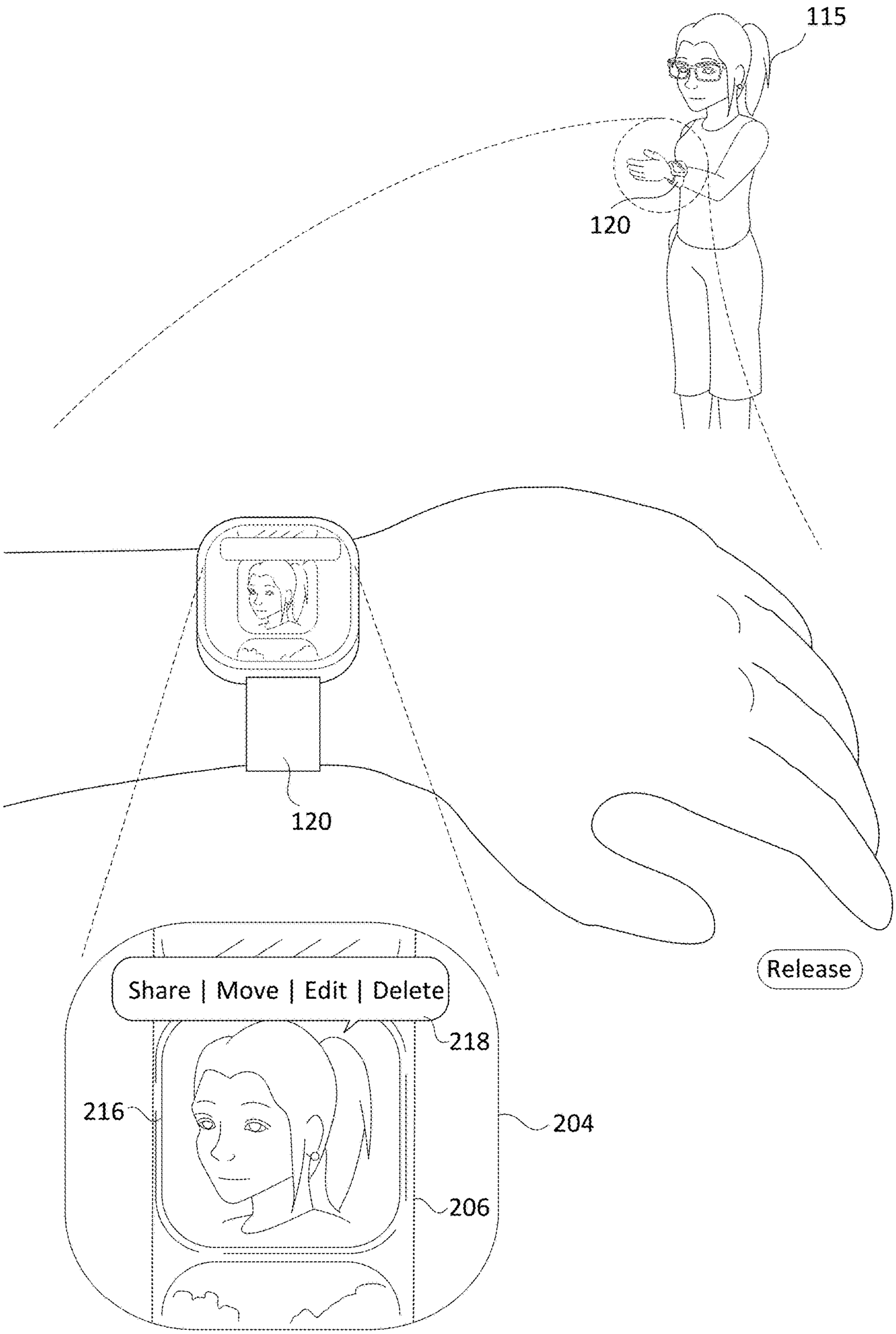


FIG. 2F

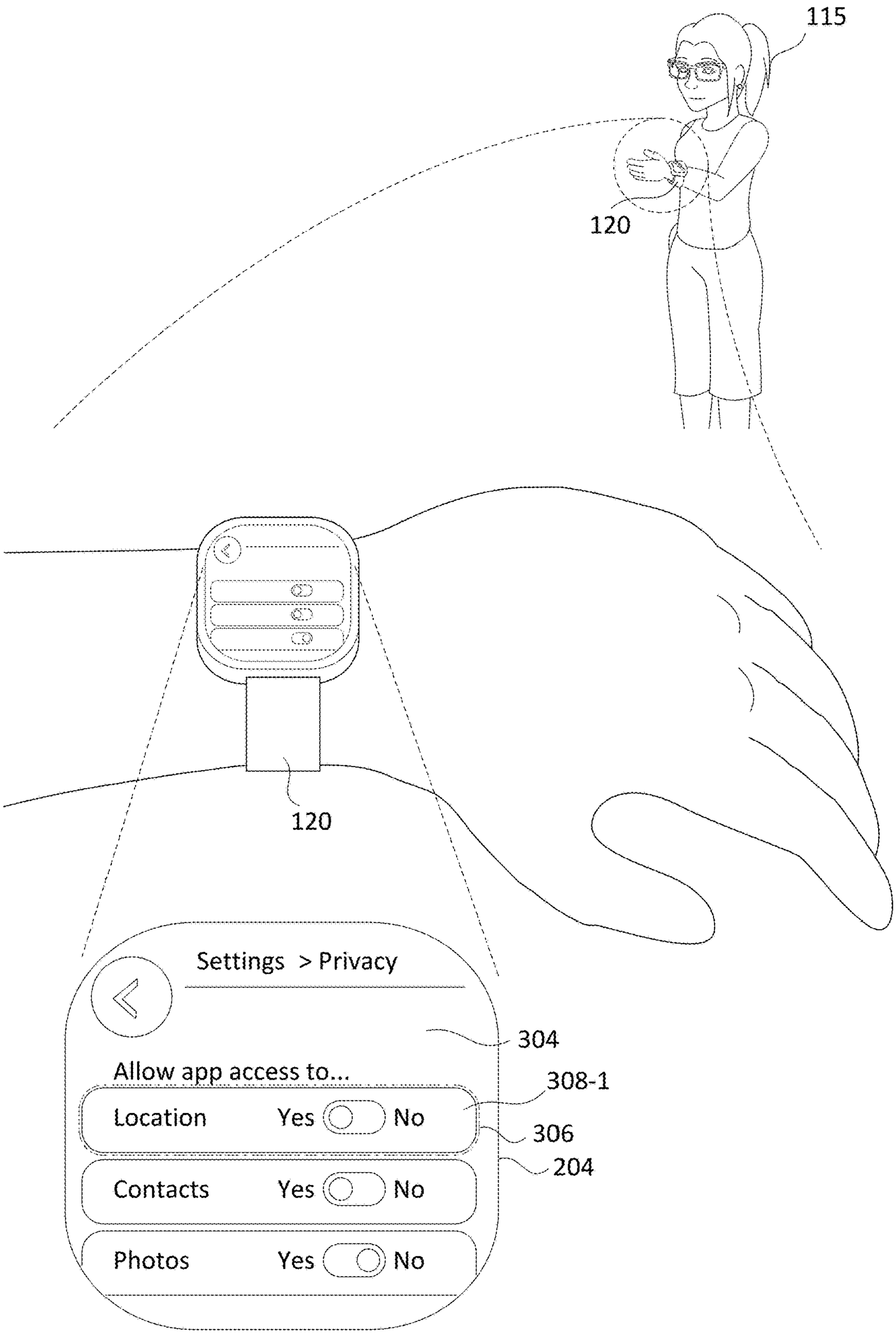

115
120
120
Settings > Privacy
304
Allow app access to...
308-1
Location Yes No
306
204
Contacts Yes No
Photos Yes No

FIG. 3A

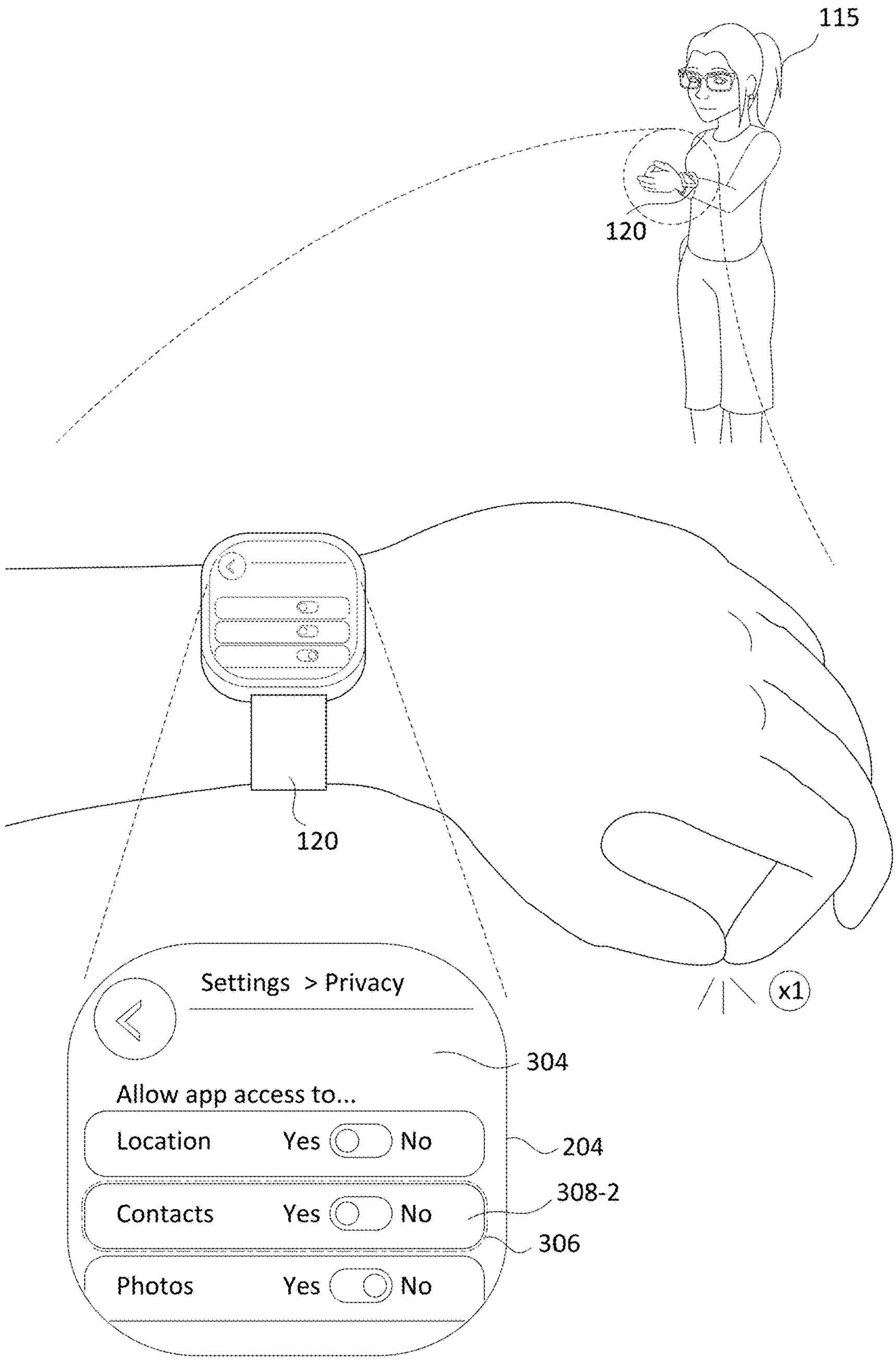

115
120
120
x1
Settings > Privacy
304
Allow app access to...
Location Yes No
204
Contacts Yes No
308-2
306
Photos Yes No

FIG. 3B

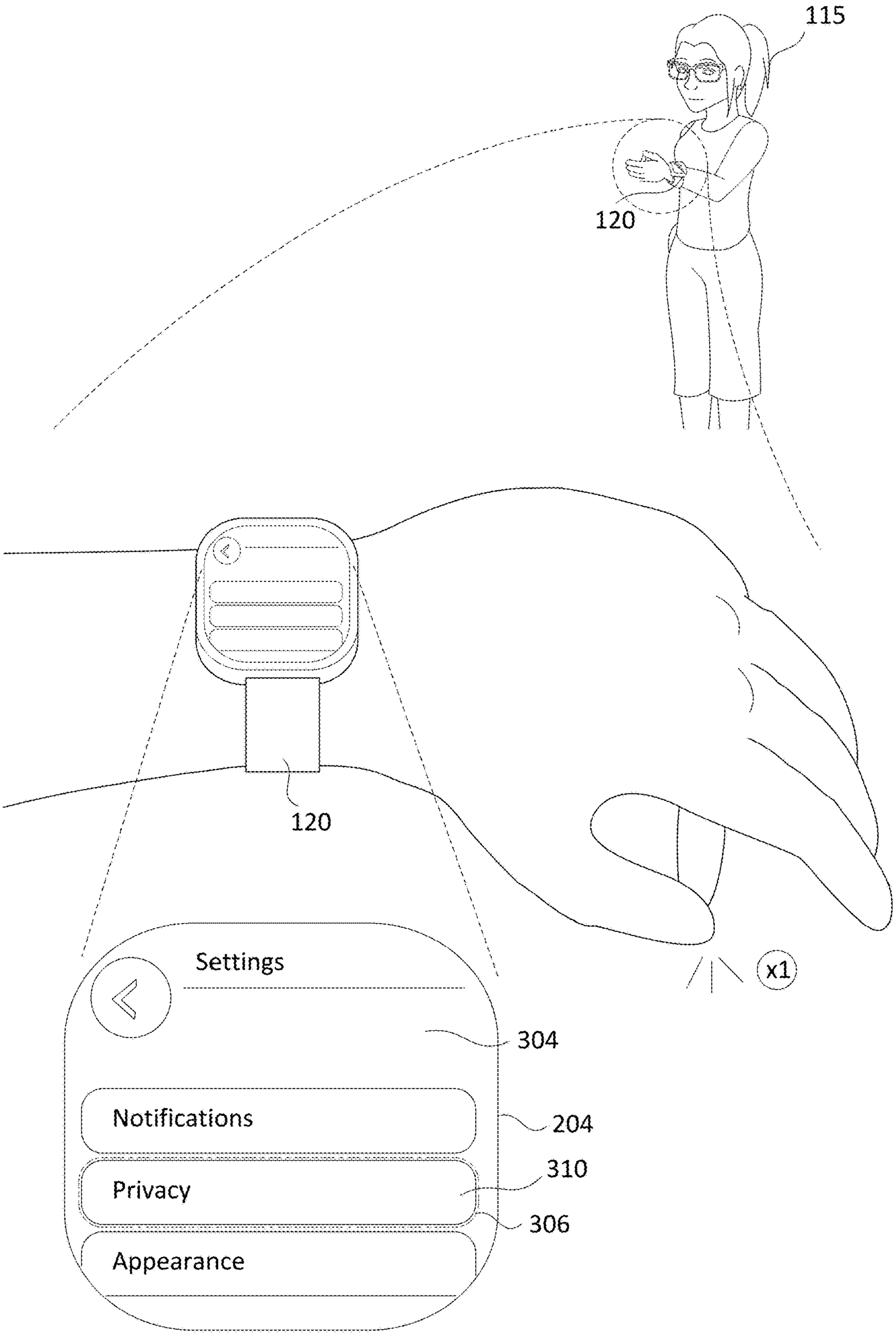

115
120
120
x1
Settings
304
Notifications
204
Privacy
310
306
Appearance

FIG. 3C

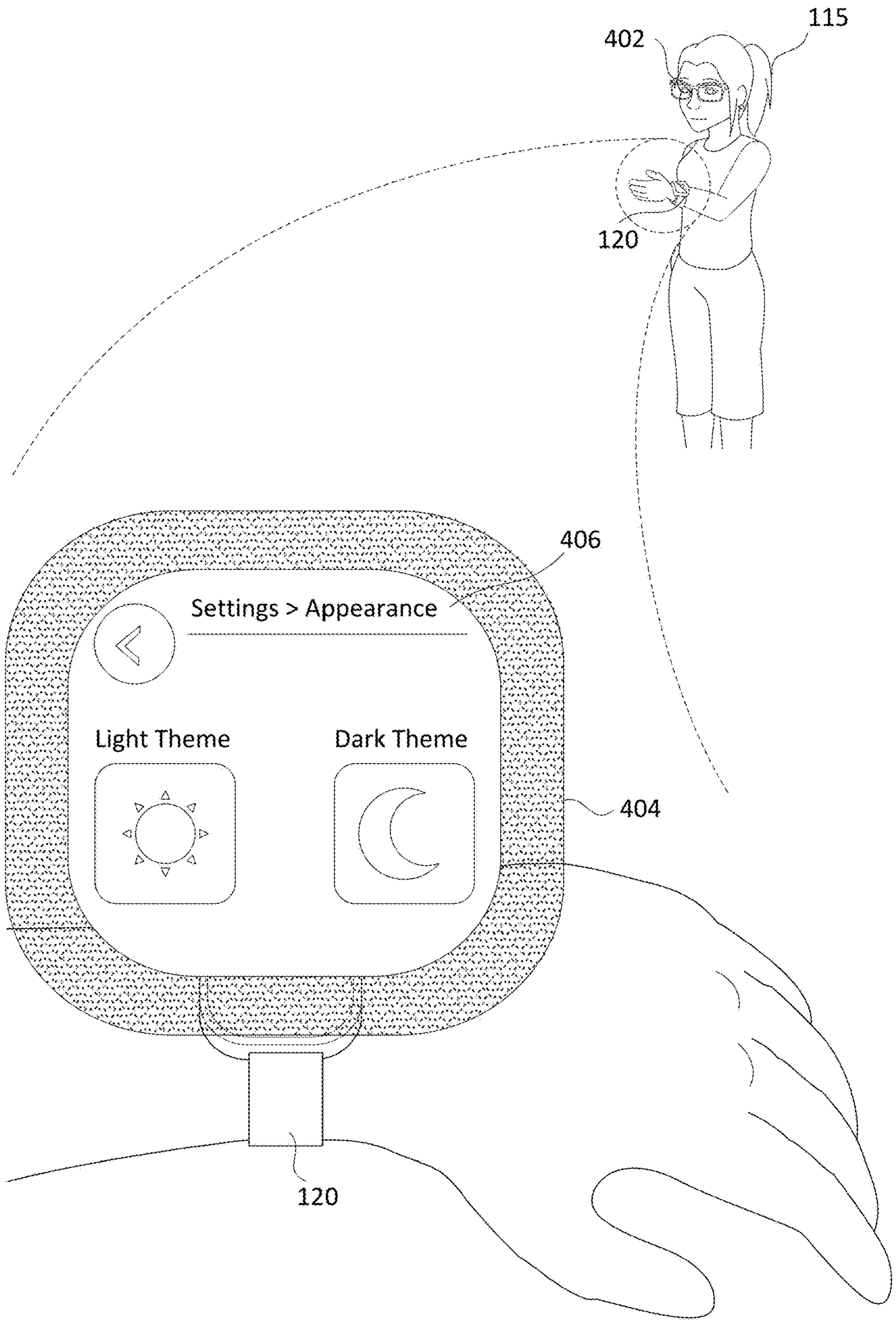

115
402
120
406
Settings > Appearance
Light Theme
Dark Theme
404
120

FIG. 4A

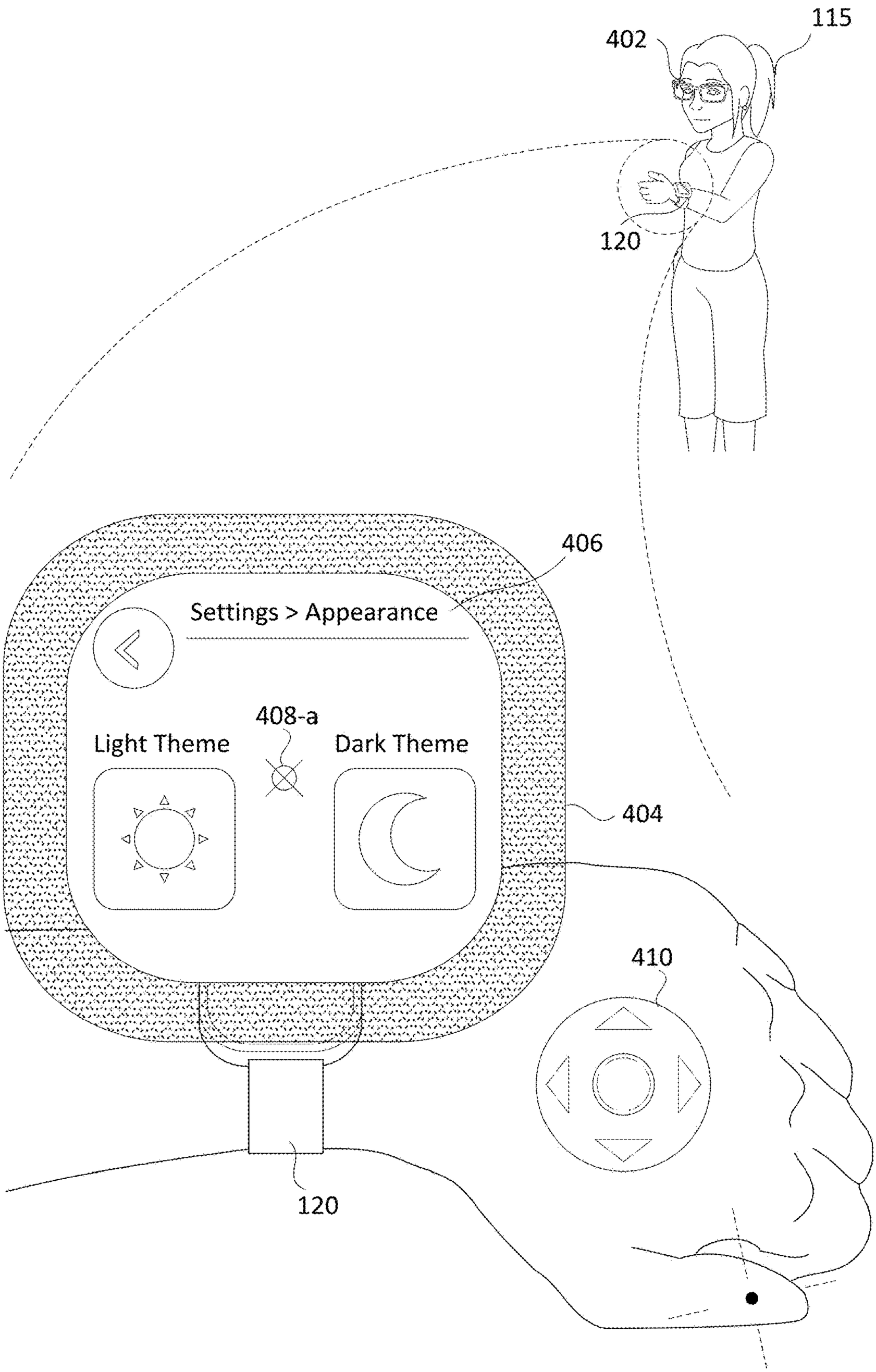

115
402
120
406
Settings > Appearance
408-a
Light Theme
Dark Theme
404
410
120

FIG. 4B

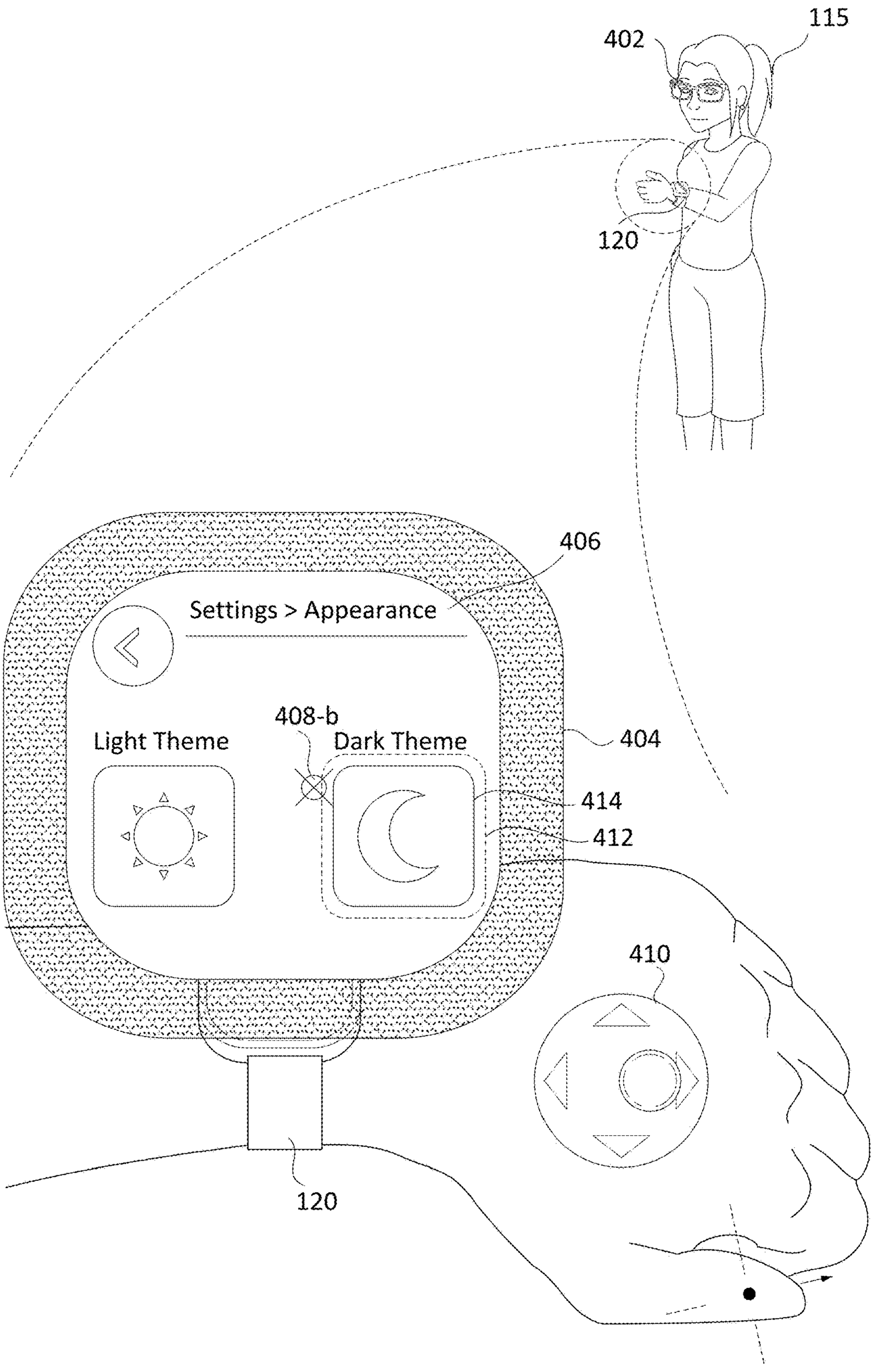

115
402
120
406
Settings > Appearance
408-b
Light Theme
Dark Theme
404
414
412
410
120

FIG. 4C

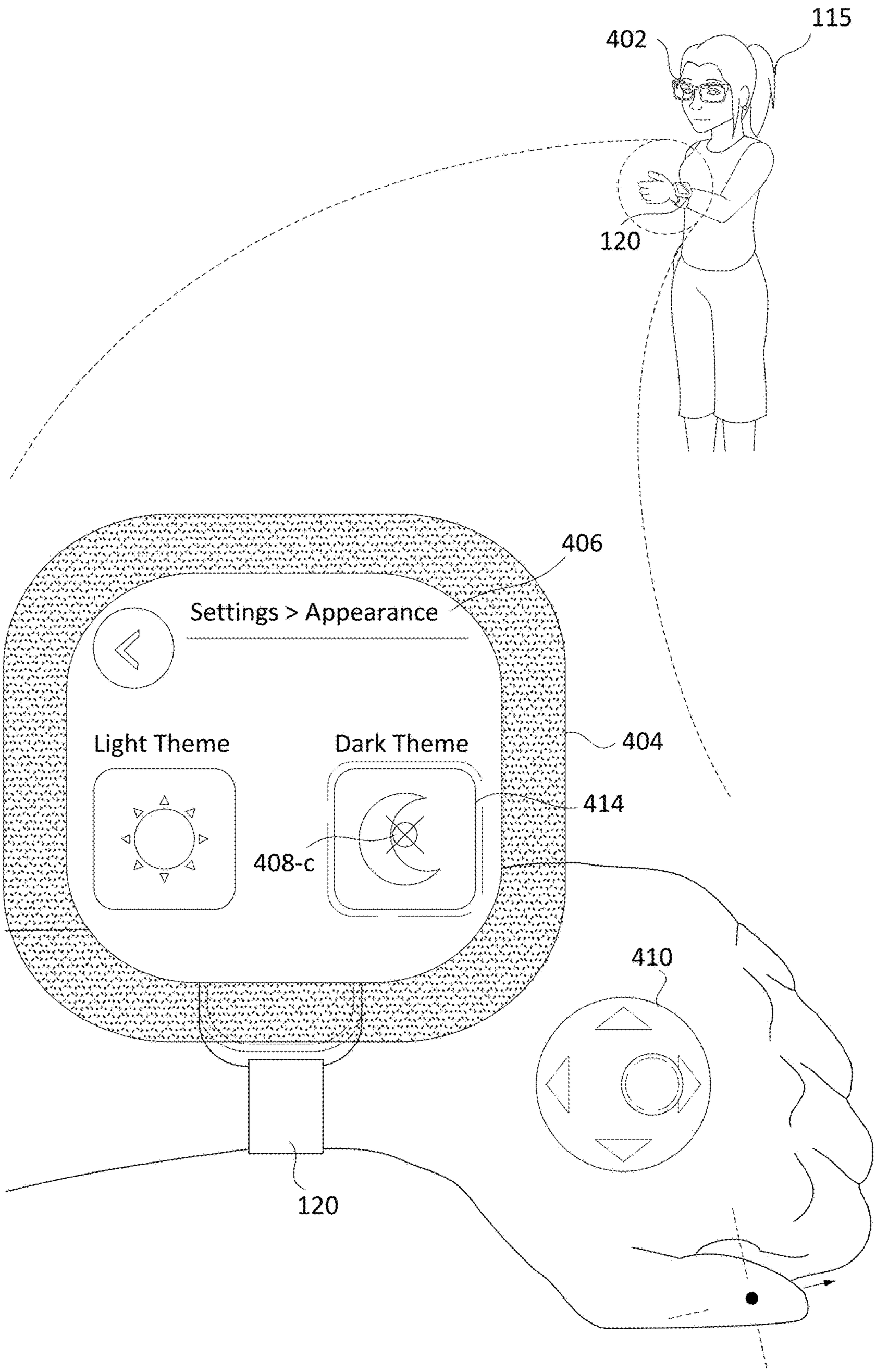

115
402
120
406
Settings > Appearance
Light Theme
Dark Theme
404
414
408-c
410
120

FIG. 4D

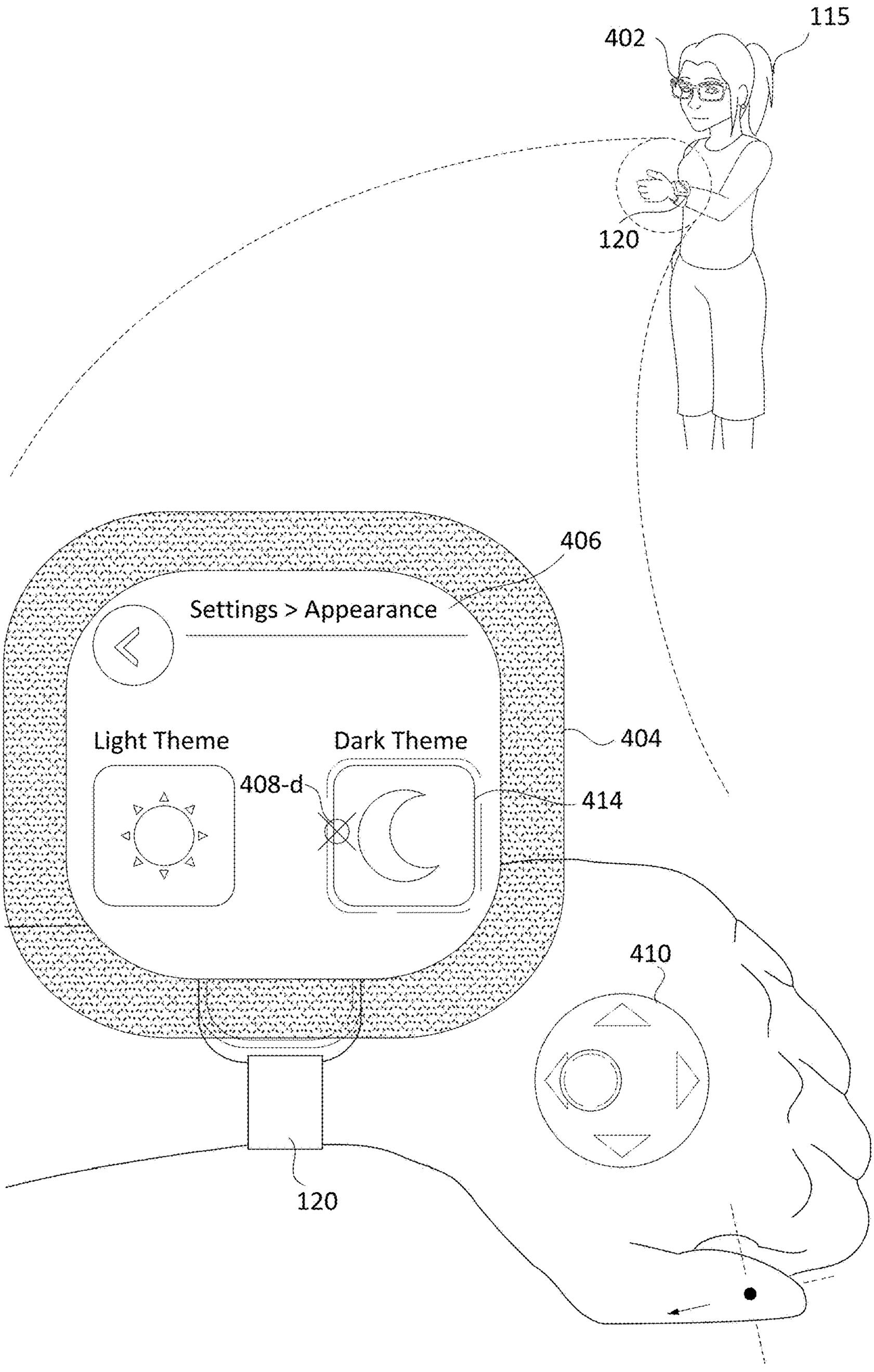

115
402
120
406
Settings > Appearance
Light Theme
Dark Theme
404
408-d
414
410
120

FIG. 4E

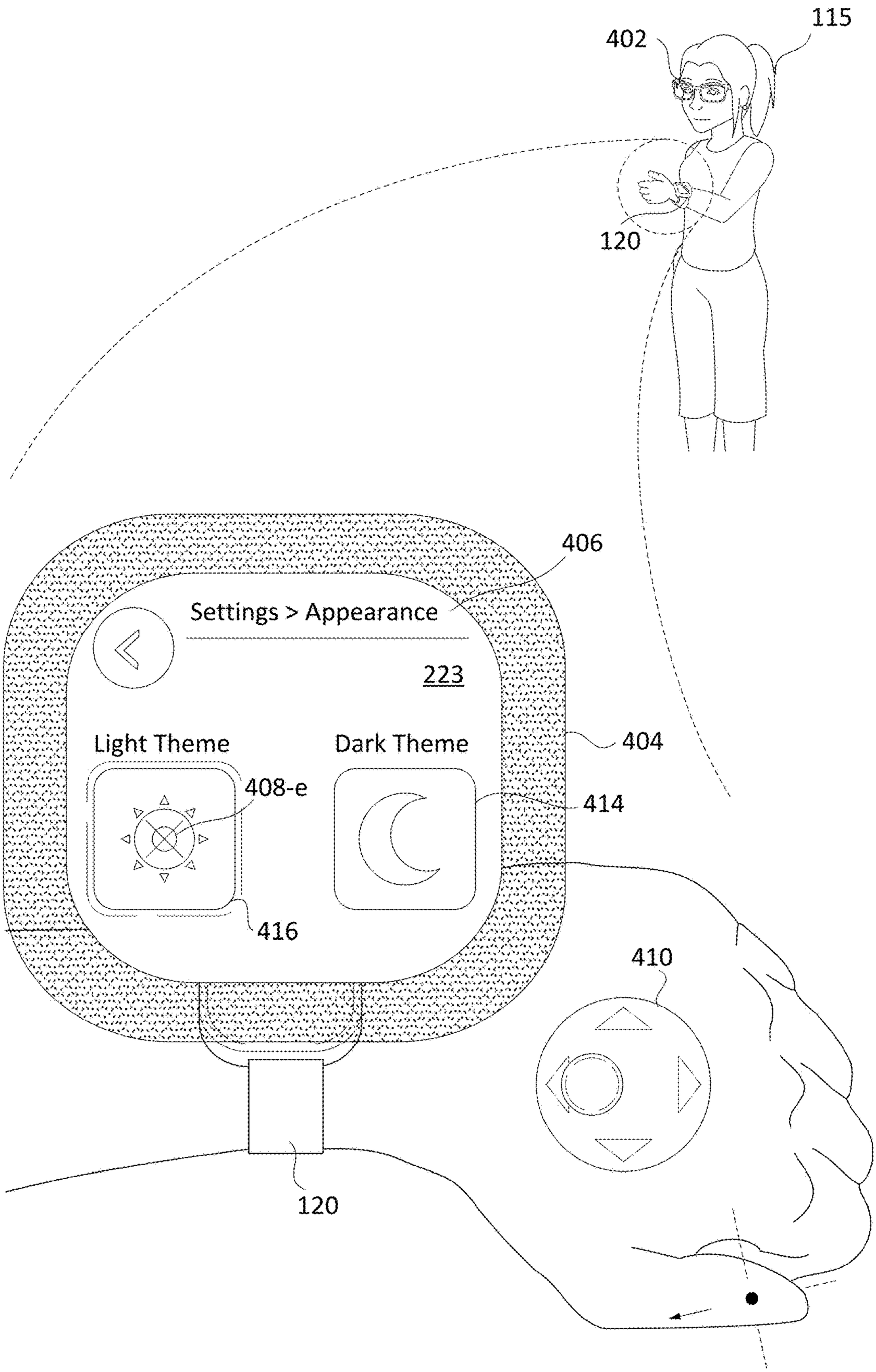

115
402
120
406
Settings > Appearance
223
Light Theme
Dark Theme
404
408-e
414
416
410
120

FIG. 4F

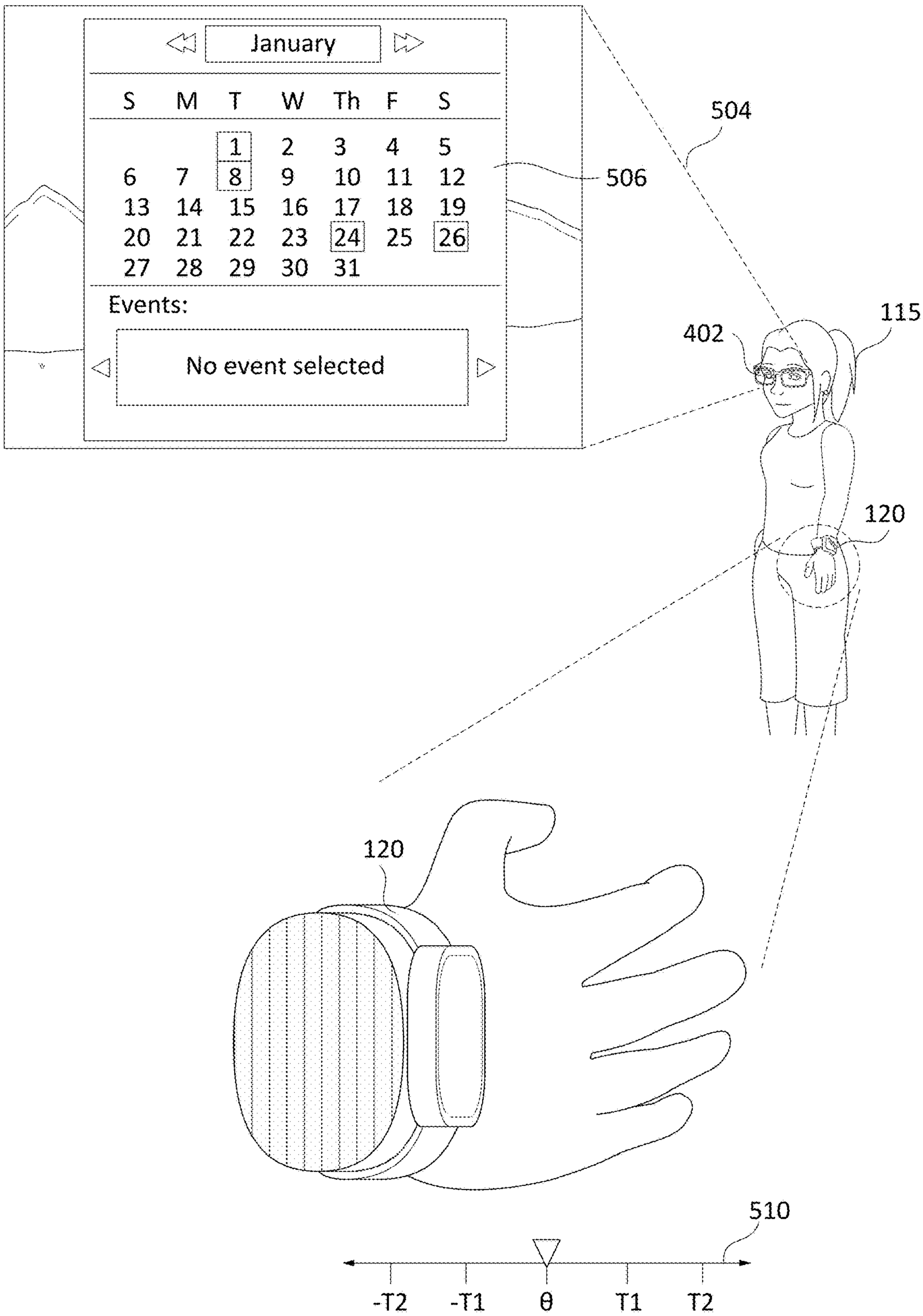

January
S M T W Th F S
1 2 3 4 5
6 7 8 9 10 11 12
13 14 15 16 17 18 19
20 21 22 23 24 25 26
27 28 29 30 31
Events:
No event selected
504
506
115
402
120
120
510
-T2
-T1
θ
T1
T2

FIG. 5A

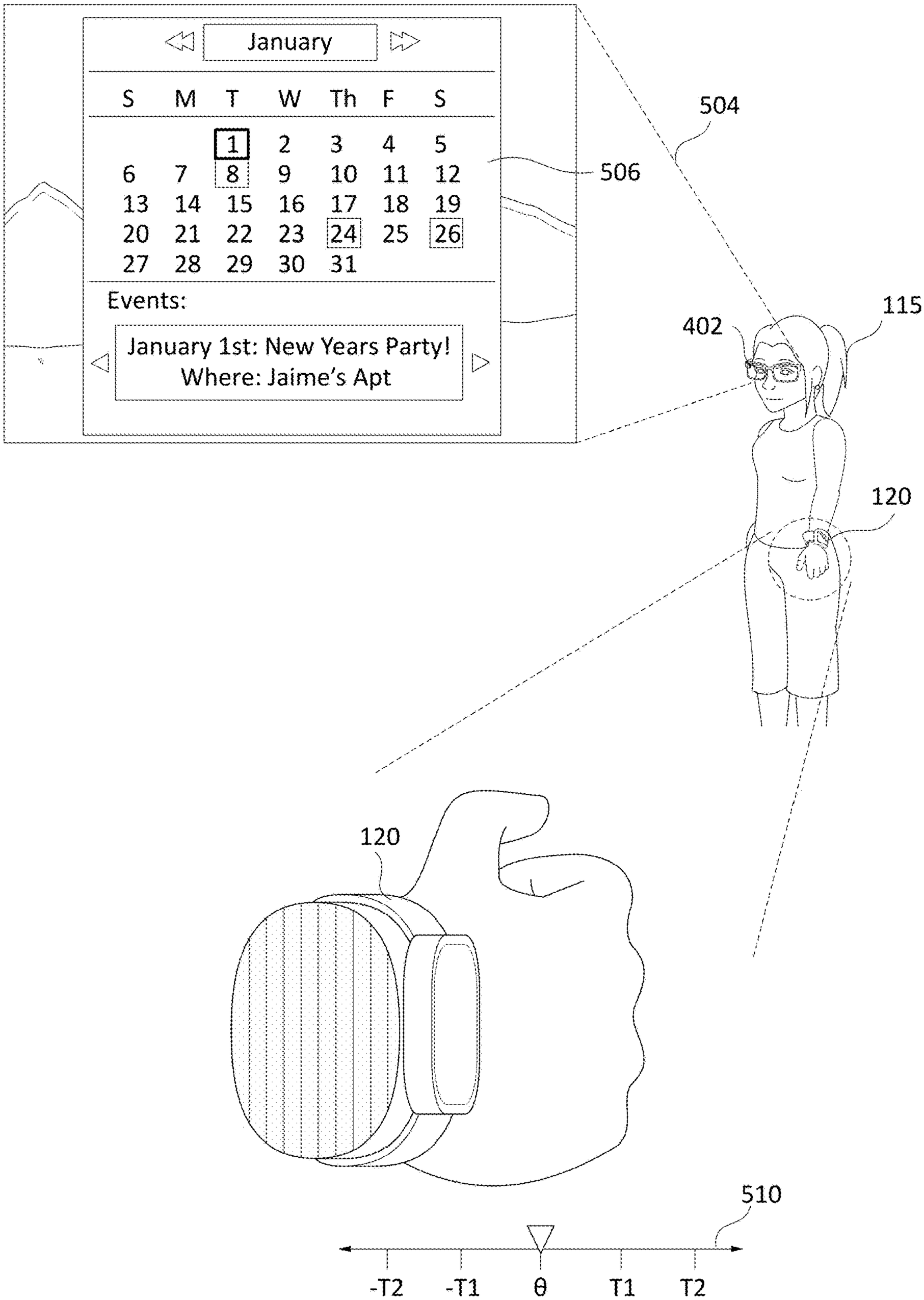

January
S M T W Th F S
1 2 3 4 5
6 7 8 9 10 11 12
13 14 15 16 17 18 19
20 21 22 23 24 25 26
27 28 29 30 31
Events:
January 1st: New Years Party!
Where: Jaime's Apt
504
506
115
402
120
120
510
-T2
-T1
θ
T1
T2

FIG. 5B

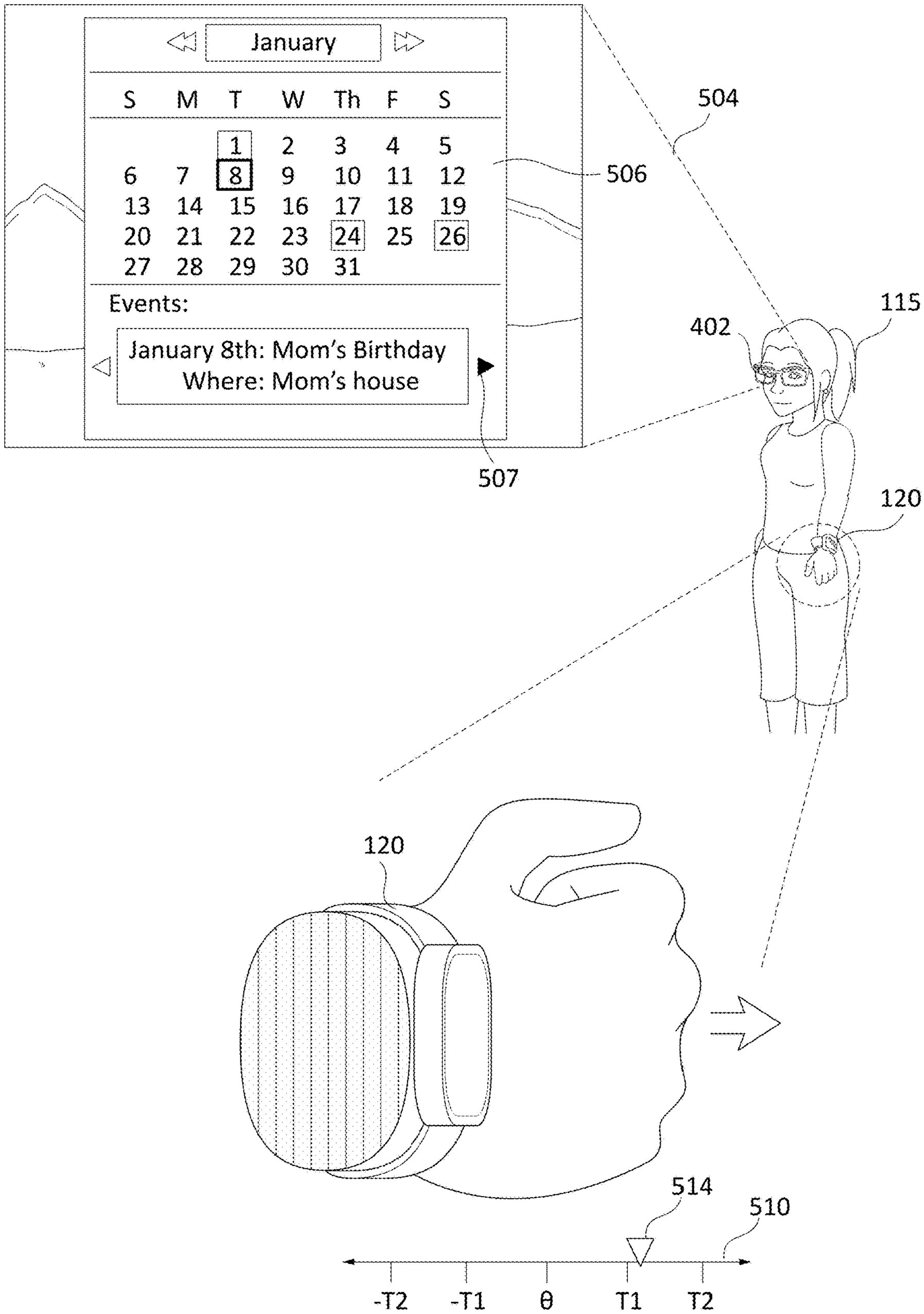

January
S M T W Th F S
1 2 3 4 5
6 7 8 9 10 11 12
13 14 15 16 17 18 19
20 21 22 23 24 25 26
27 28 29 30 31
Events:
January 8th: Mom's Birthday
Where: Mom's house
504
506
507
115
402
120
120
514
510
-T2
-T1
θ
T1
T2

FIG. 5C

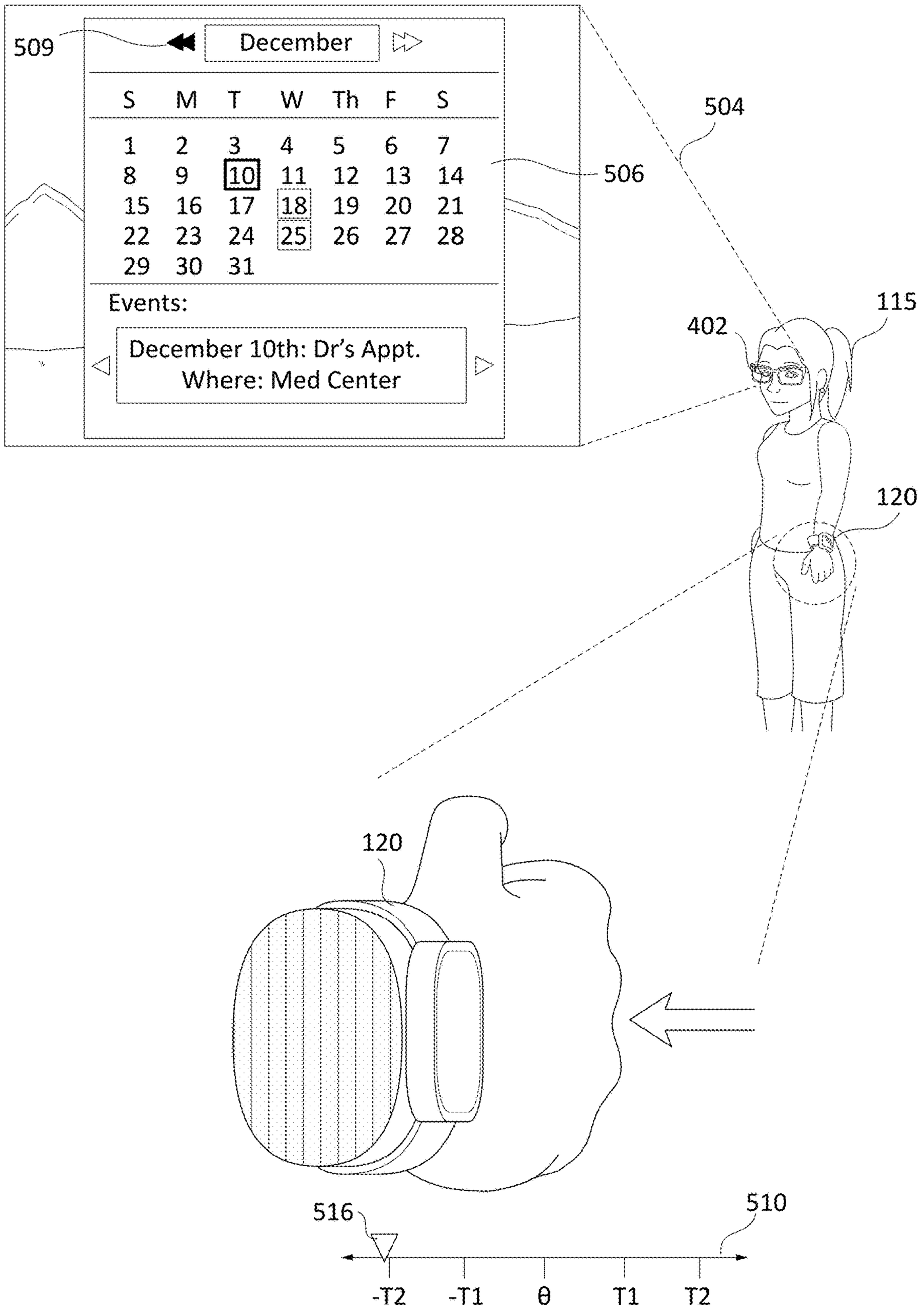

509
December
S M T W Th F S
1 2 3 4 5 6 7
8 9 10 11 12 13 14
15 16 17 18 19 20 21
22 23 24 25 26 27 28
29 30 31
Events:
December 10th: Dr's Appt.
Where: Med Center
504
506
115
402
120
120
516
510
-T2
-T1
θ
T1
T2

FIG. 5D

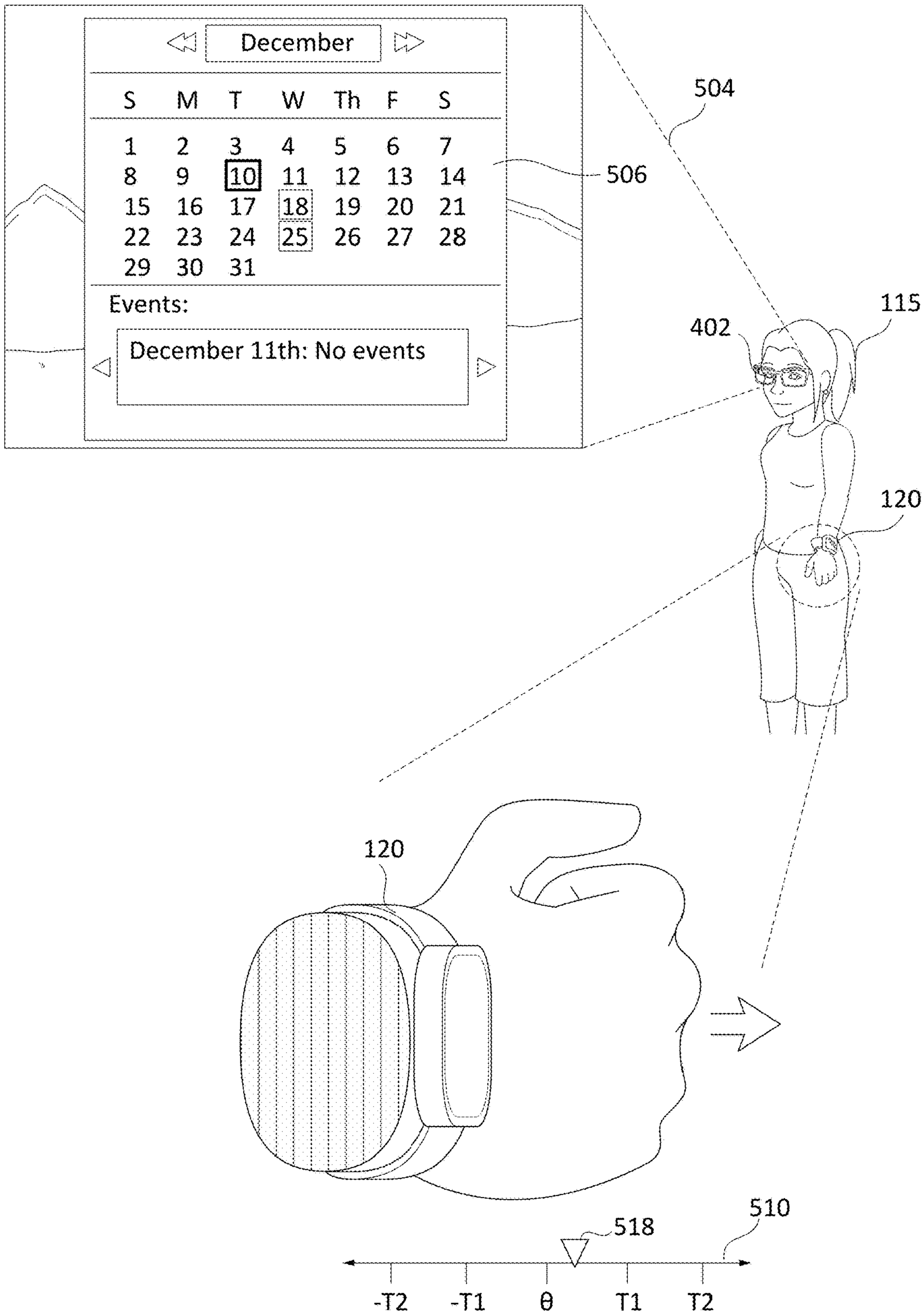

December
S M T W Th F S
1 2 3 4 5 6 7
8 9 10 11 12 13 14
15 16 17 18 19 20 21
22 23 24 25 26 27 28
29 30 31
Events:
December 11th: No events
504
506
115
402
120
120
510
518
-T2
-T1
θ
T1
T2

FIG. 5E

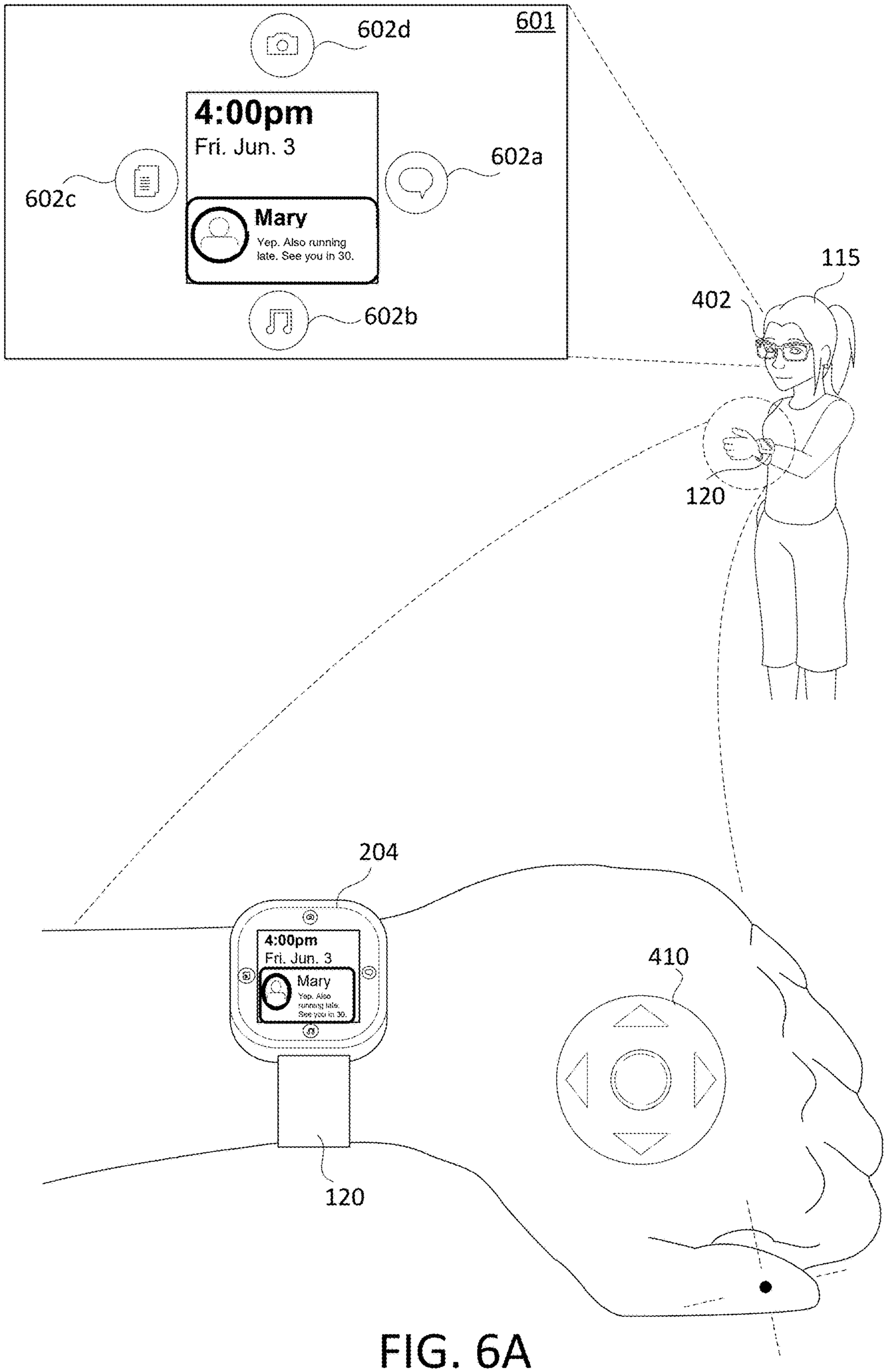

601
602d
4:00pm
Fri. Jun. 3
602c
602a
Mary
Yep. Also running late. See you in 30.
602b
115
402
120
204
4:00pm
Fri. Jun. 3
Mary
Yep. Also running late. See you in 30.
410
120

FIG. 6A

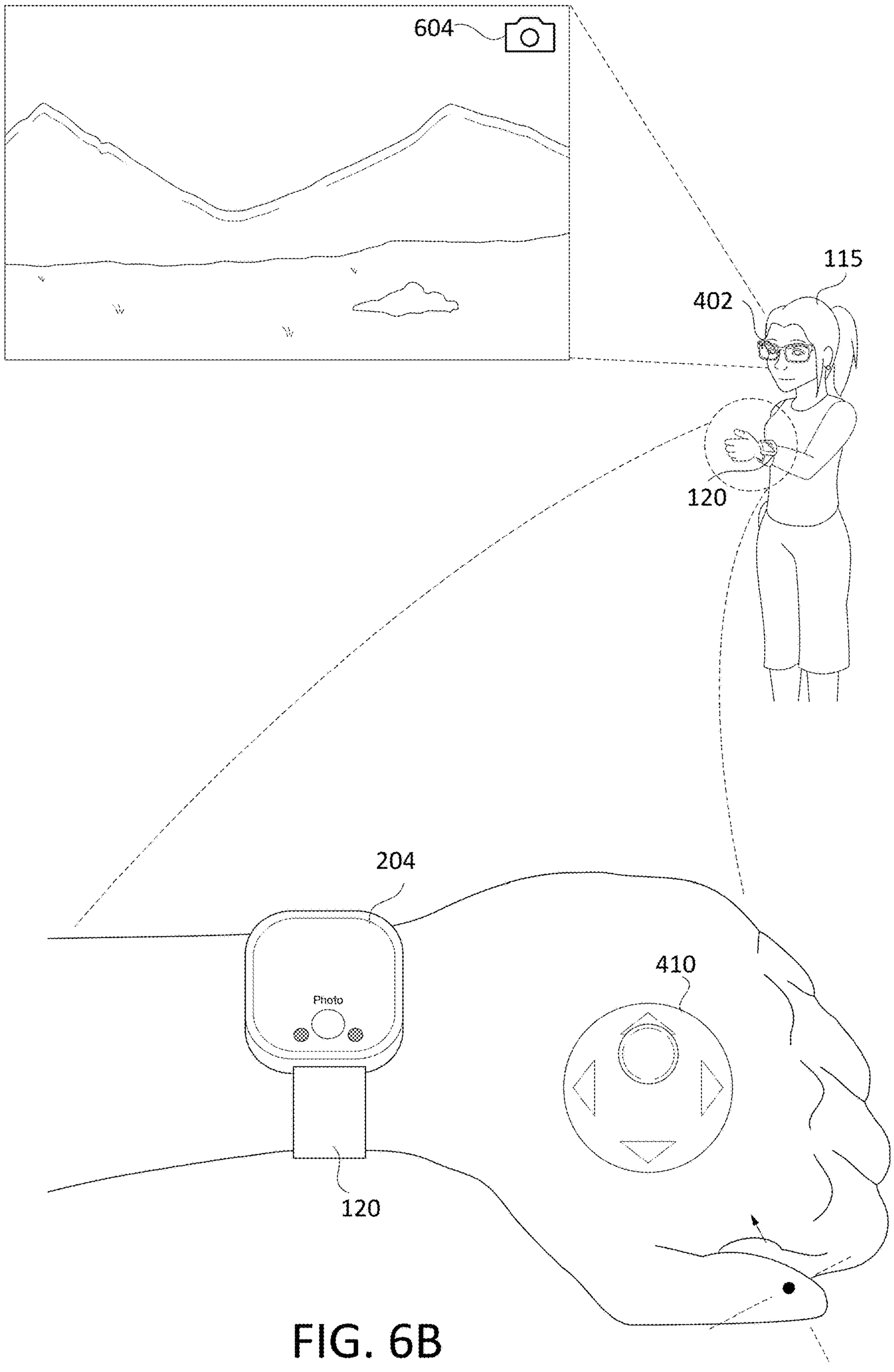


FIG. 6B

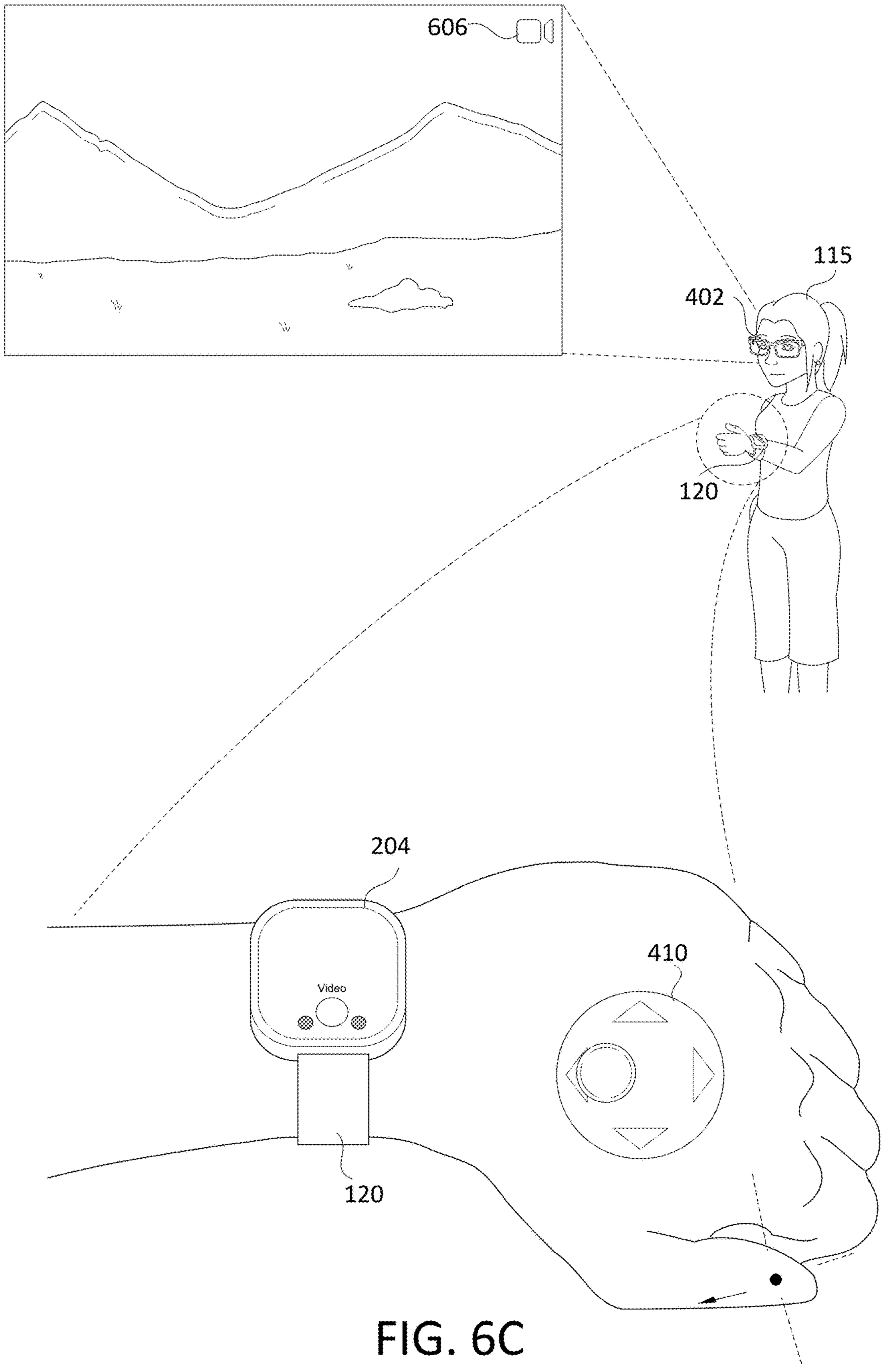


FIG. 6C

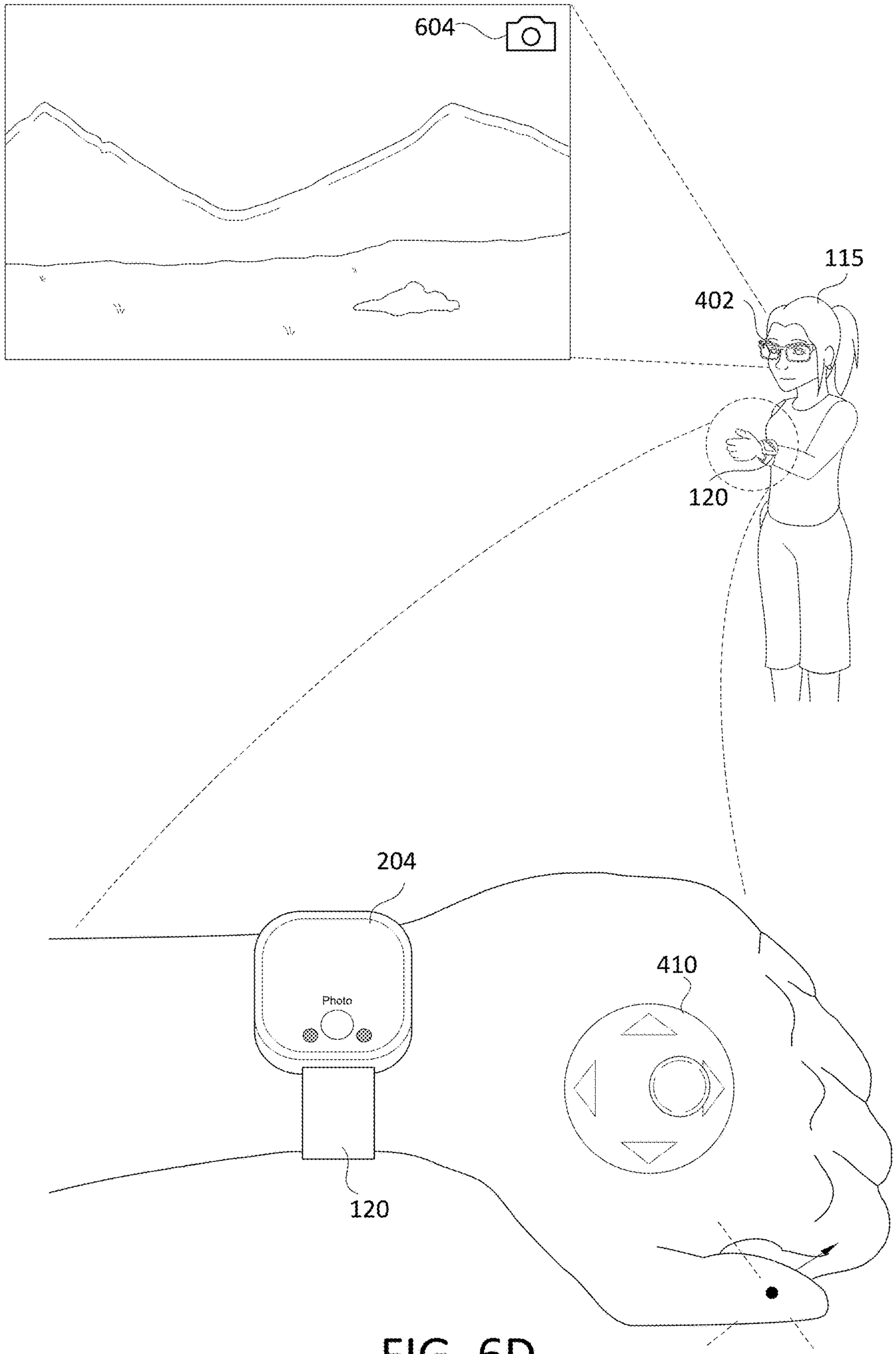


FIG. 6D

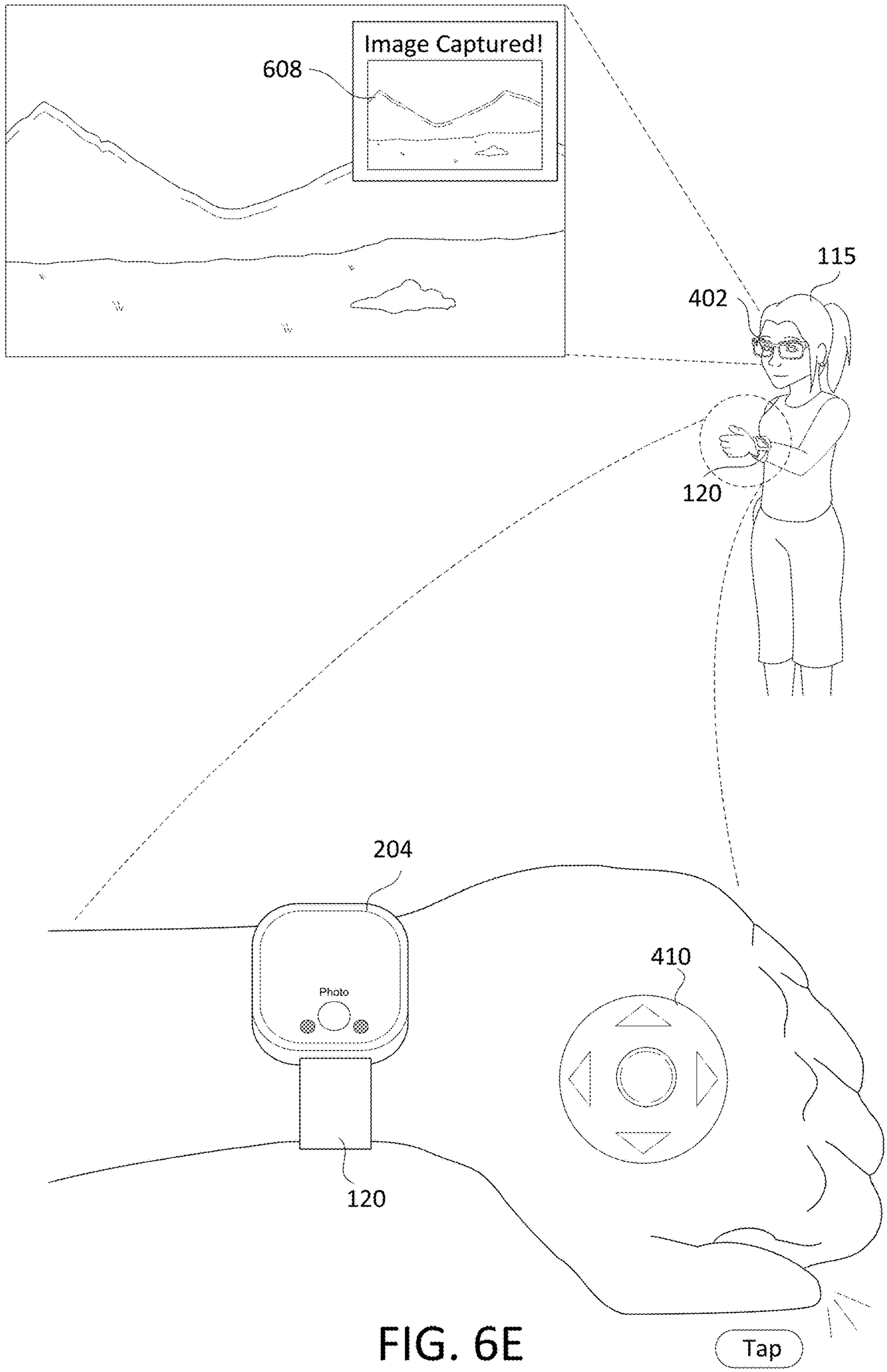


FIG. 6E

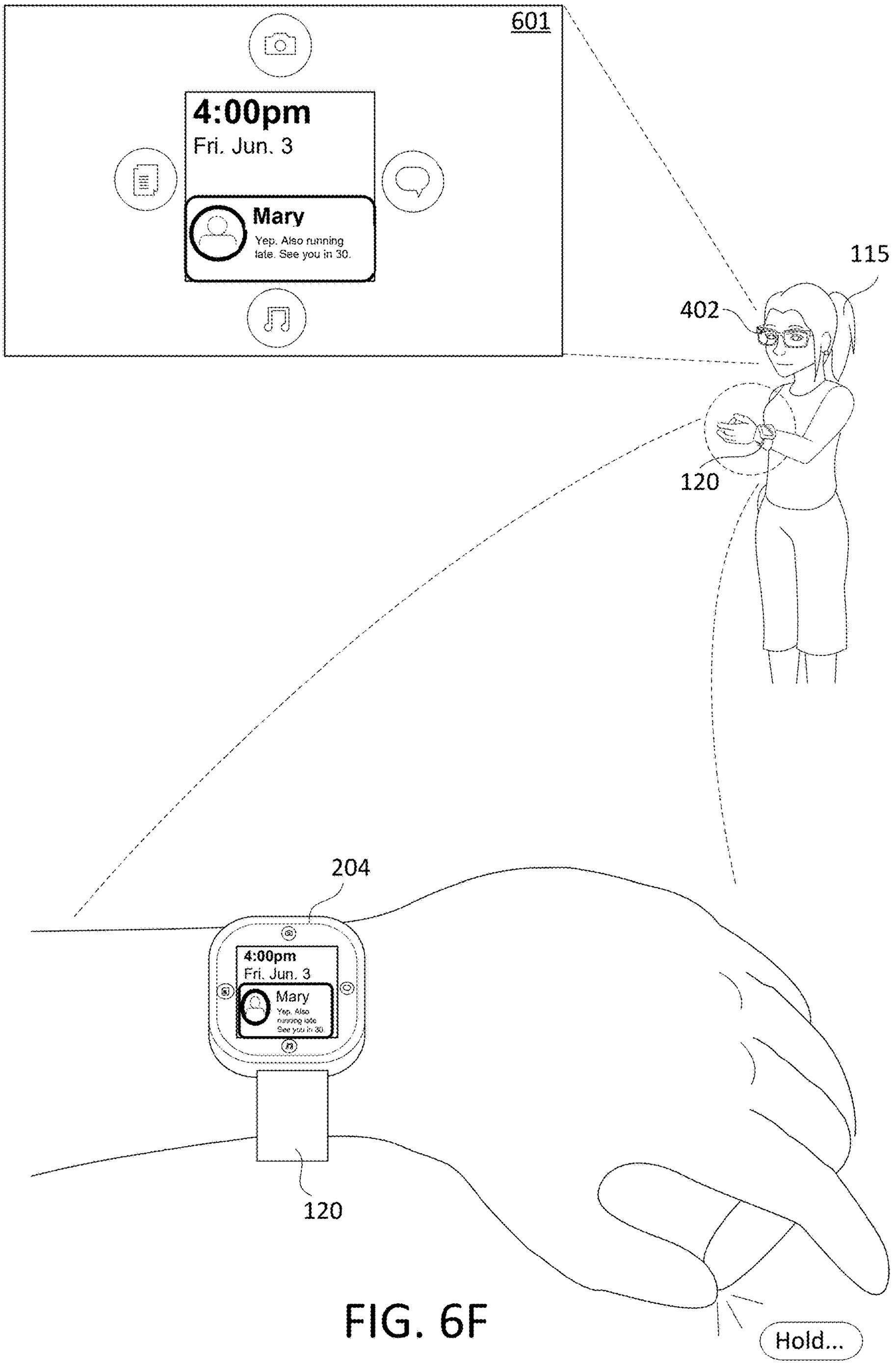

601
4:00pm
Fri. Jun. 3
Mary
Yep. Also running late. See you in 30.
115
402
120
204
4:00pm
Fri. Jun. 3
Mary
Yep. Also running late See you in 30.
120
Hold...

FIG. 6F

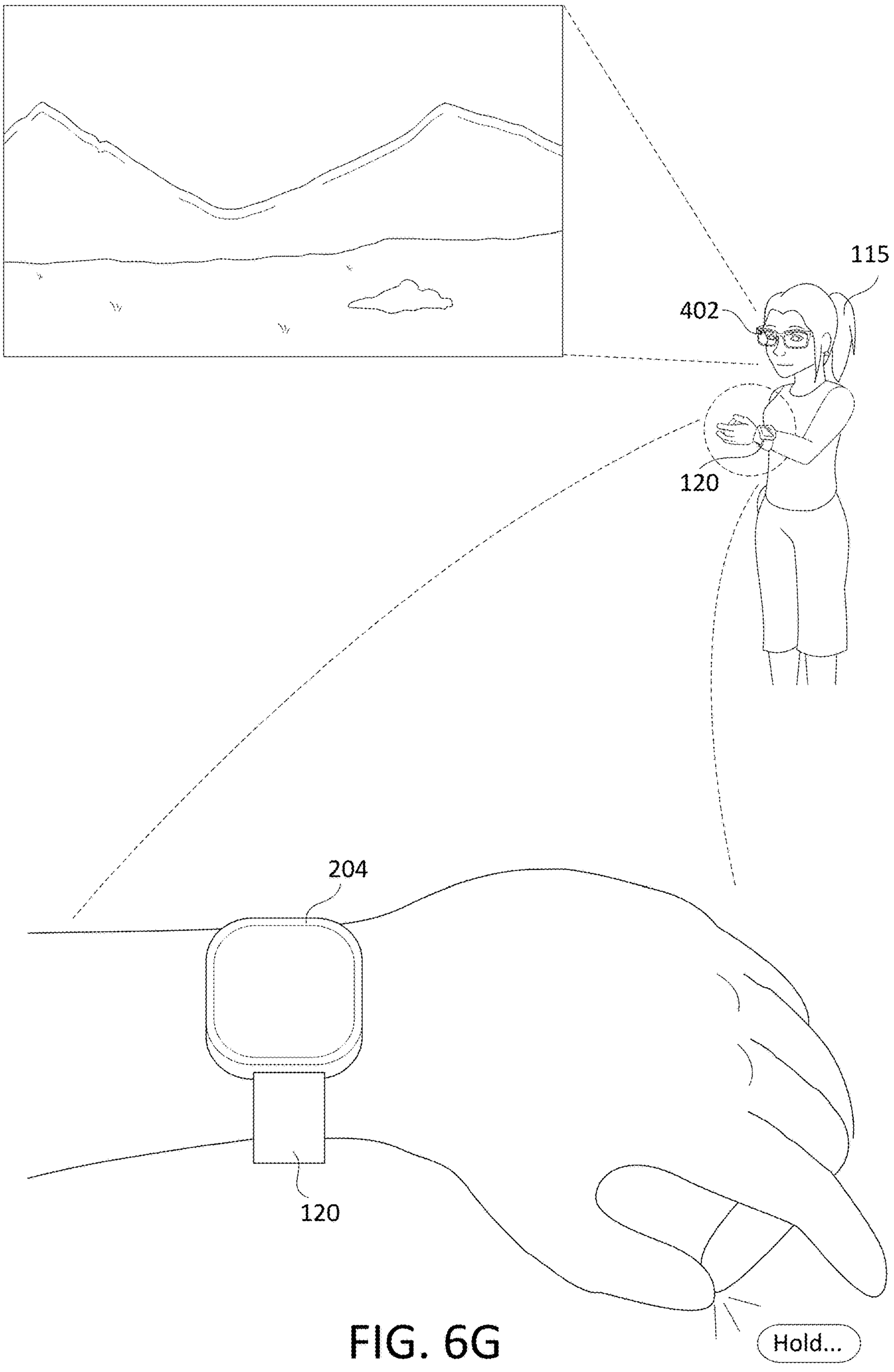


FIG. 6G

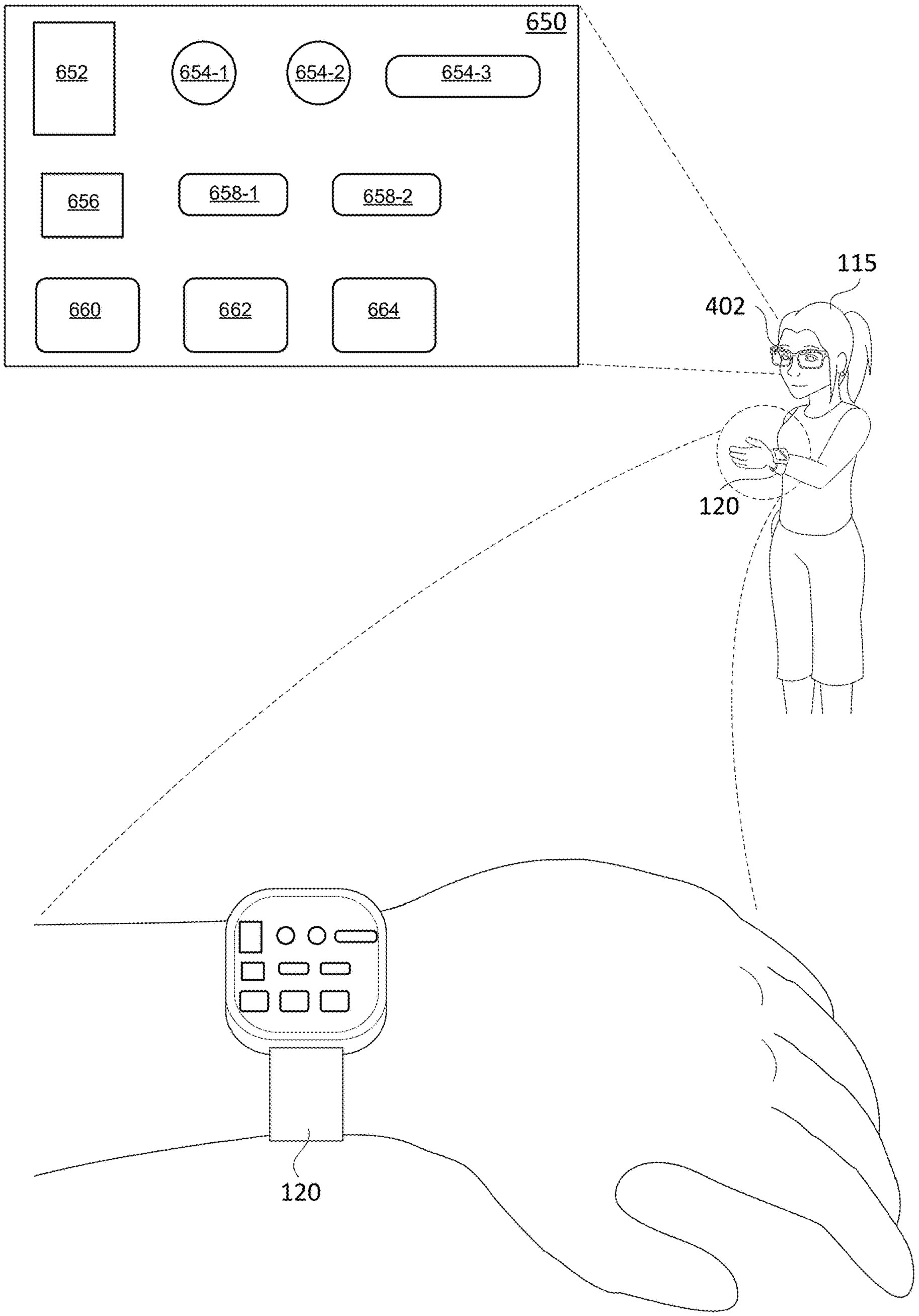

650
652
654-1
654-2
654-3
656
658-1
658-2
660
662
664
115
402
120
120

FIG. 6H

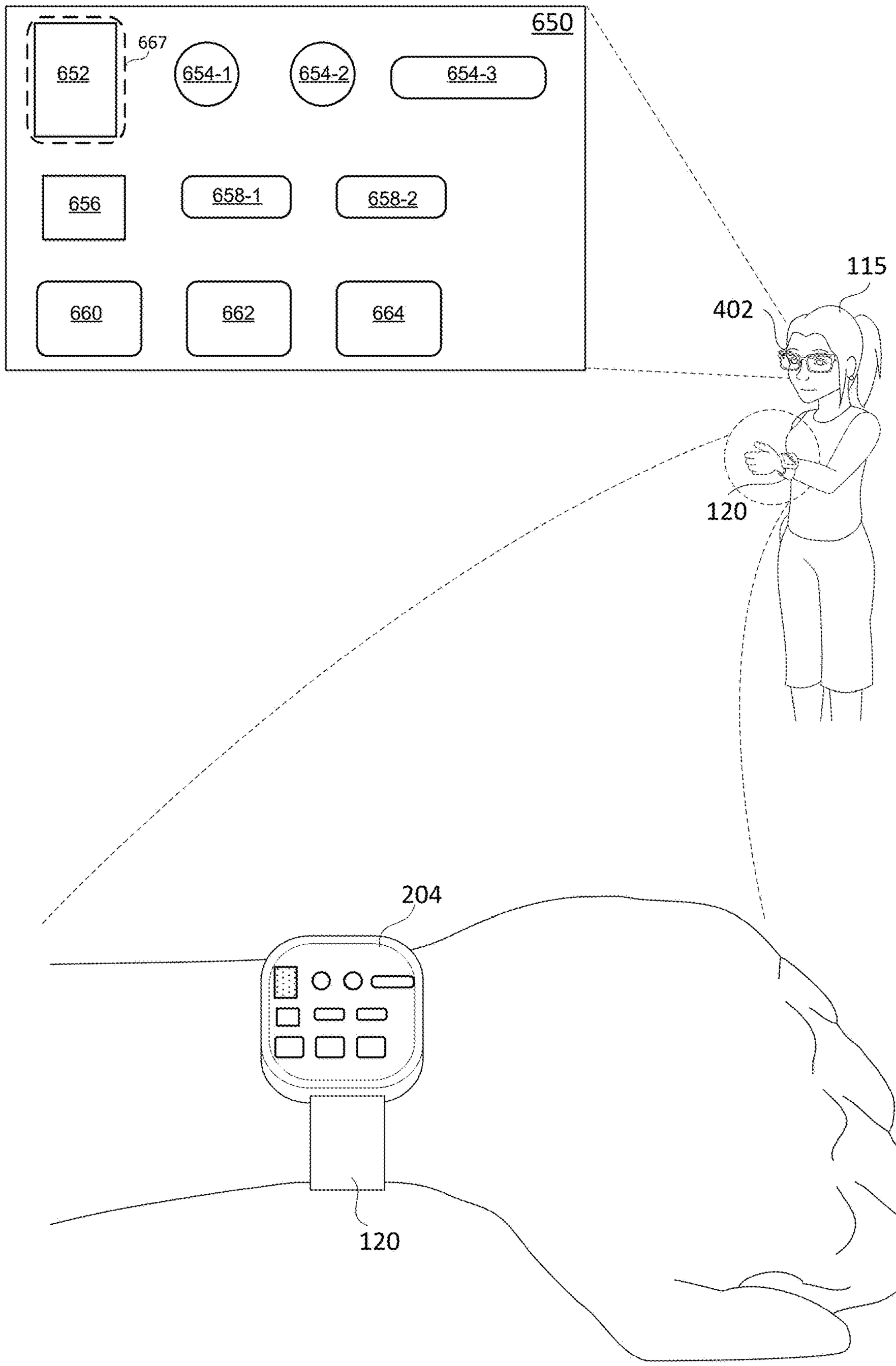

650
652
667
654-1
654-2
654-3
656
658-1
658-2
660
662
664
115
402
120
204
120

FIG. 6I

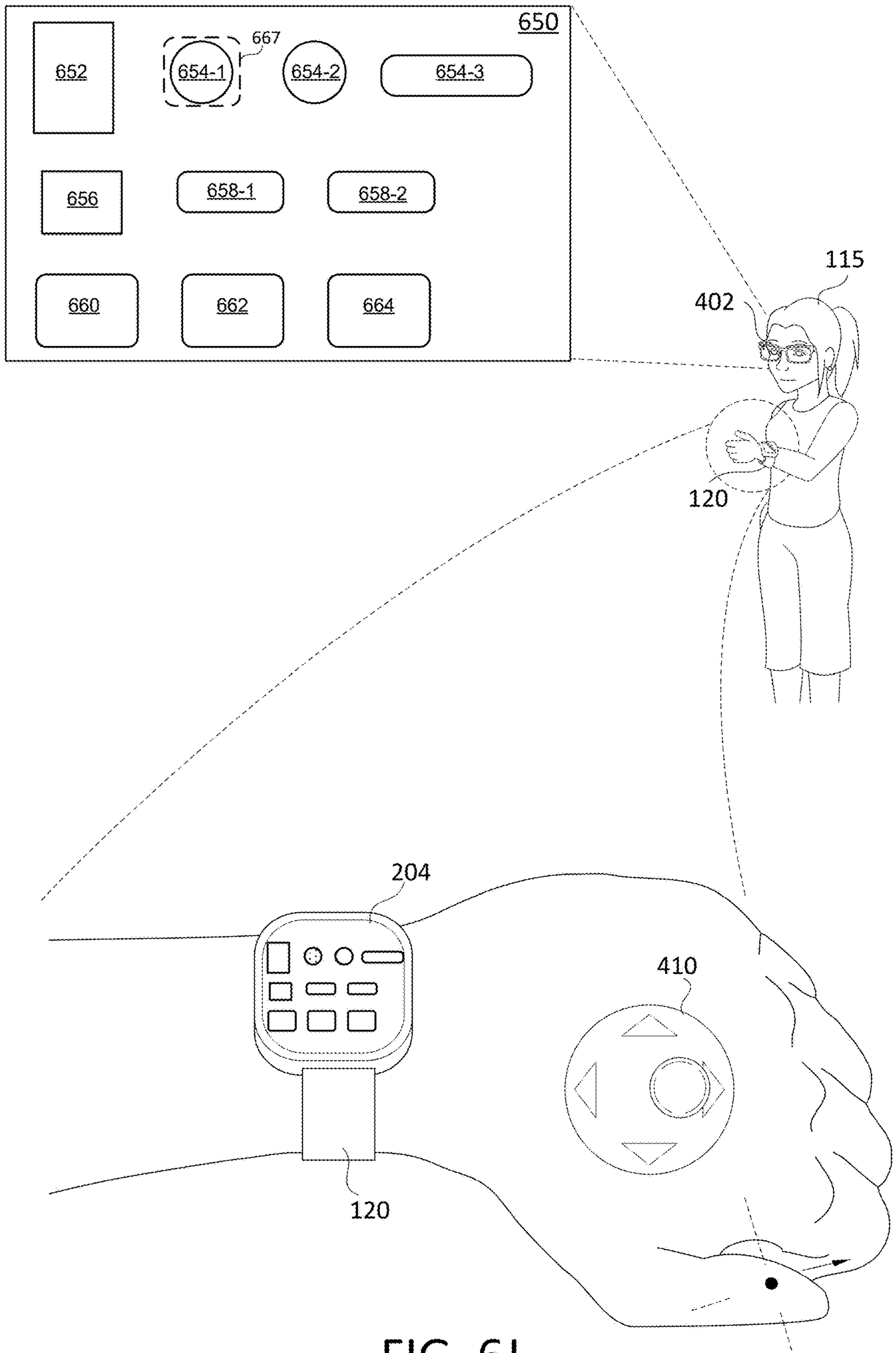

650
652
667
654-1
654-2
654-3
656
658-1
658-2
660
662
664
115
402
120
204
410
120

FIG. 6J

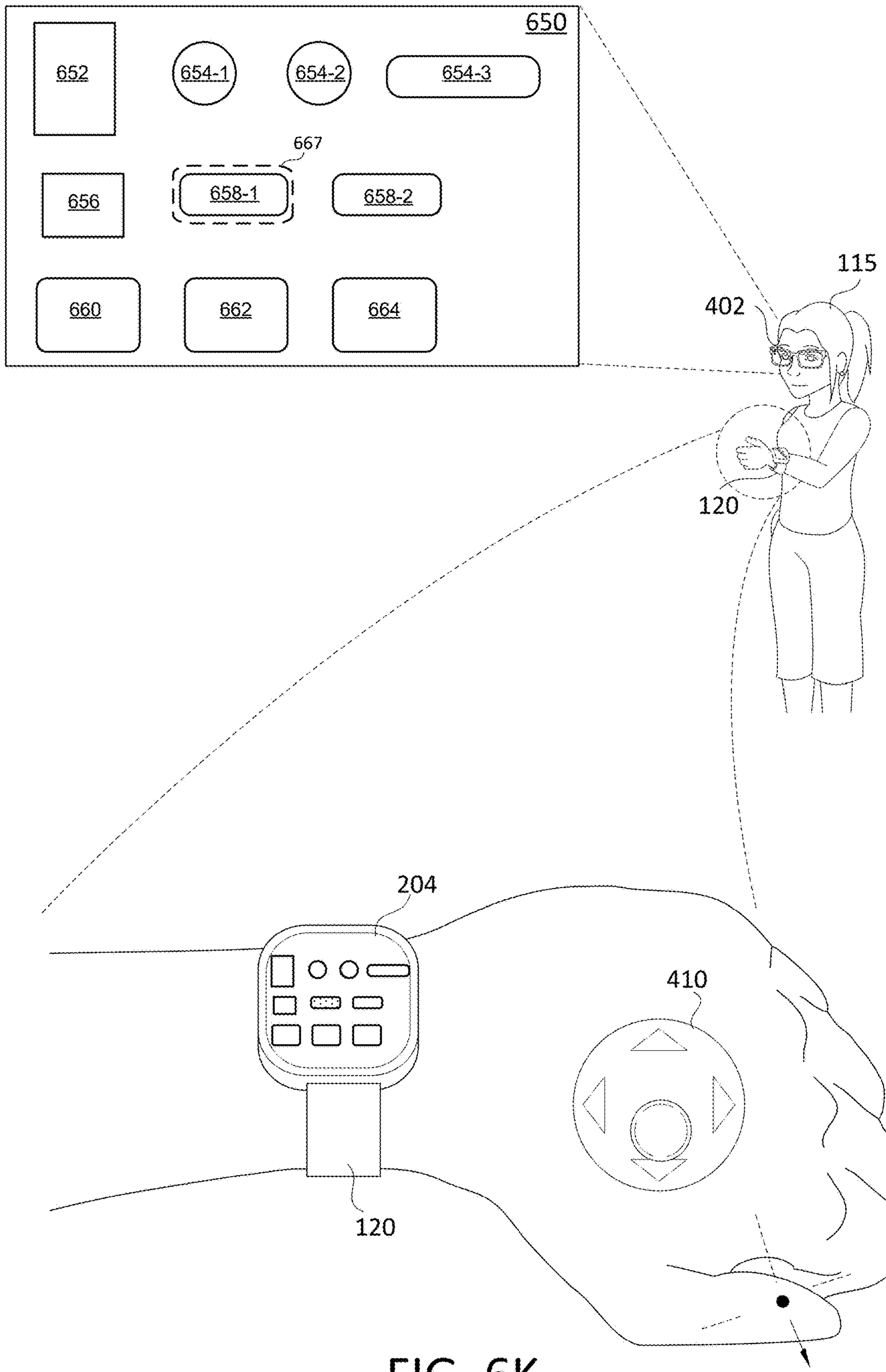

650
652
654-1
654-2
654-3
667
656
658-1
658-2
660
662
664
115
402
120
204
410
120

FIG. 6K

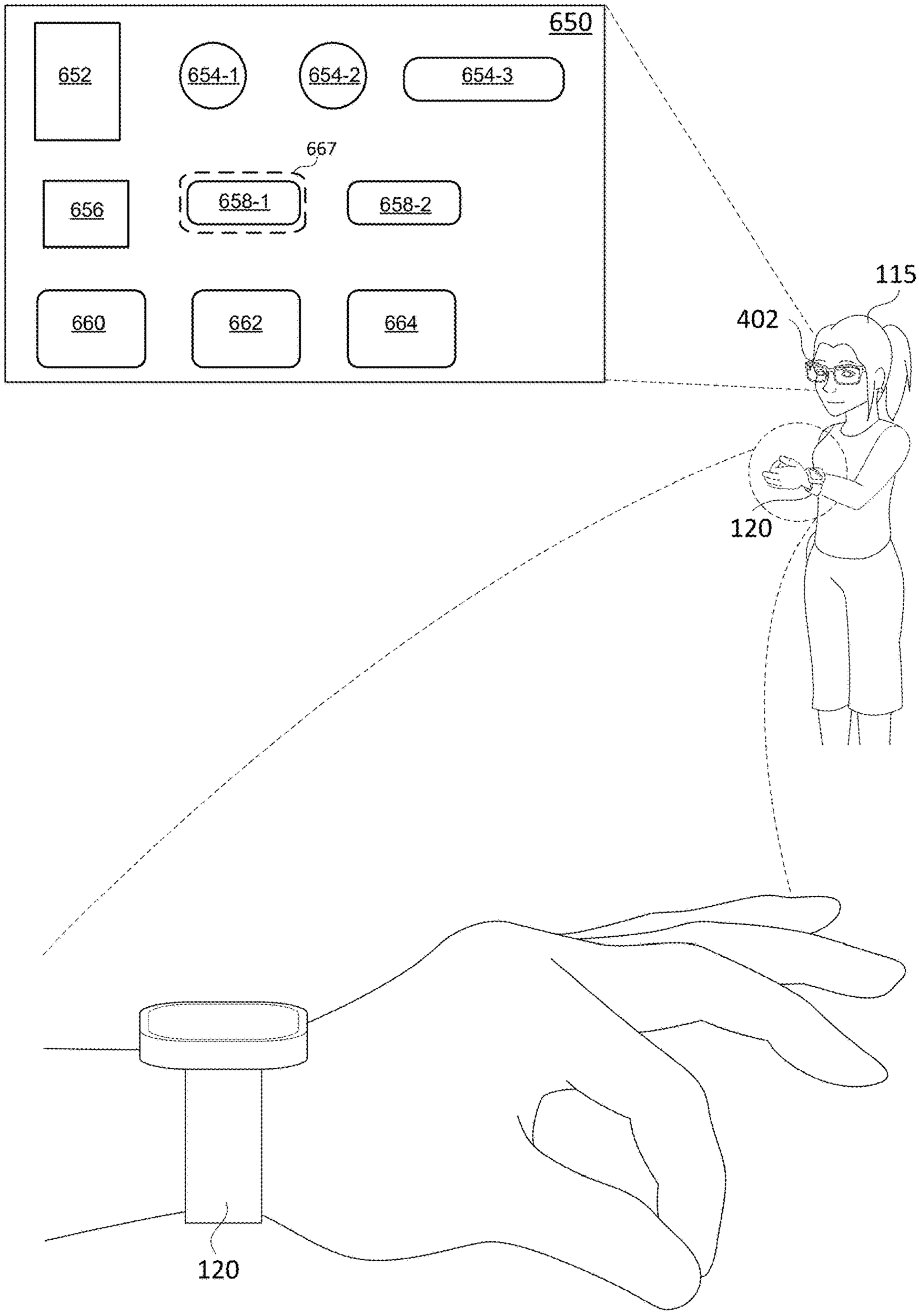

650
652
654-1
654-2
654-3
667
656
658-1
658-2
660
662
664
115
402
120
120

FIG. 6L

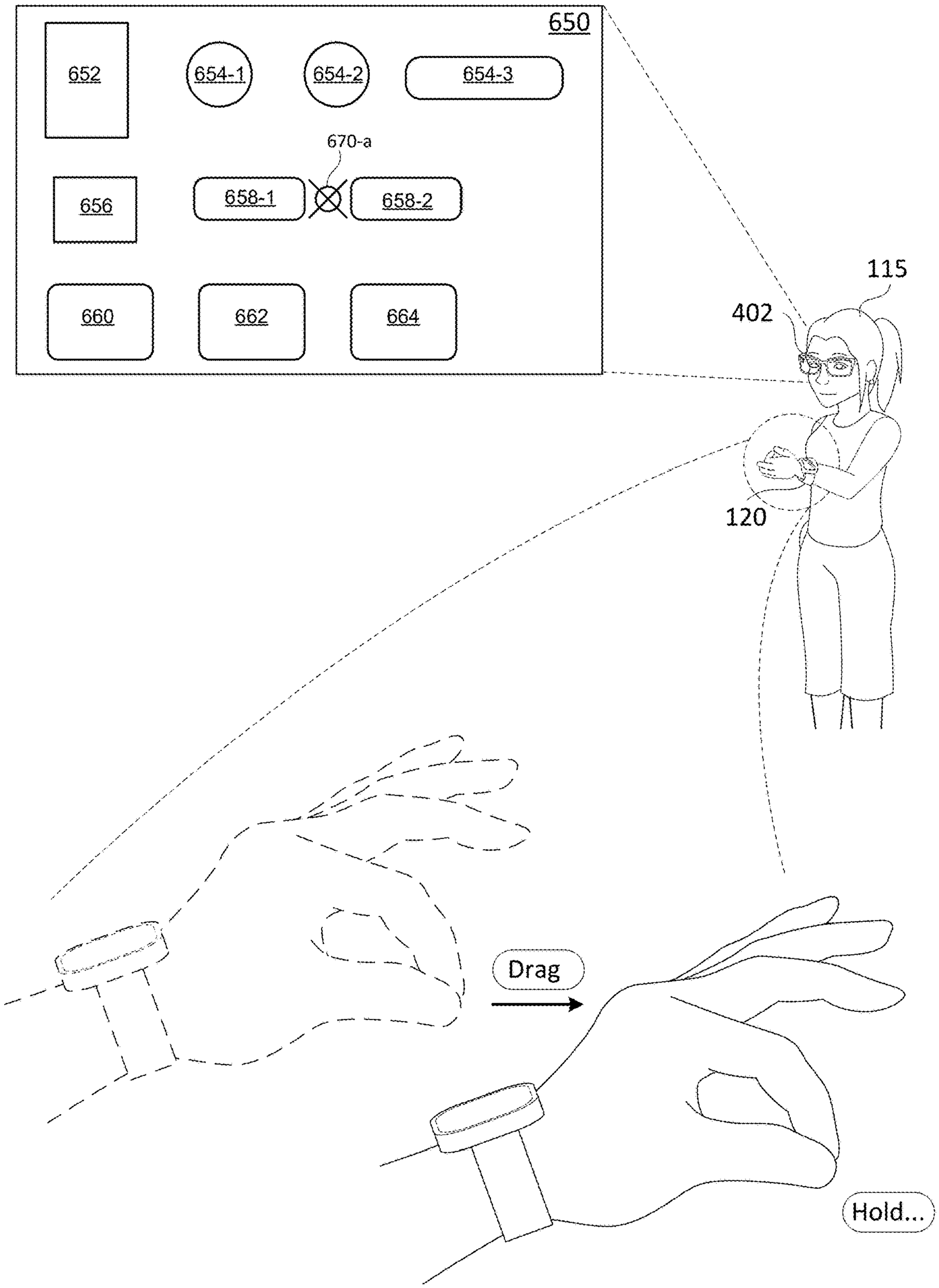

650
652
654-1
654-2
654-3
670-a
656
658-1
658-2
660
662
664
115
402
120
Drag
Hold...

FIG. 6M

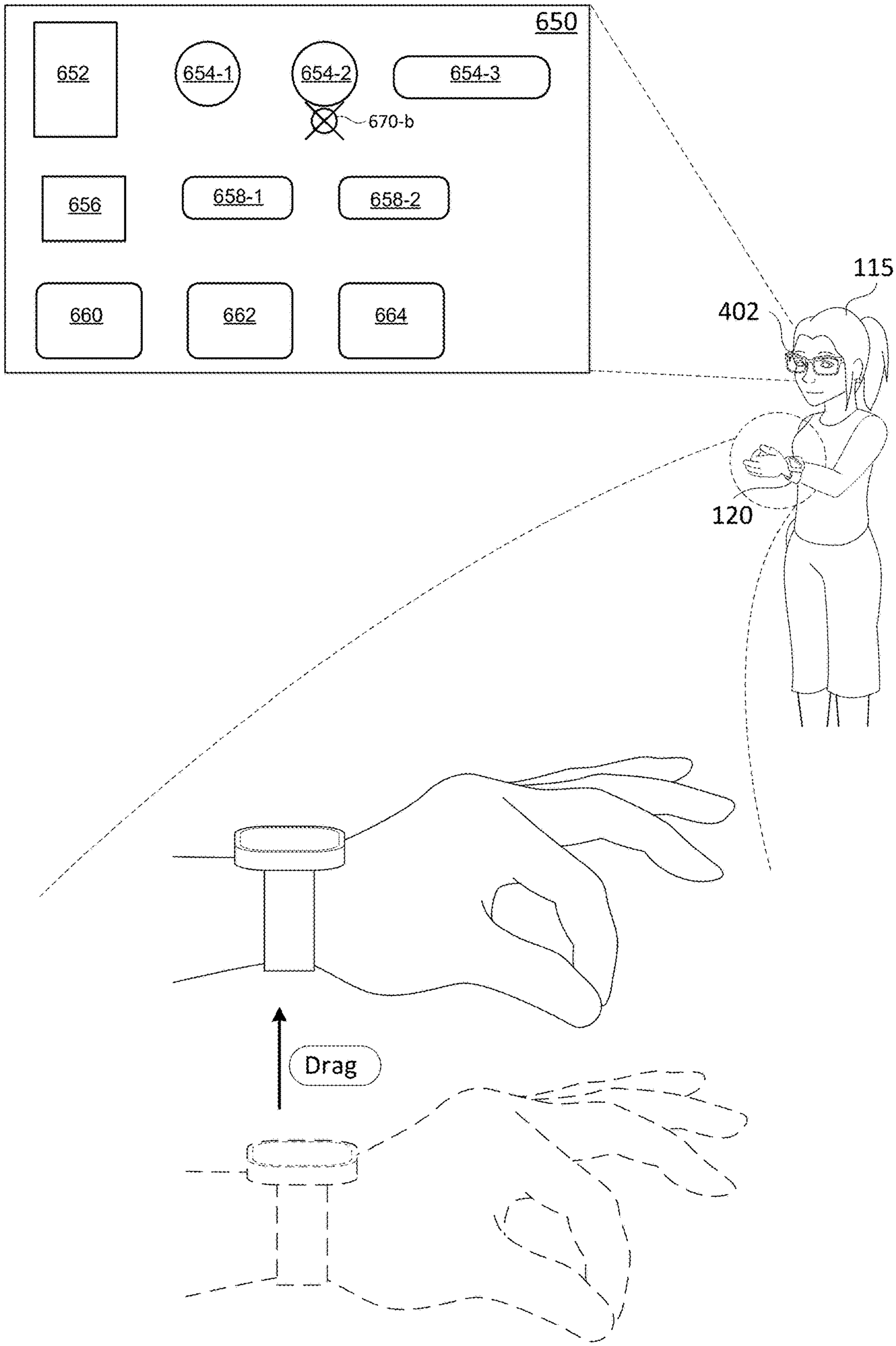

650
652
654-1
654-2
654-3
670-b
656
658-1
658-2
660
662
664
115
402
120
Drag

FIG. 6N

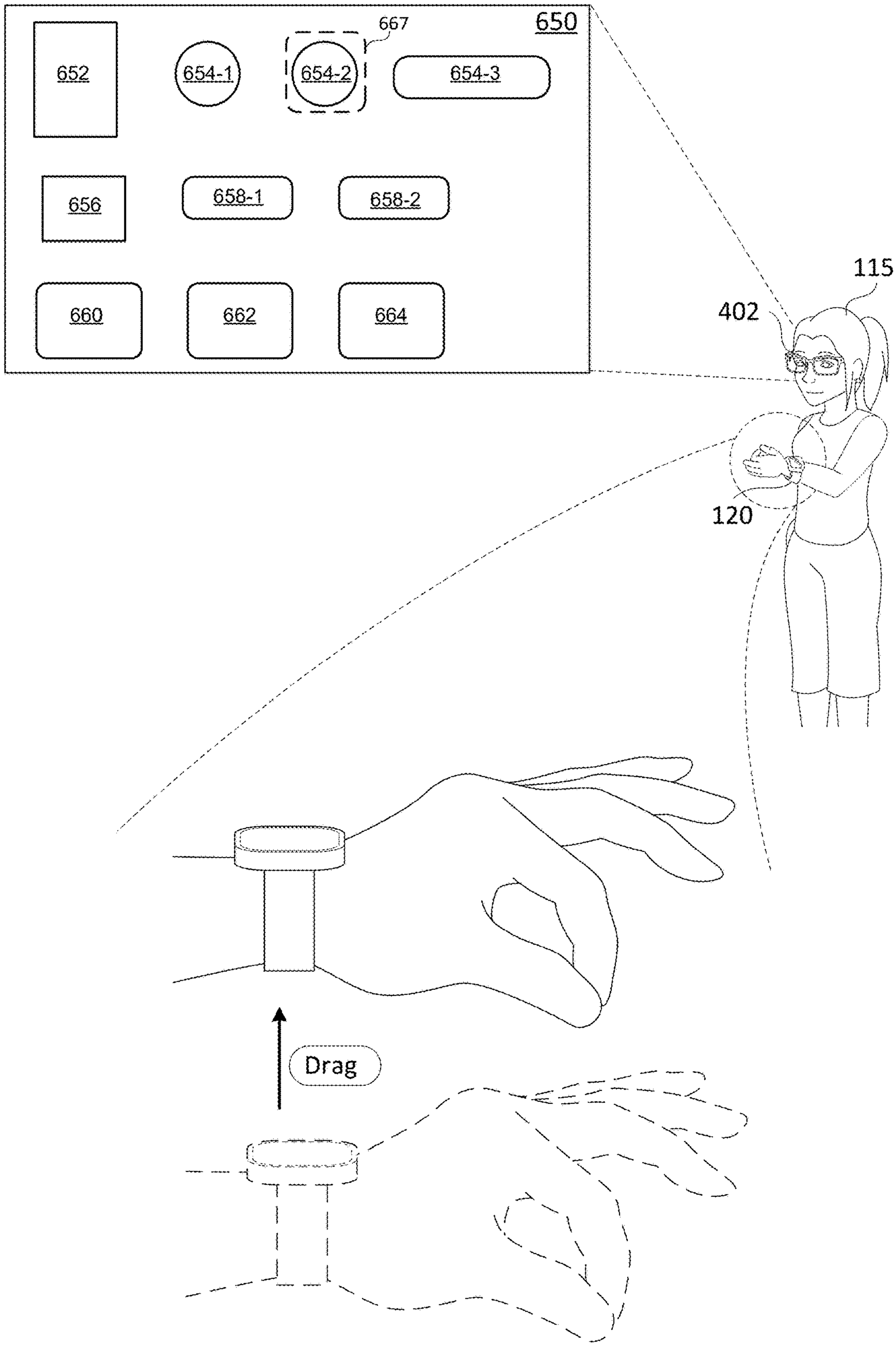

650
667
652
654-1
654-2
654-3
656
658-1
658-2
660
662
664
115
402
120
Drag

FIG. 6O

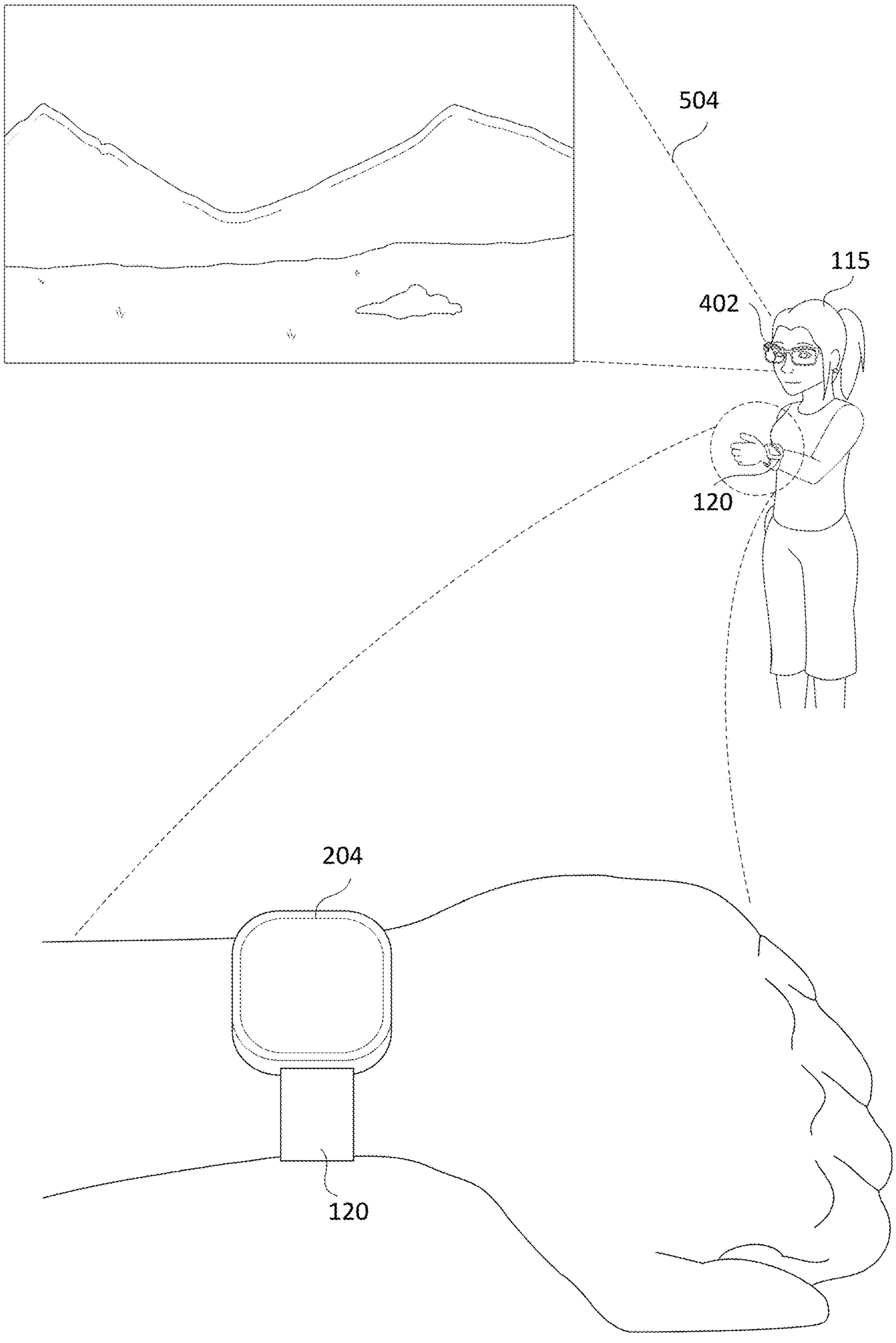


FIG. 7A

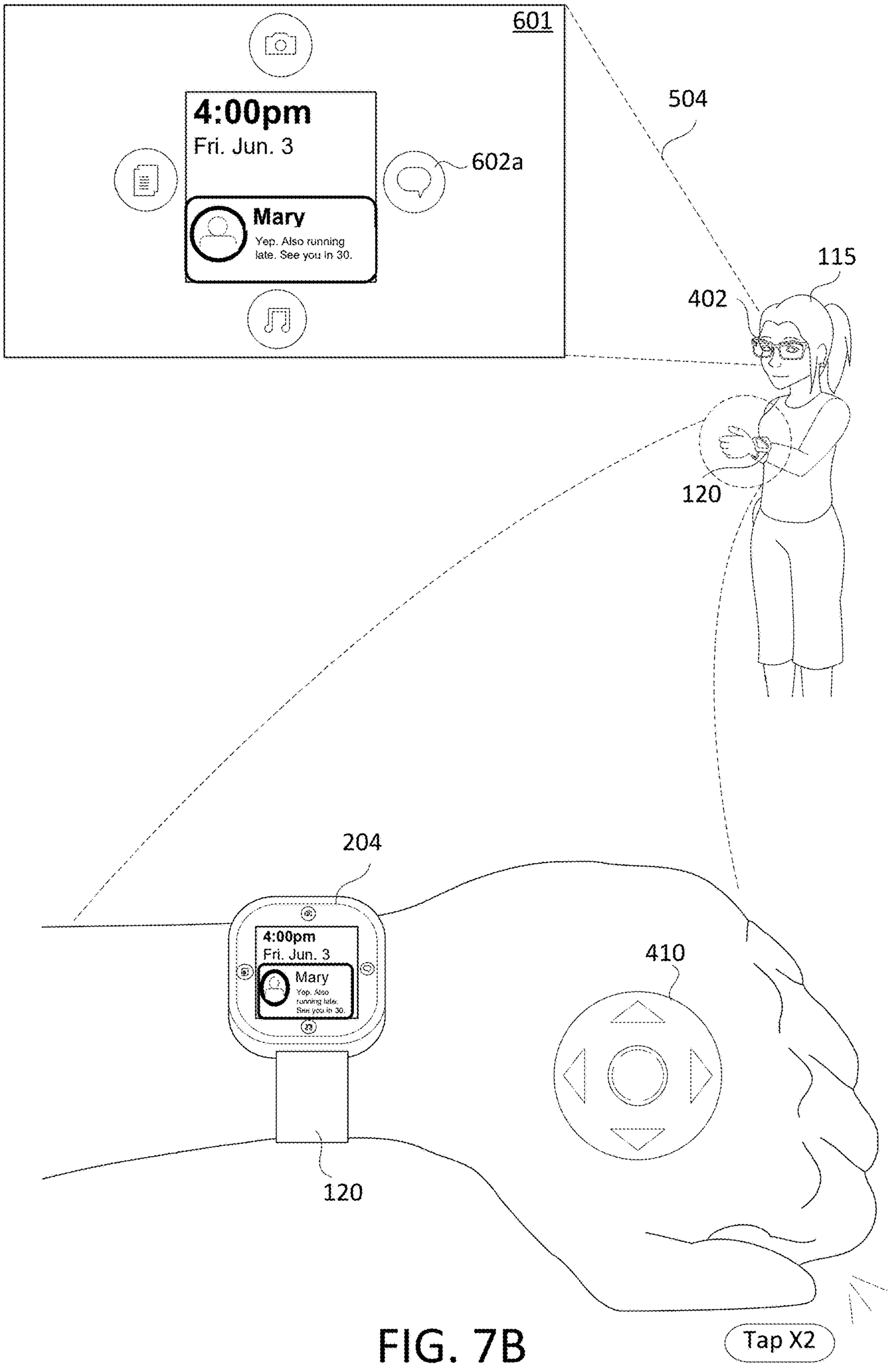

601
4:00pm
Fri. Jun. 3
Mary
Yep. Also running late. See you in 30.
602a
504
115
402
120
204
4:00pm
Fri. Jun. 3
Mary
Yep. Also running late. See you in 30.
410
120
Tap X2

FIG. 7B

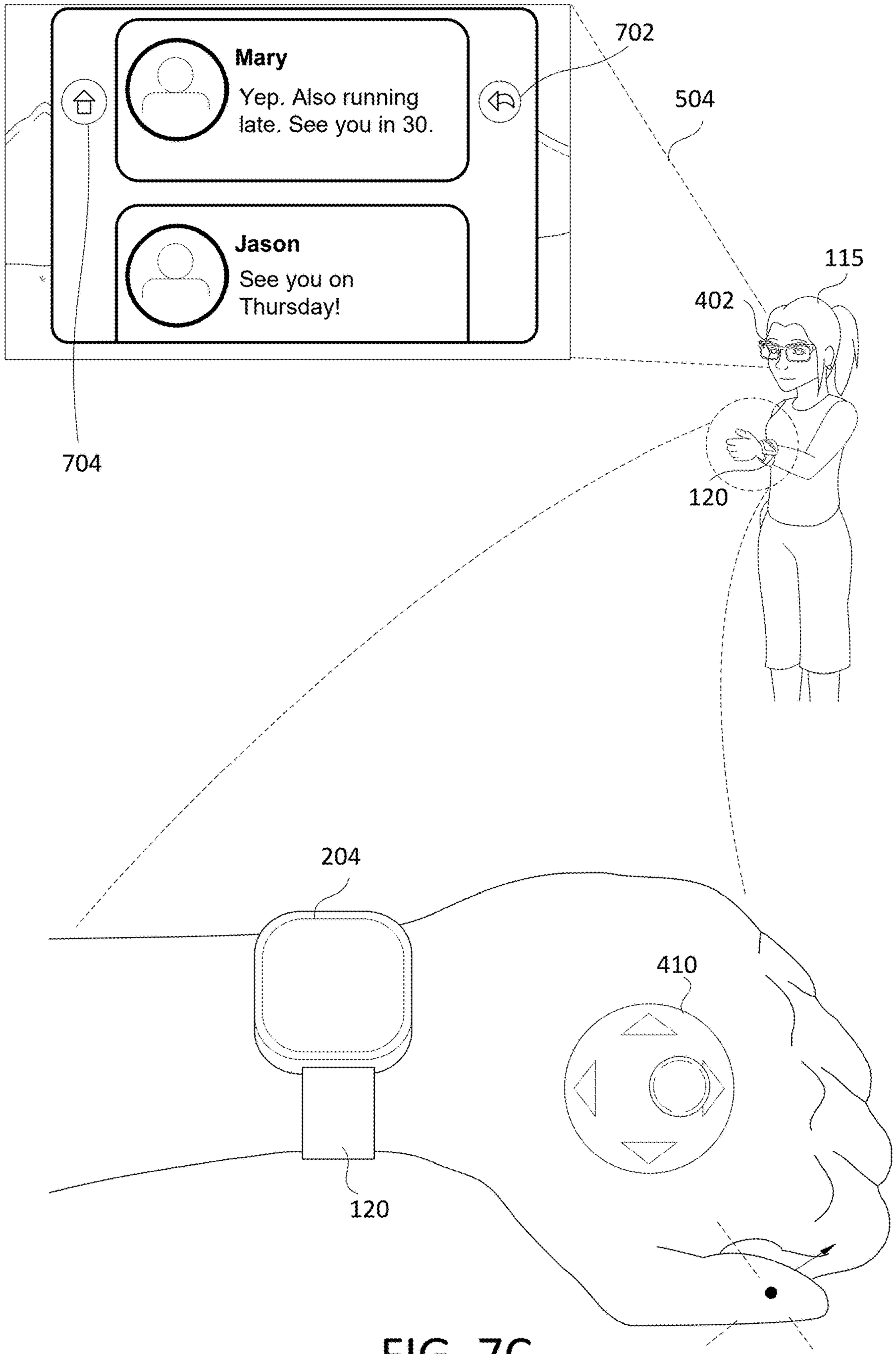

Mary
Yep. Also running late. See you in 30.
Jason
See you on Thursday!
702
504
115
402
120
704
204
410
120

FIG. 7C

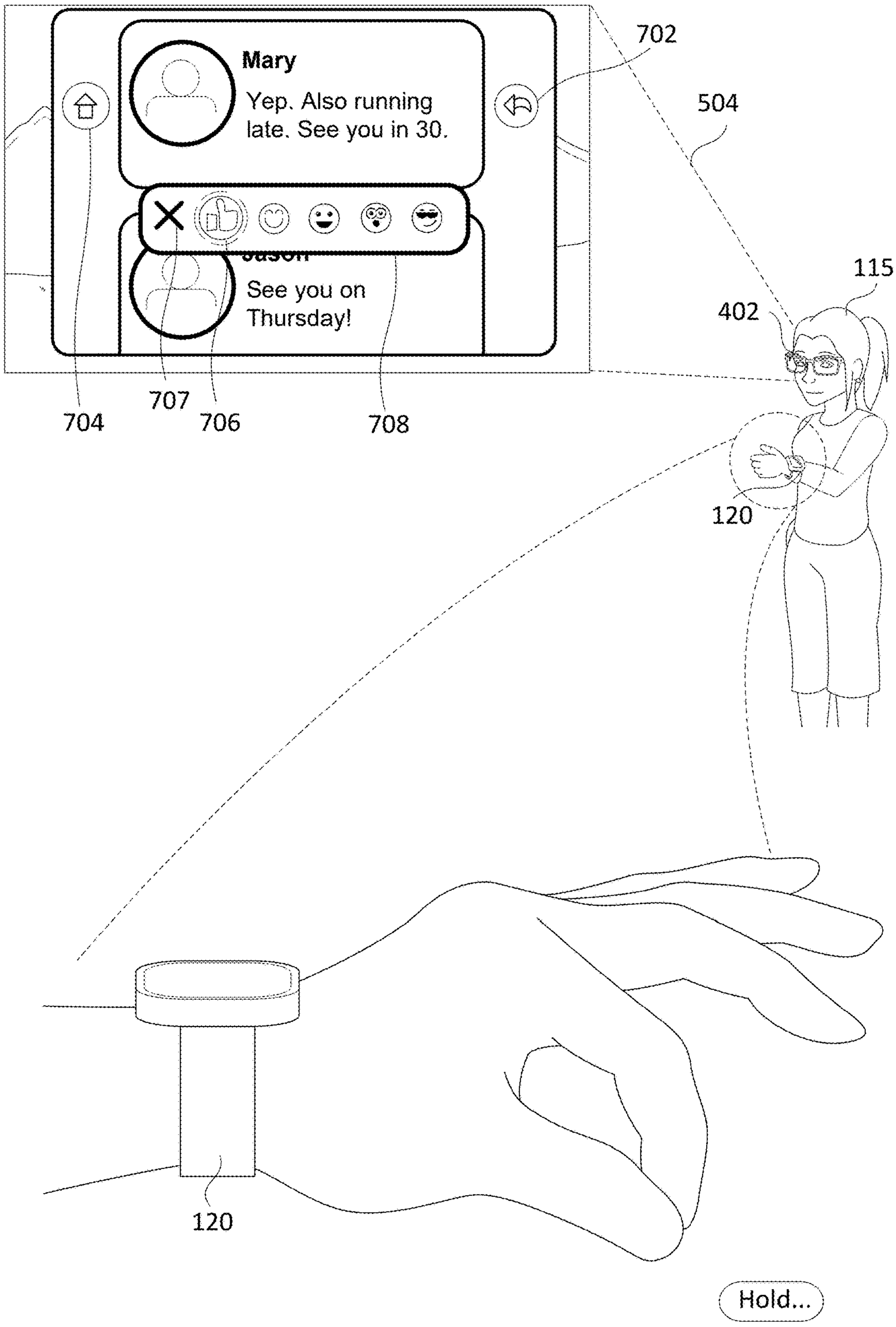

Mary
Yep. Also running late. See you in 30.
See you on Thursday!
Hold...
702
504
115
402
120
704
707
706
708
120

FIG. 7D

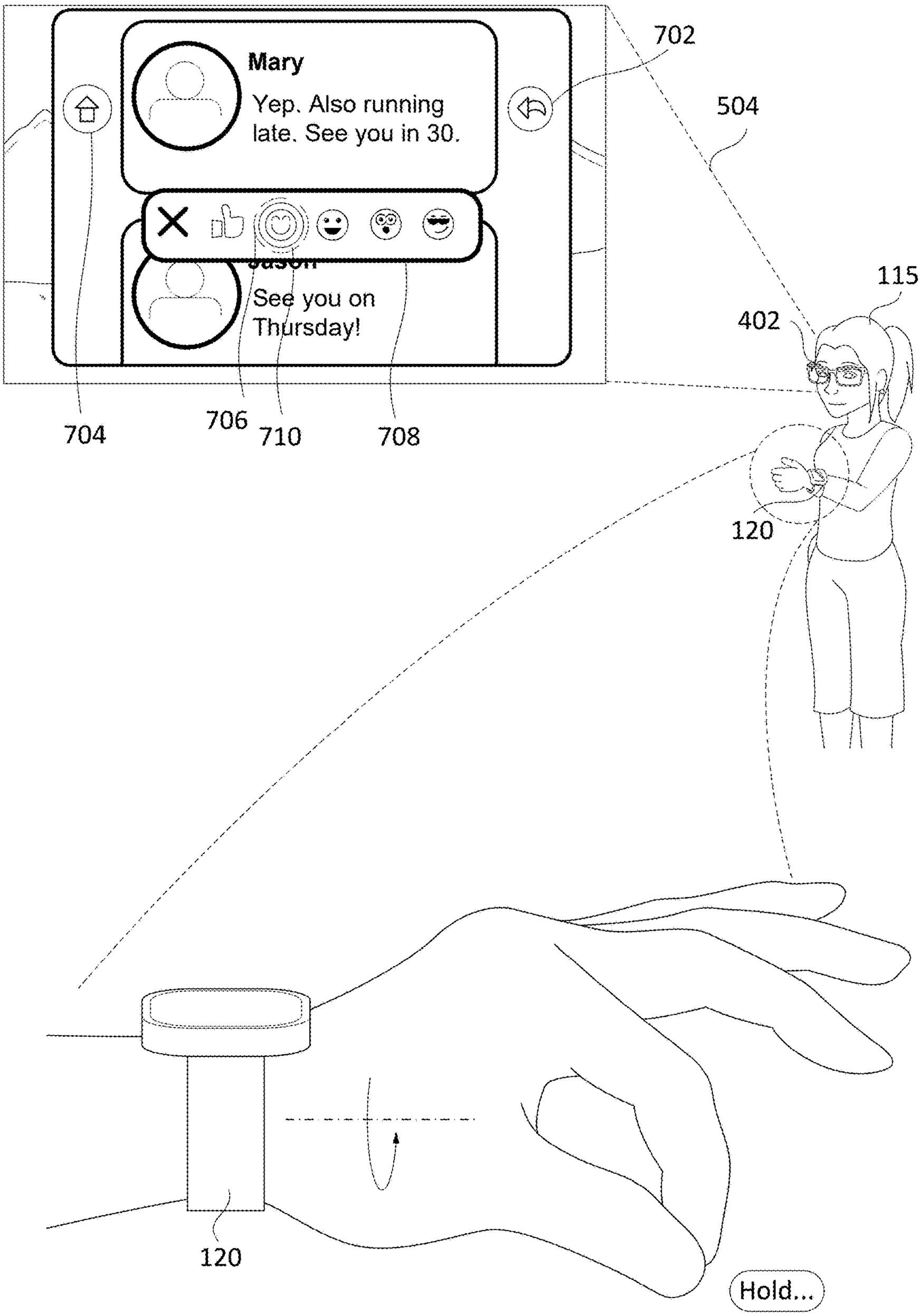

Mary
Yep. Also running late. See you in 30.
See you on Thursday!
Hold...
702
504
115
402
120
704
706
710
708
120

FIG. 7E

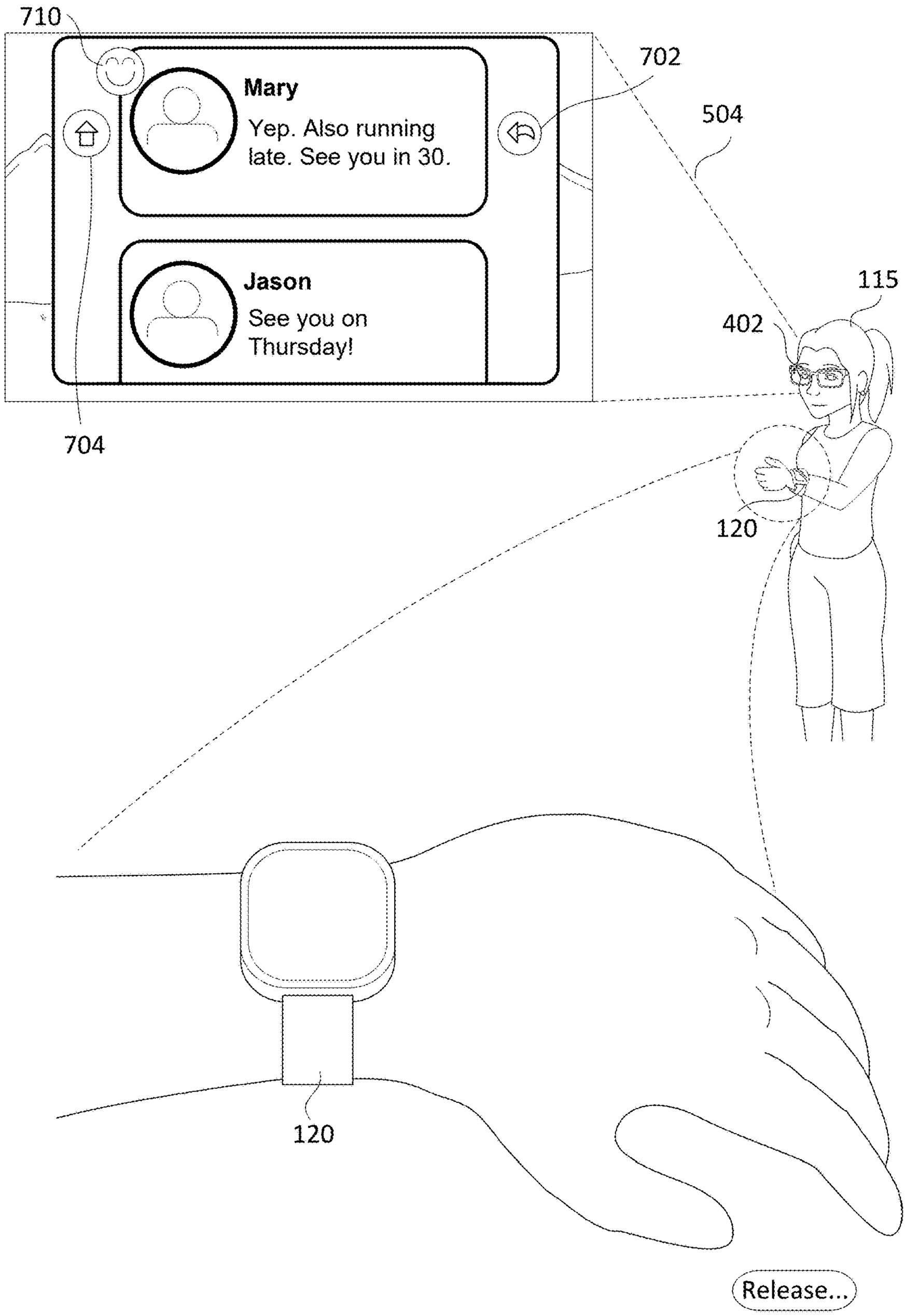

710
Mary
Yep. Also running late. See you in 30.
Jason
See you on Thursday!
702
504
115
402
120
704
120
Release...

FIG. 7F

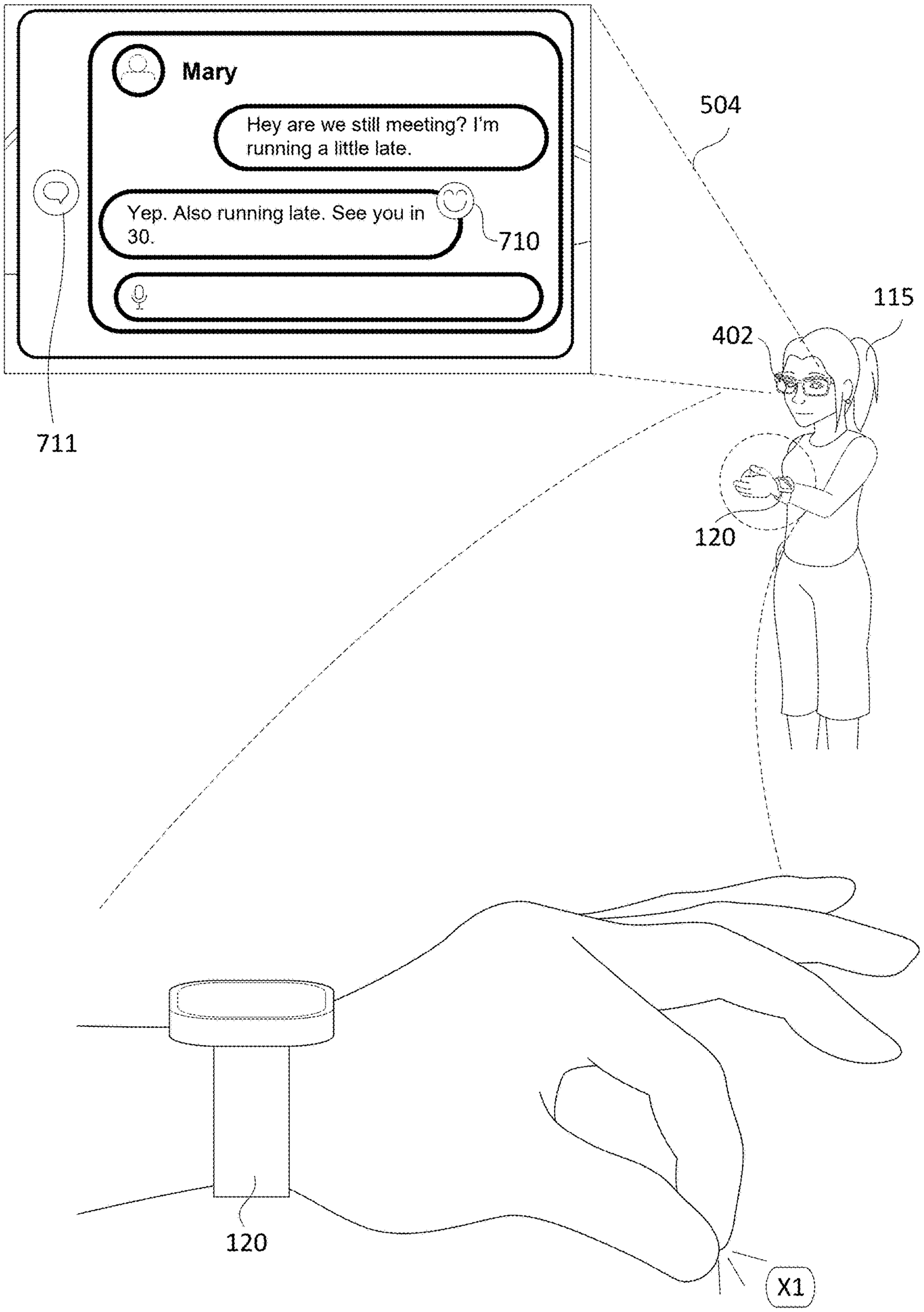

Mary
Hey are we still meeting? I'm running a little late.
Yep. Also running late. See you in 30.
710
711
504
115
402
120
120
X1

FIG. 7G

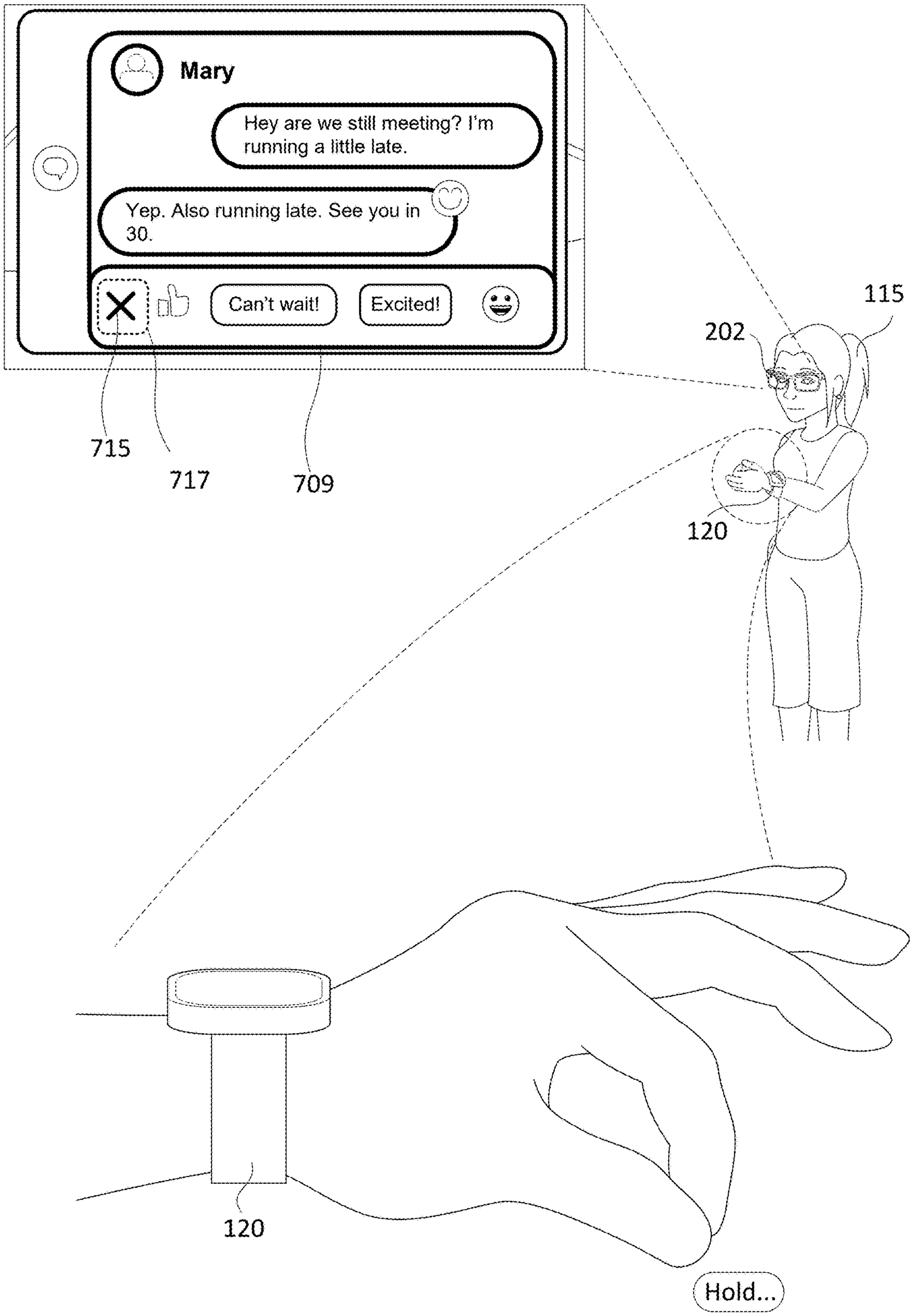

Mary
Hey are we still meeting? I'm running a little late.
Yep. Also running late. See you in 30.
Can't wait!
Excited!
715
717
709
115
202
120
120
Hold...

FIG. 7H

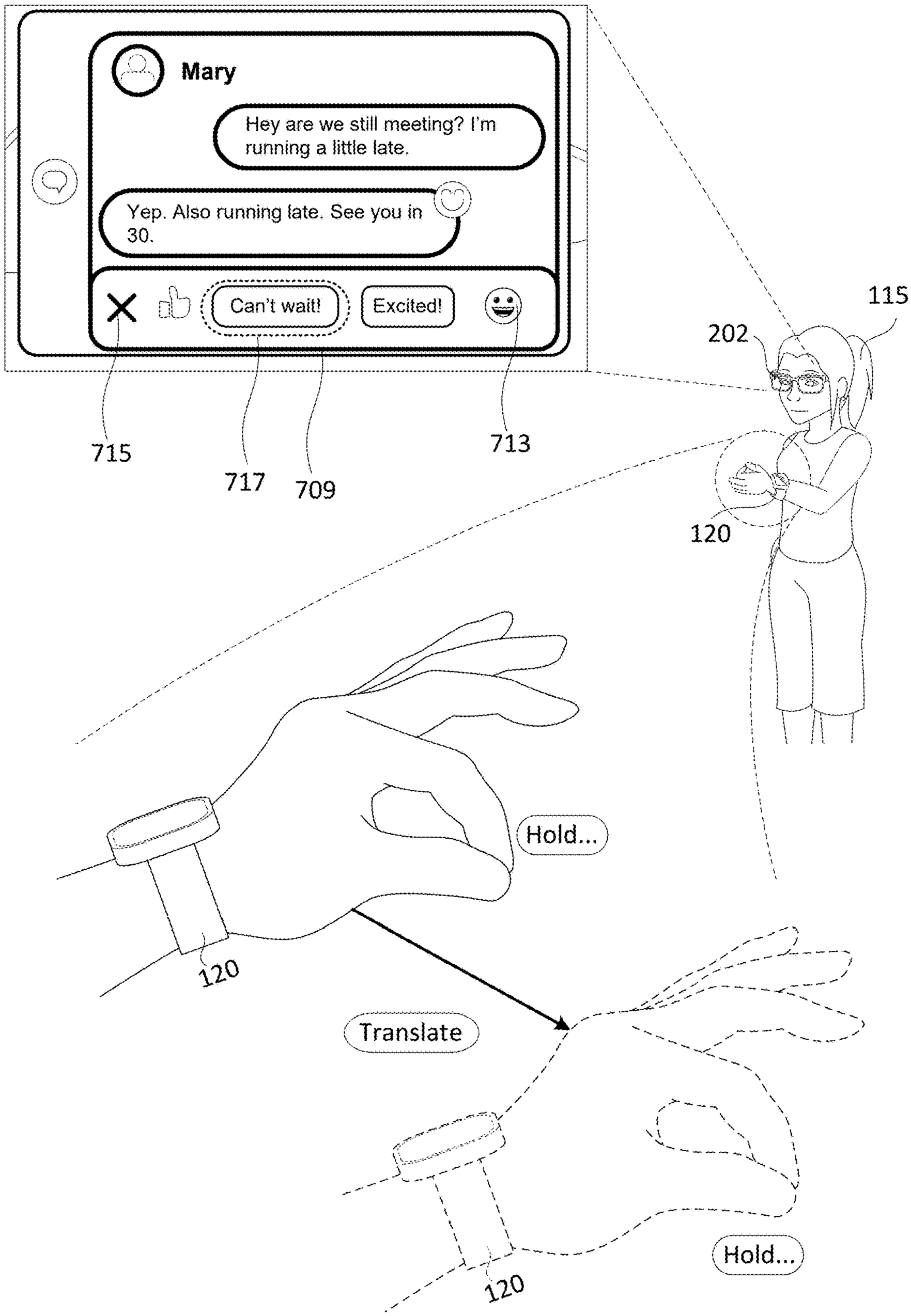

Mary
Hey are we still meeting? I'm running a little late.
Yep. Also running late. See you in 30.
Can't wait!
Excited!
715
717
709
713
115
202
120
Hold...
120
Translate
Hold...
120

FIG. 7I

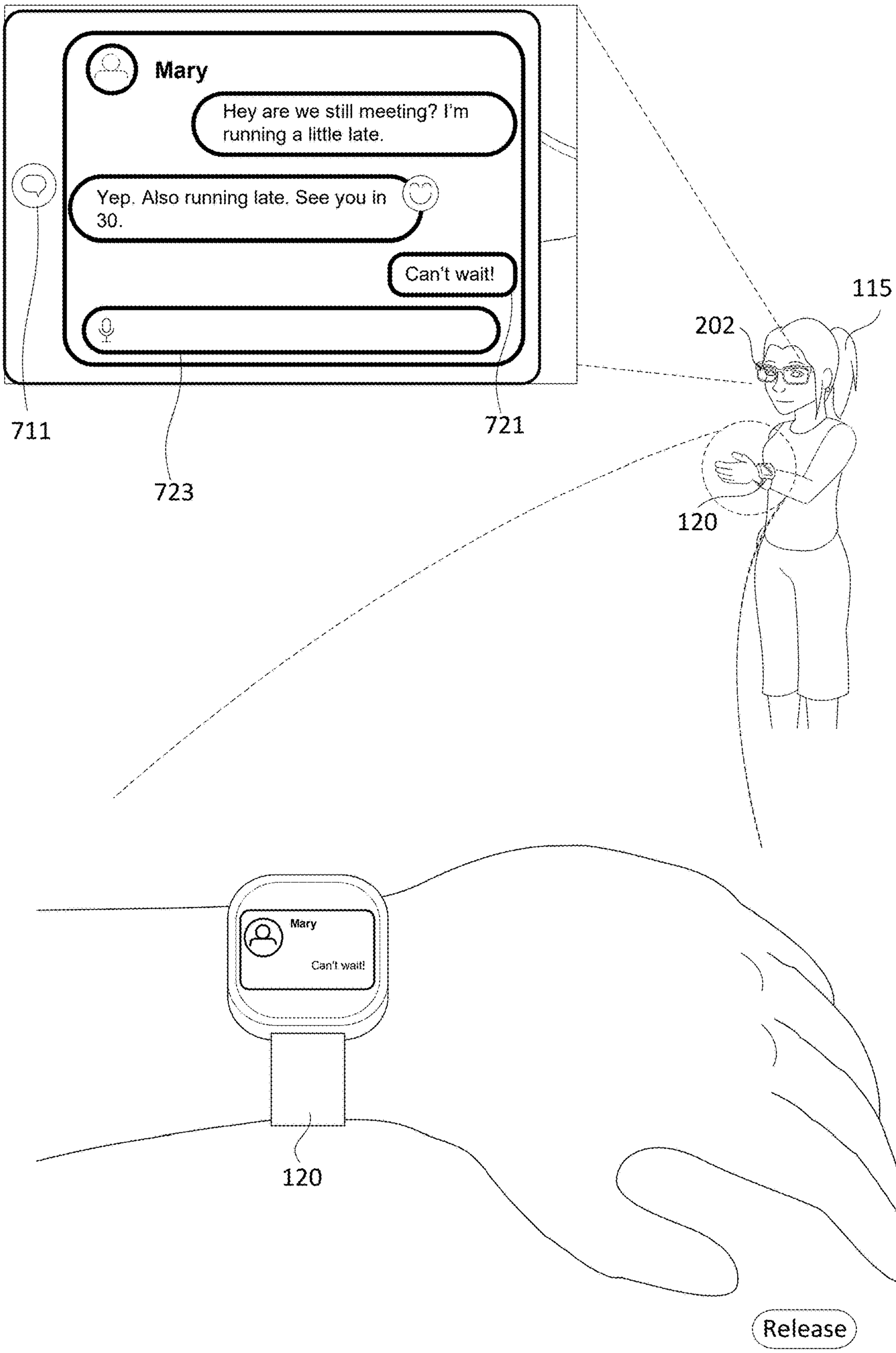

Mary
Hey are we still meeting? I'm running a little late.
Yep. Also running late. See you in 30.
Can't wait!
711
721
723
115
202
120
Mary
Can't wait!
120
Release

FIG. 7J

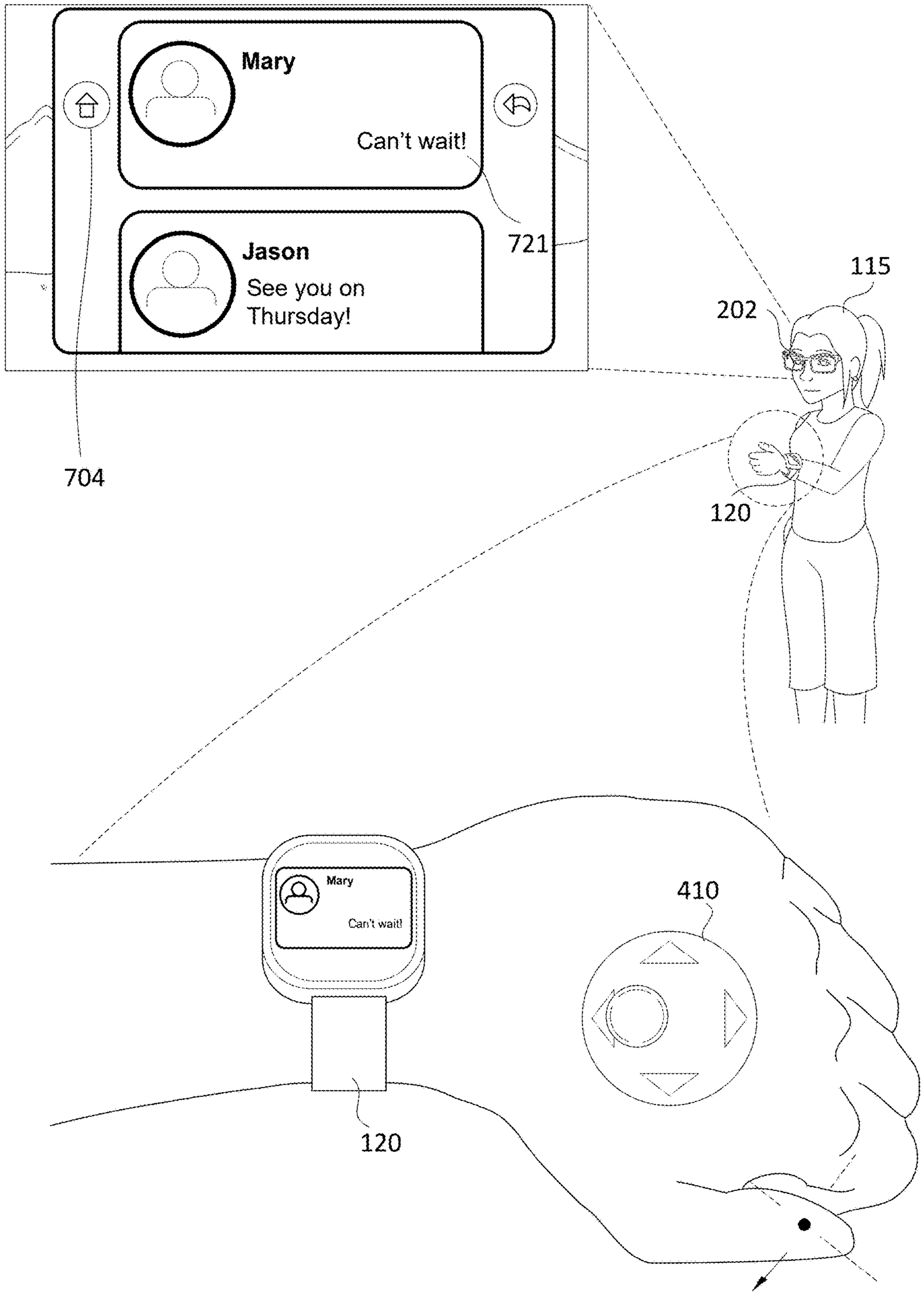

Mary
Can't wait!
721
Jason
See you on Thursday!
704
115
202
120
Mary
Can't wait!
410
120

FIG. 7K

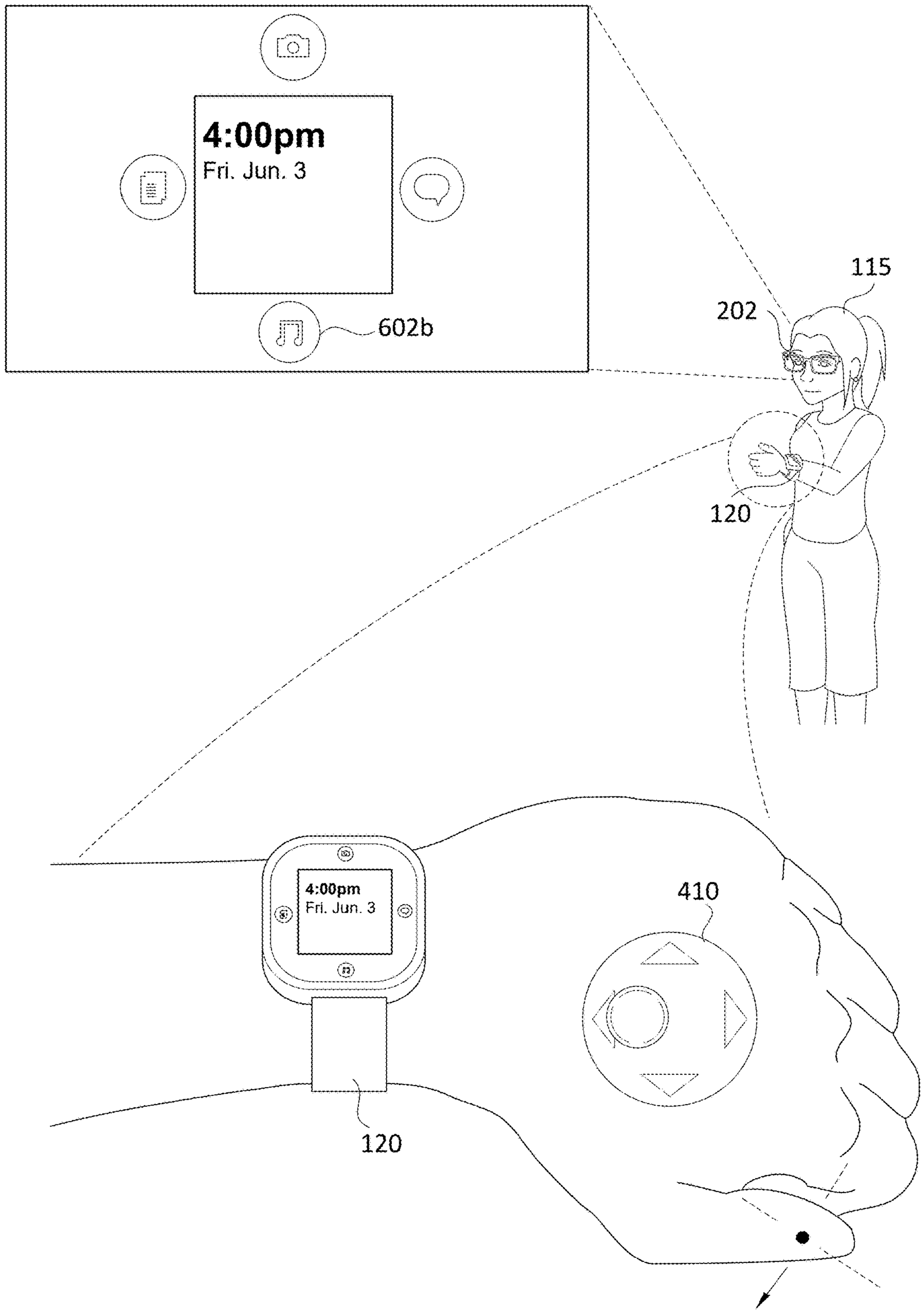


FIG. 7L

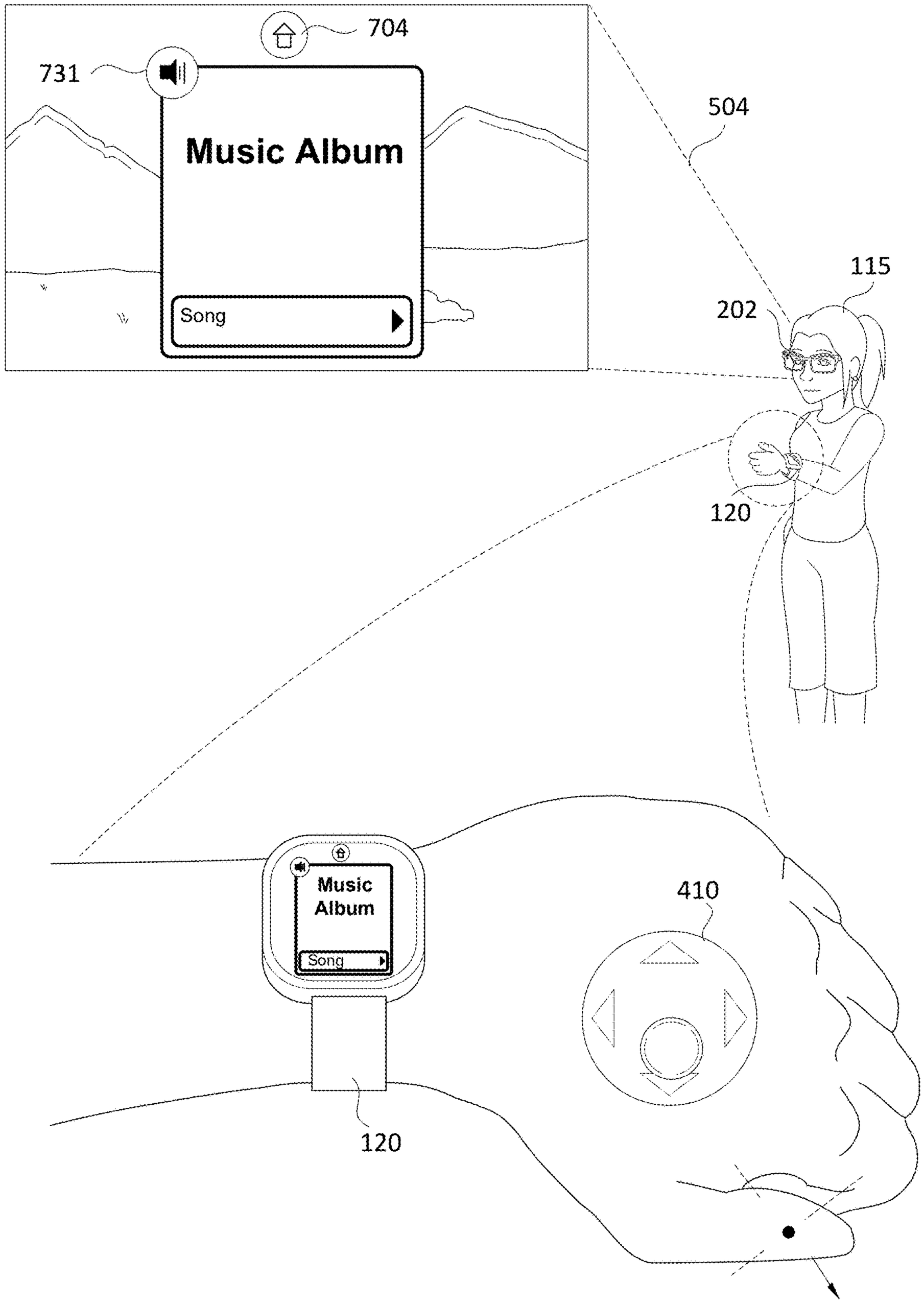

704
731
Music Album
Song
504
115
202
120
Music Album
Song
410
120

FIG. 7M

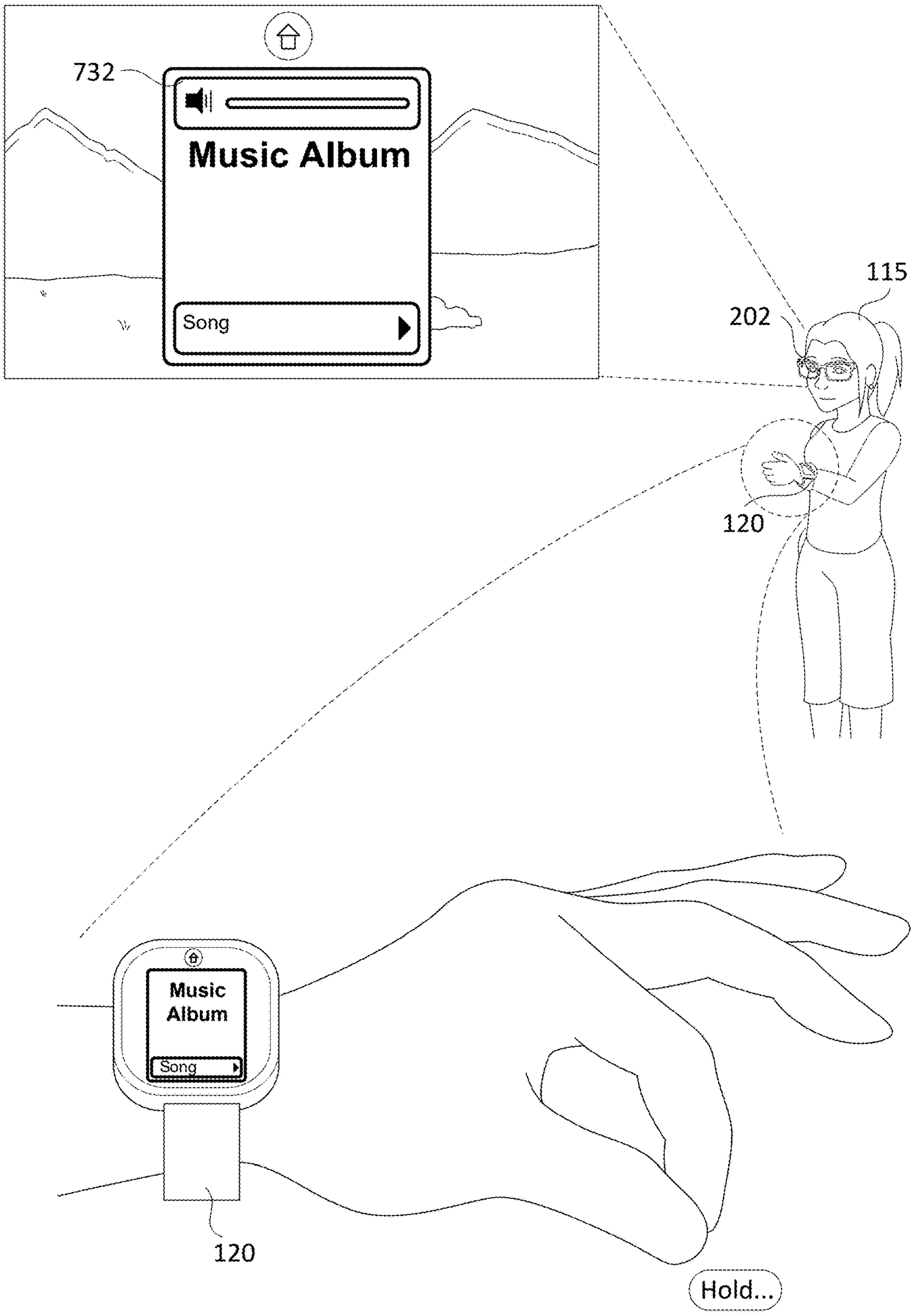


FIG. 7N

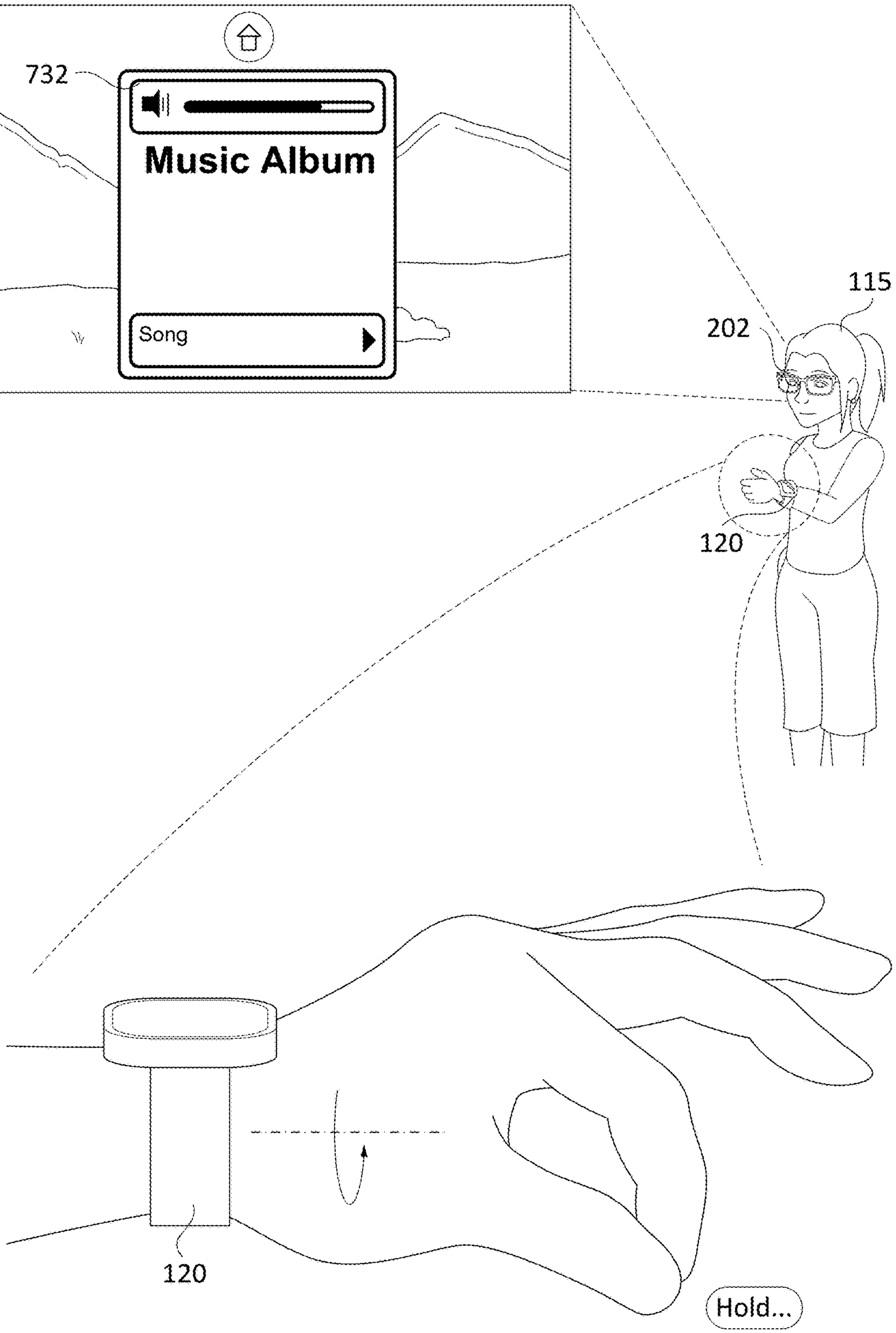


FIG. 7O

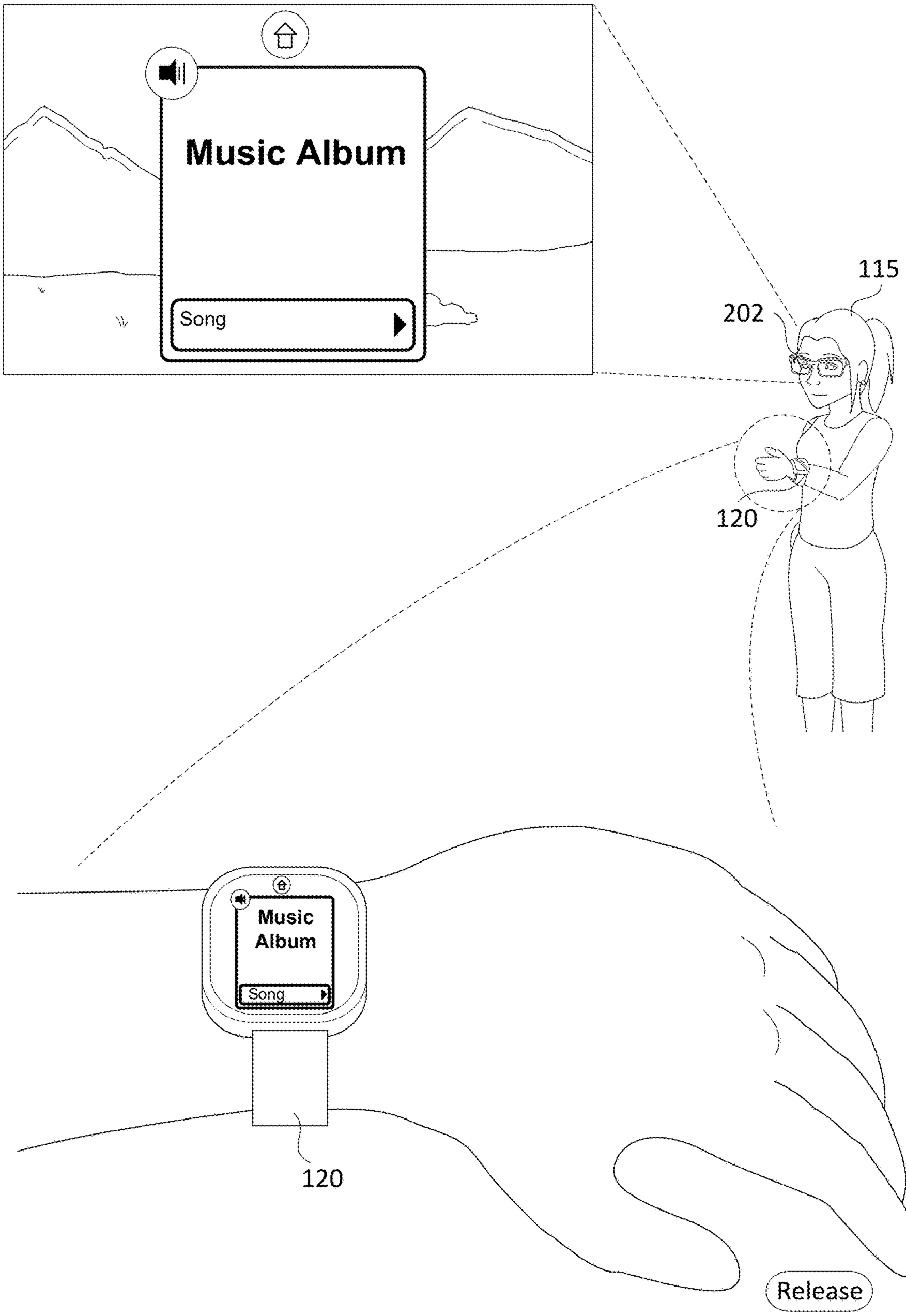


FIG. 7P

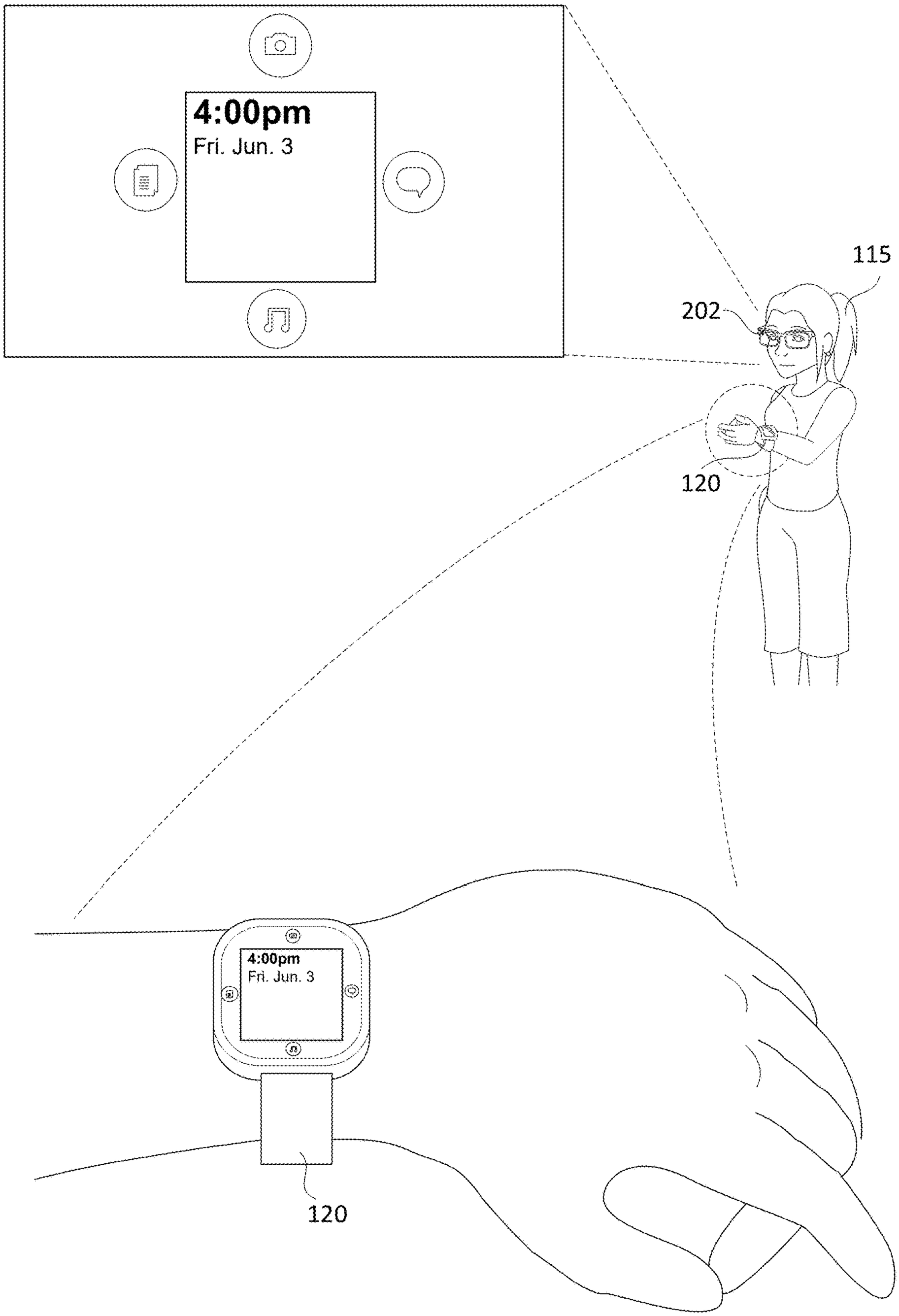


FIG. 7Q

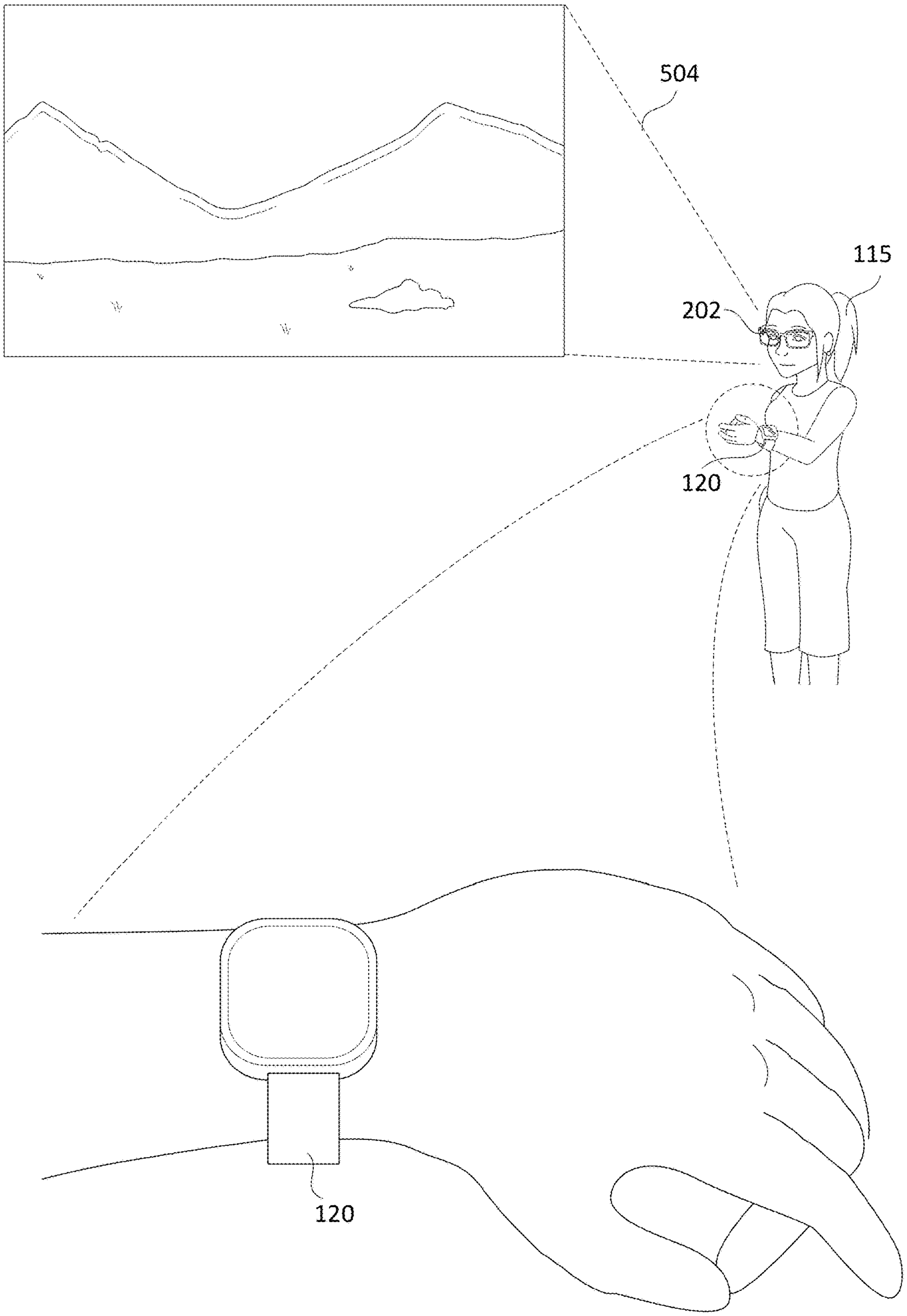


FIG. 7R

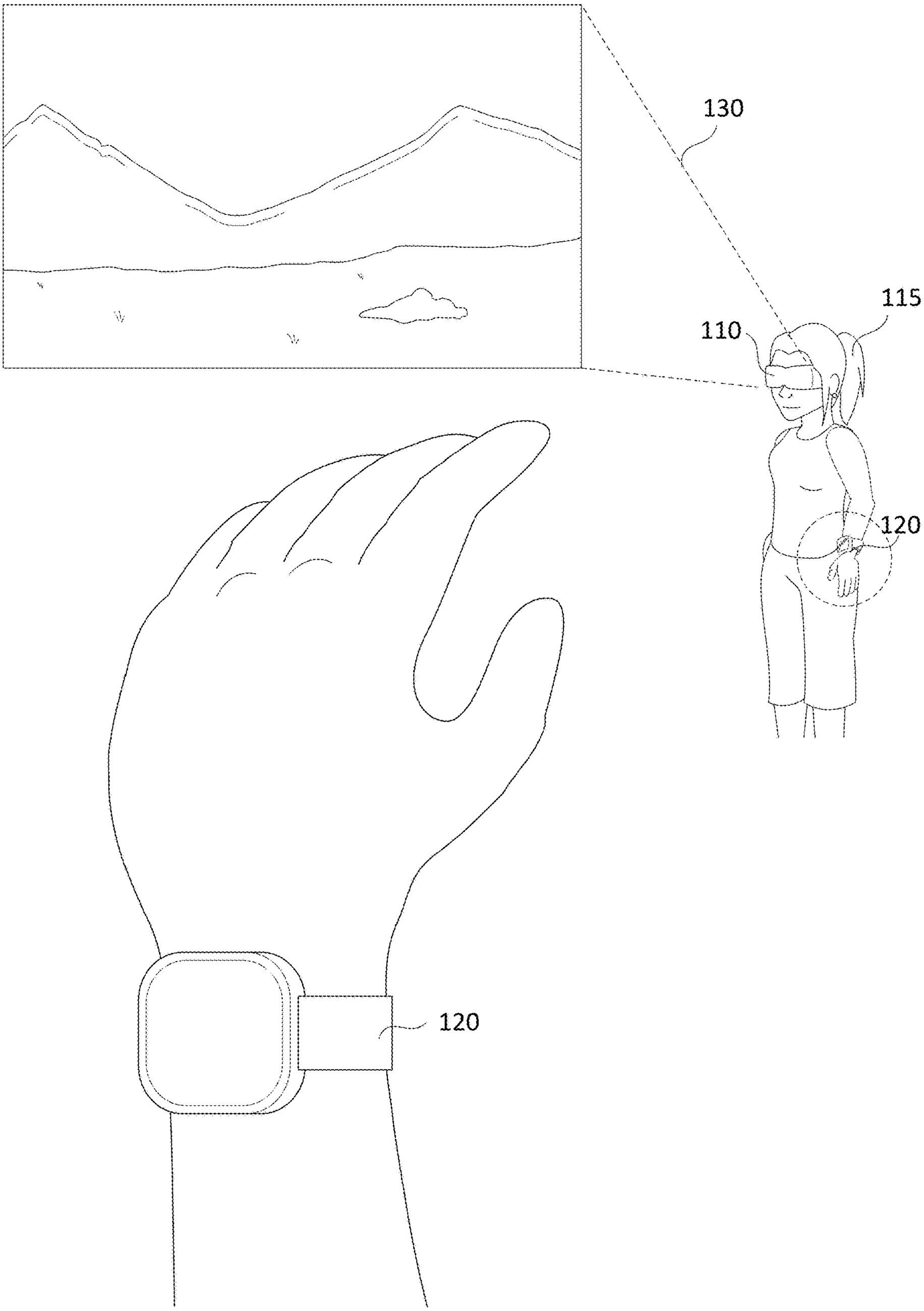


FIG. 7S

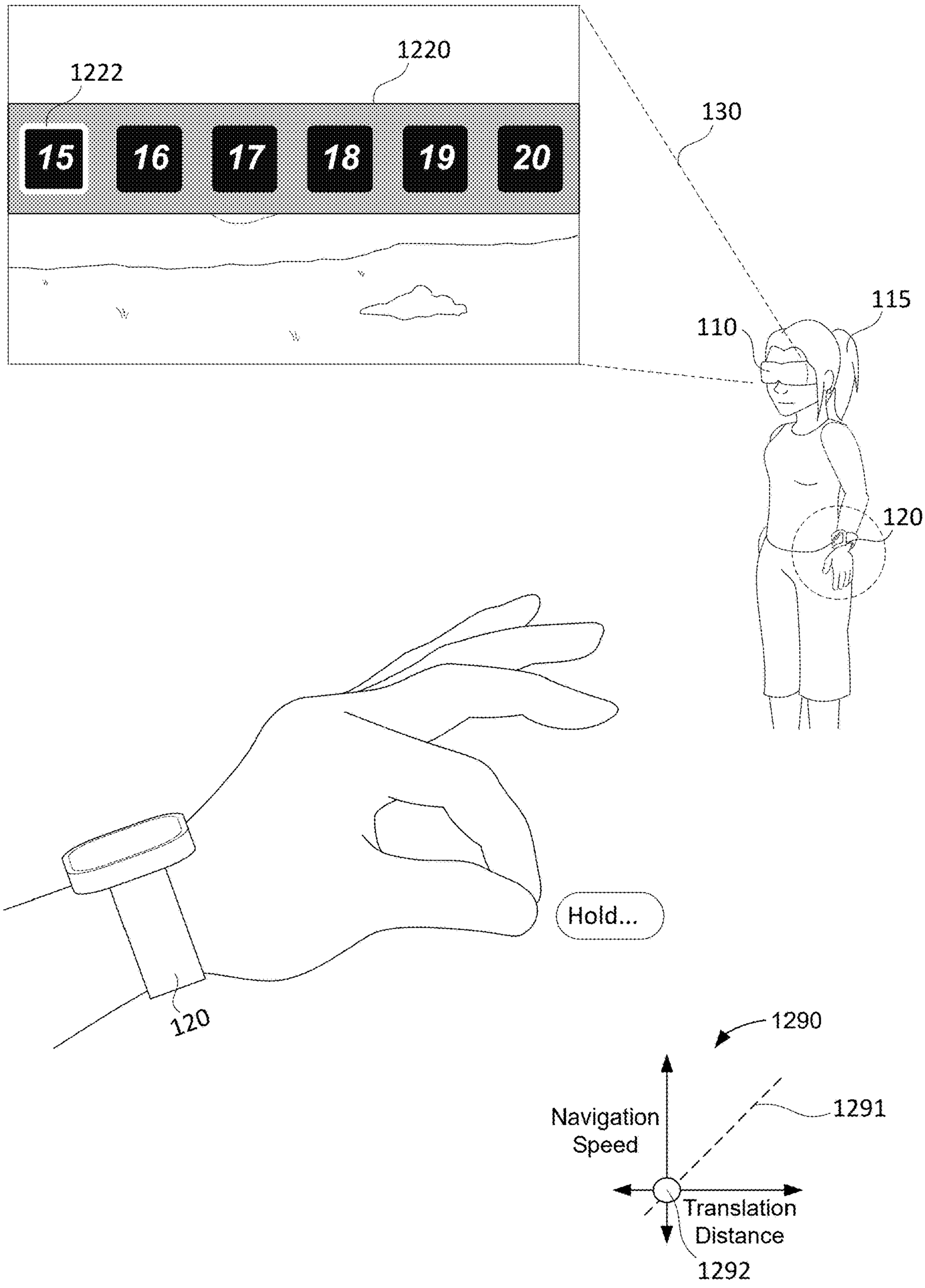

1222
1220
15
16
17
18
19
20
130
115
110
120
Hold...
120
1290
Navigation Speed
1291
Translation Distance
1292

FIG. 7T

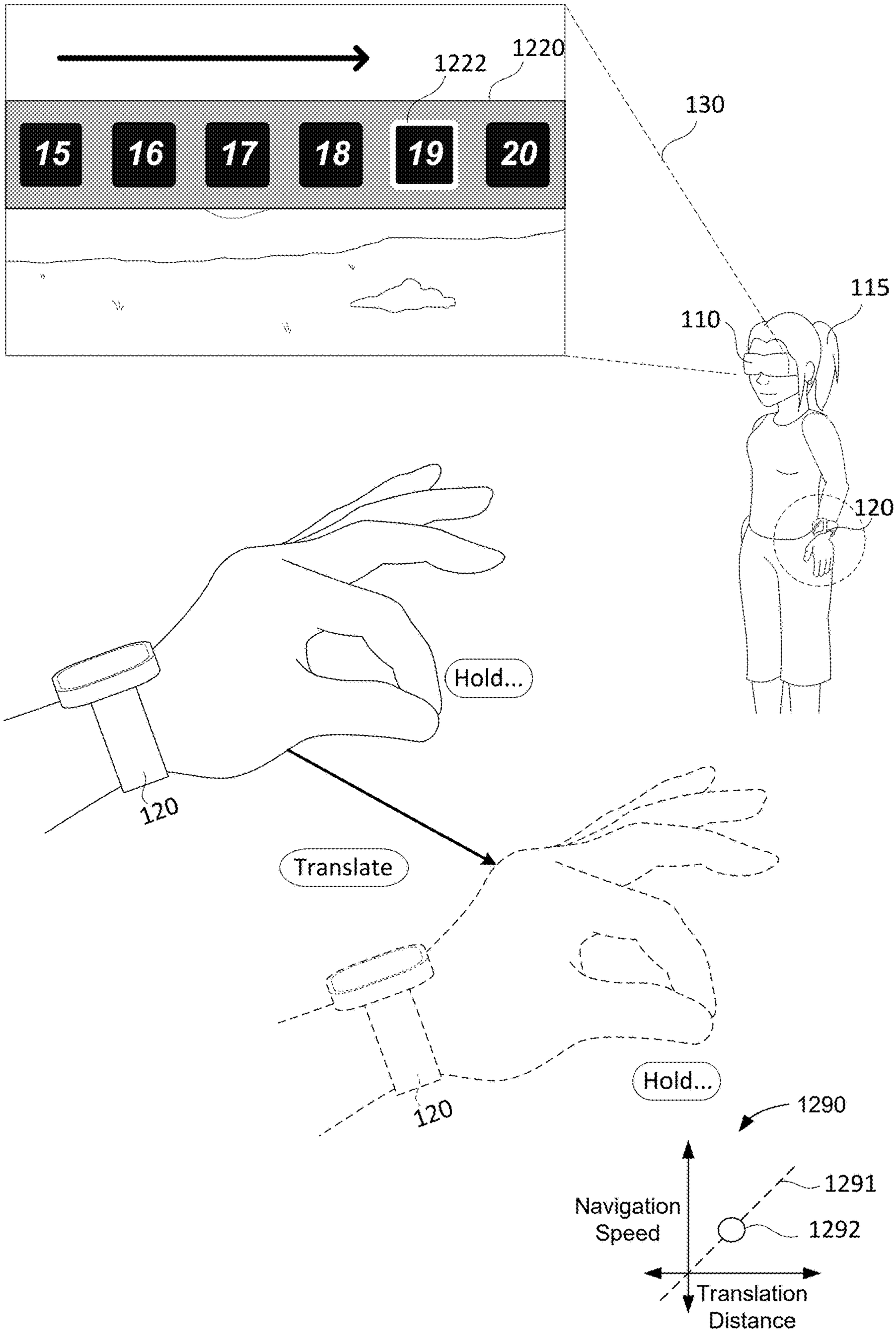

15
16
17
18
19
20
1222
1220
130
115
110
120
Hold...
120
Translate
Hold...
1290
1291
1292
Navigation Speed
Translation Distance

FIG. 7U

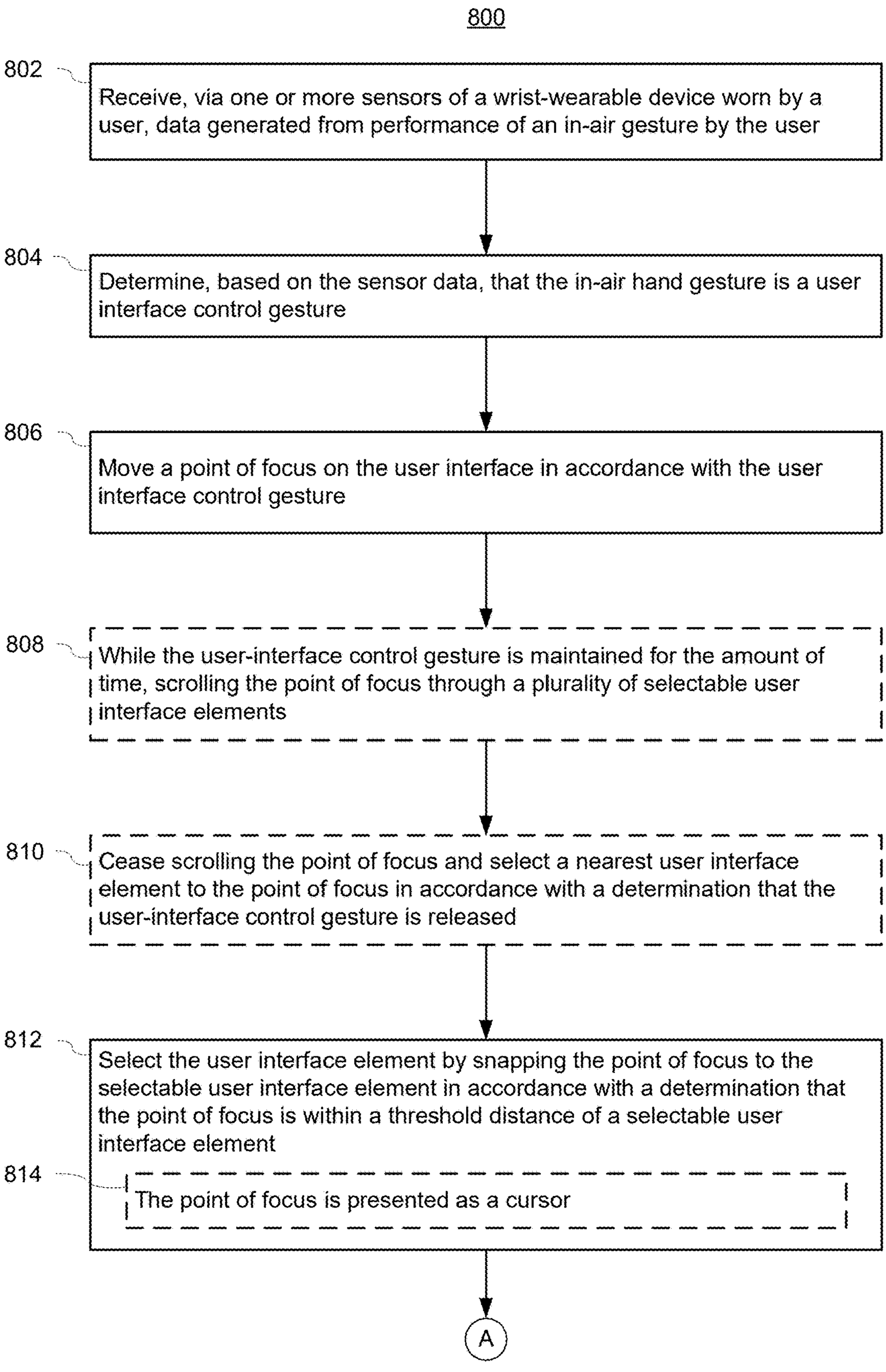

800
802
Receive, via one or more sensors of a wrist-wearable device worn by a user, data generated from performance of an in-air gesture by the user
804
Determine, based on the sensor data, that the in-air hand gesture is a user interface control gesture
806
Move a point of focus on the user interface in accordance with the user interface control gesture
808
While the user-interface control gesture is maintained for the amount of time, scrolling the point of focus through a plurality of selectable user interface elements
810
Cease scrolling the point of focus and select a nearest user interface element to the point of focus in accordance with a determination that the user-interface control gesture is released
812
Select the user interface element by snapping the point of focus to the selectable user interface element in accordance with a determination that the point of focus is within a threshold distance of a selectable user interface element
814
The point of focus is presented as a cursor
A

Figure 8A

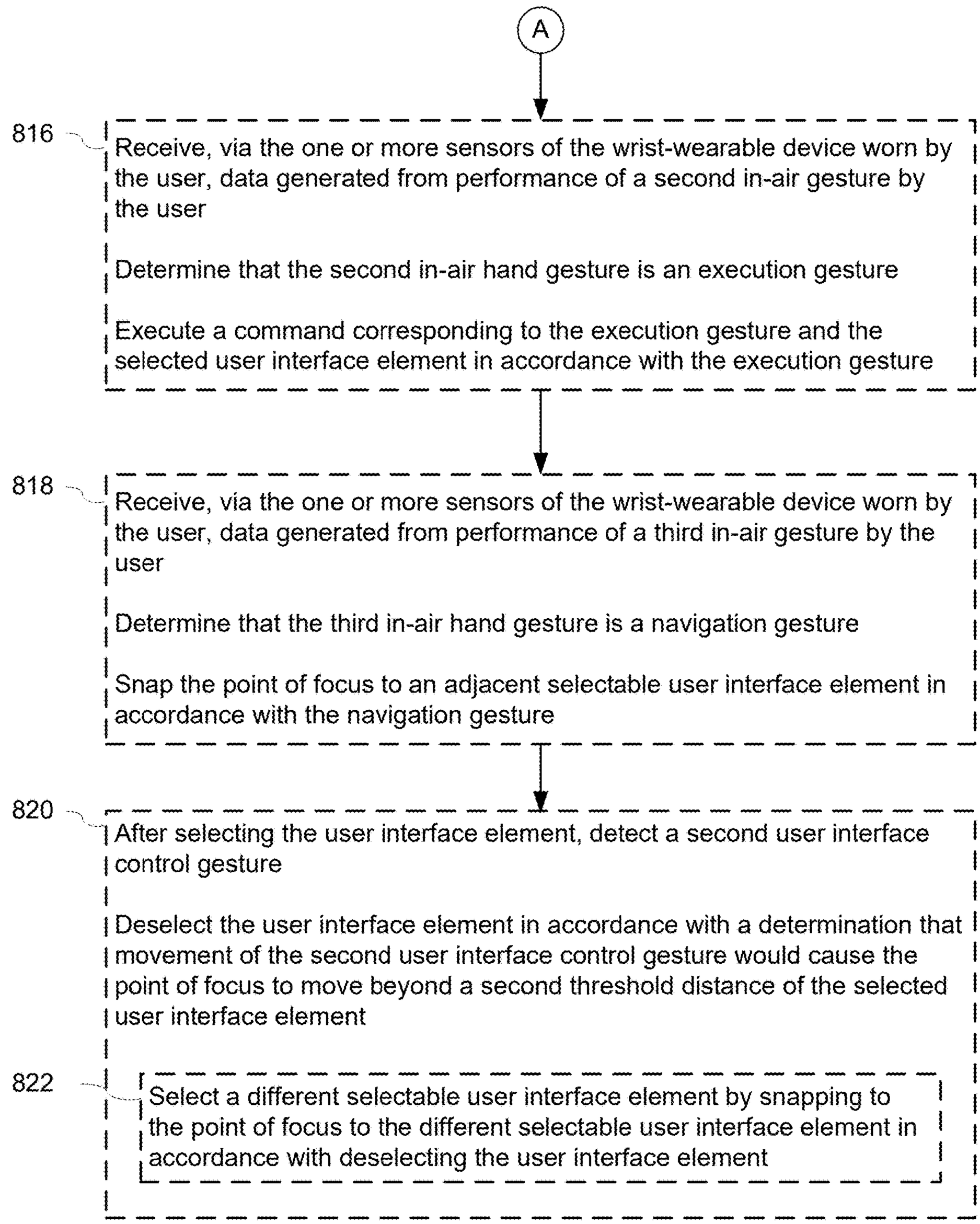

A
816
Receive, via the one or more sensors of the wrist-wearable device worn by the user, data generated from performance of a second in-air gesture by the user
Determine that the second in-air hand gesture is an execution gesture
Execute a command corresponding to the execution gesture and the selected user interface element in accordance with the execution gesture
818
Receive, via the one or more sensors of the wrist-wearable device worn by the user, data generated from performance of a third in-air gesture by the user
Determine that the third in-air hand gesture is a navigation gesture
Snap the point of focus to an adjacent selectable user interface element in accordance with the navigation gesture
820
After selecting the user interface element, detect a second user interface control gesture
Deselect the user interface element in accordance with a determination that movement of the second user interface control gesture would cause the point of focus to move beyond a second threshold distance of the selected user interface element
822
Select a different selectable user interface element by snapping to the point of focus to the different selectable user interface element in accordance with deselecting the user interface element

Figure 8B

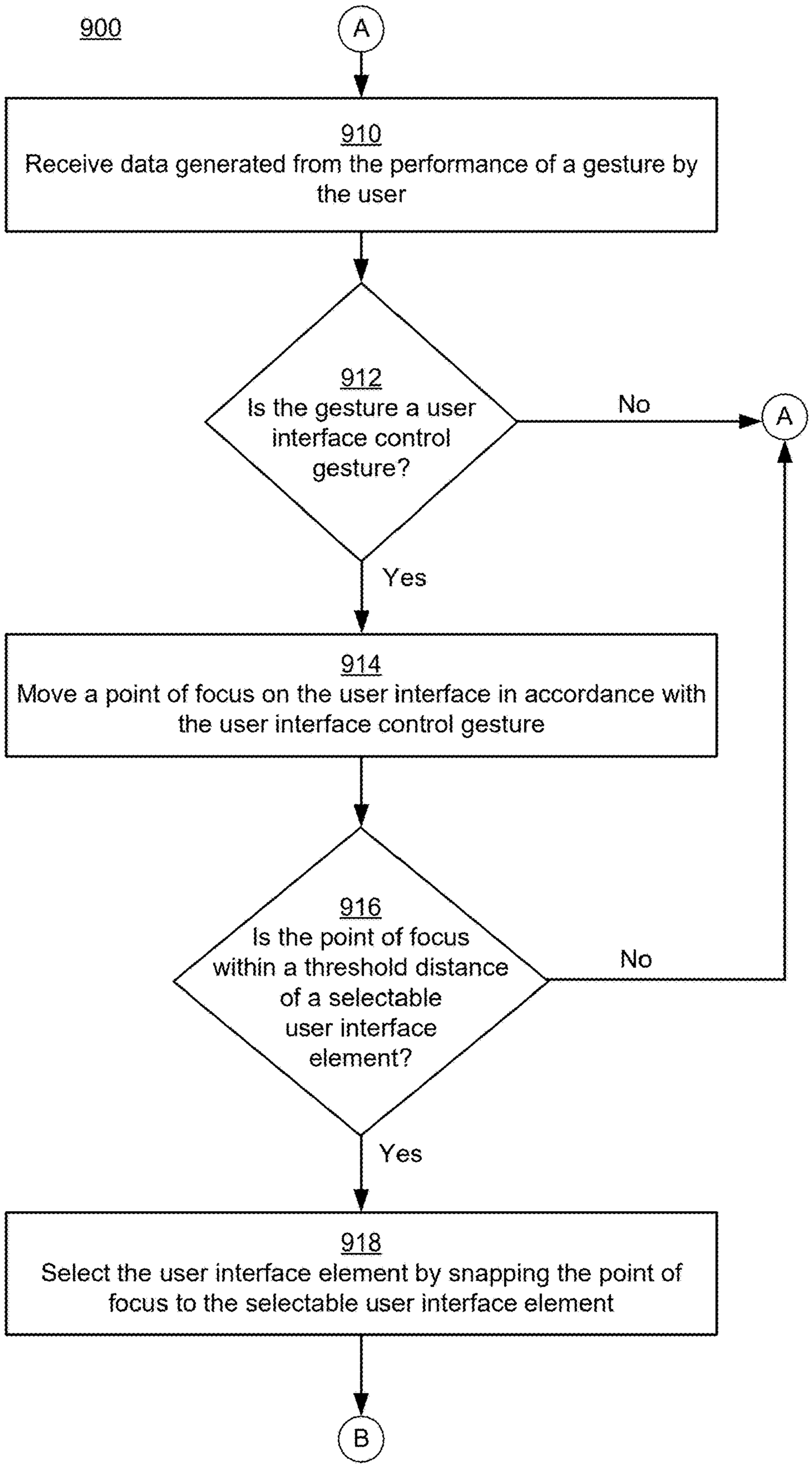

900
A
910
Receive data generated from the performance of a gesture by the user
912
Is the gesture a user interface control gesture?
No
A
Yes
914
Move a point of focus on the user interface in accordance with the user interface control gesture
916
Is the point of focus within a threshold distance of a selectable user interface element?
No
Yes
918
Select the user interface element by snapping the point of focus to the selectable user interface element
B

Figure 9A

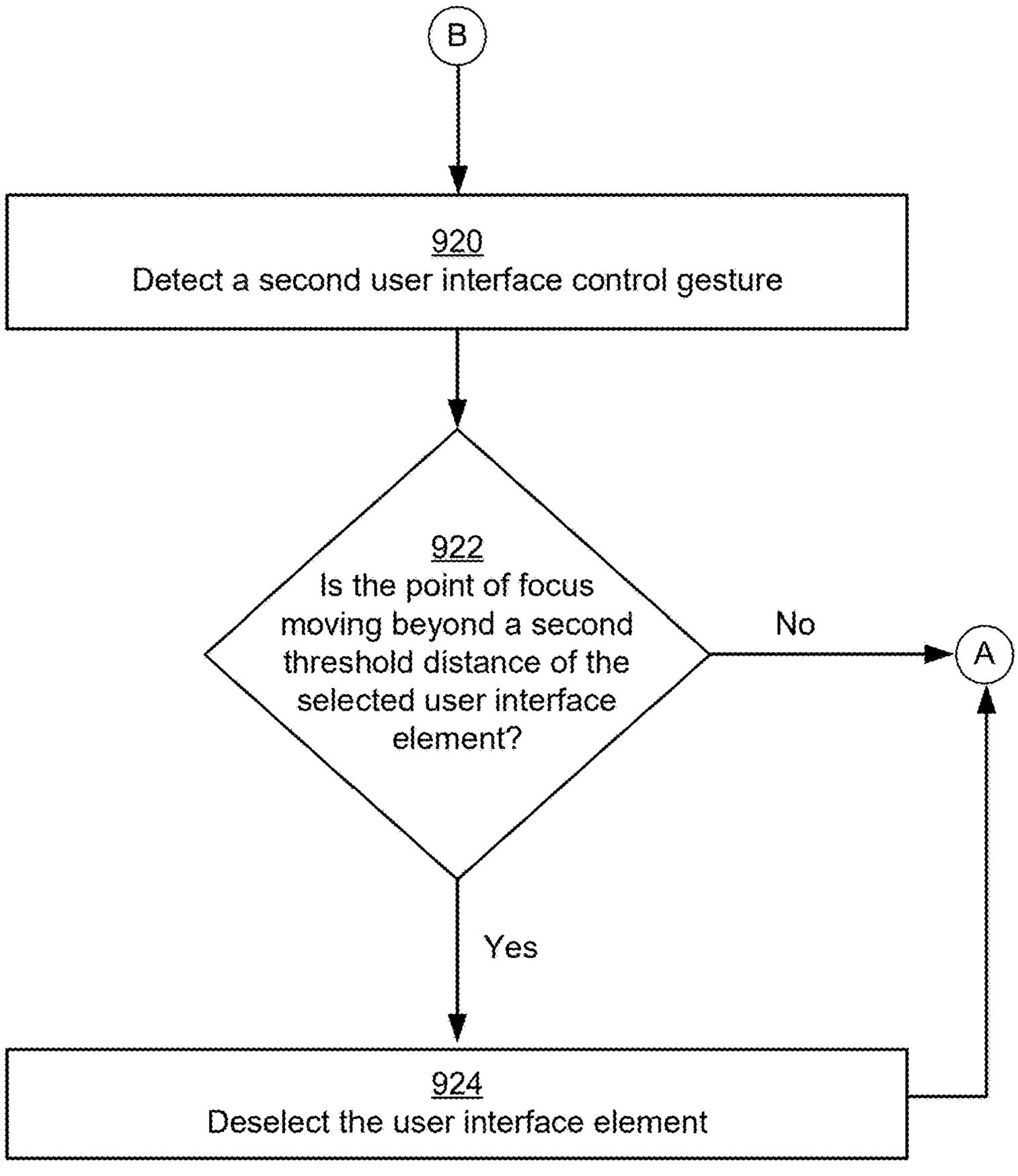

B
920
Detect a second user interface control gesture
922
Is the point of focus moving beyond a second threshold distance of the selected user interface element?
No
A
Yes
924
Deselect the user interface element

Figure 9B

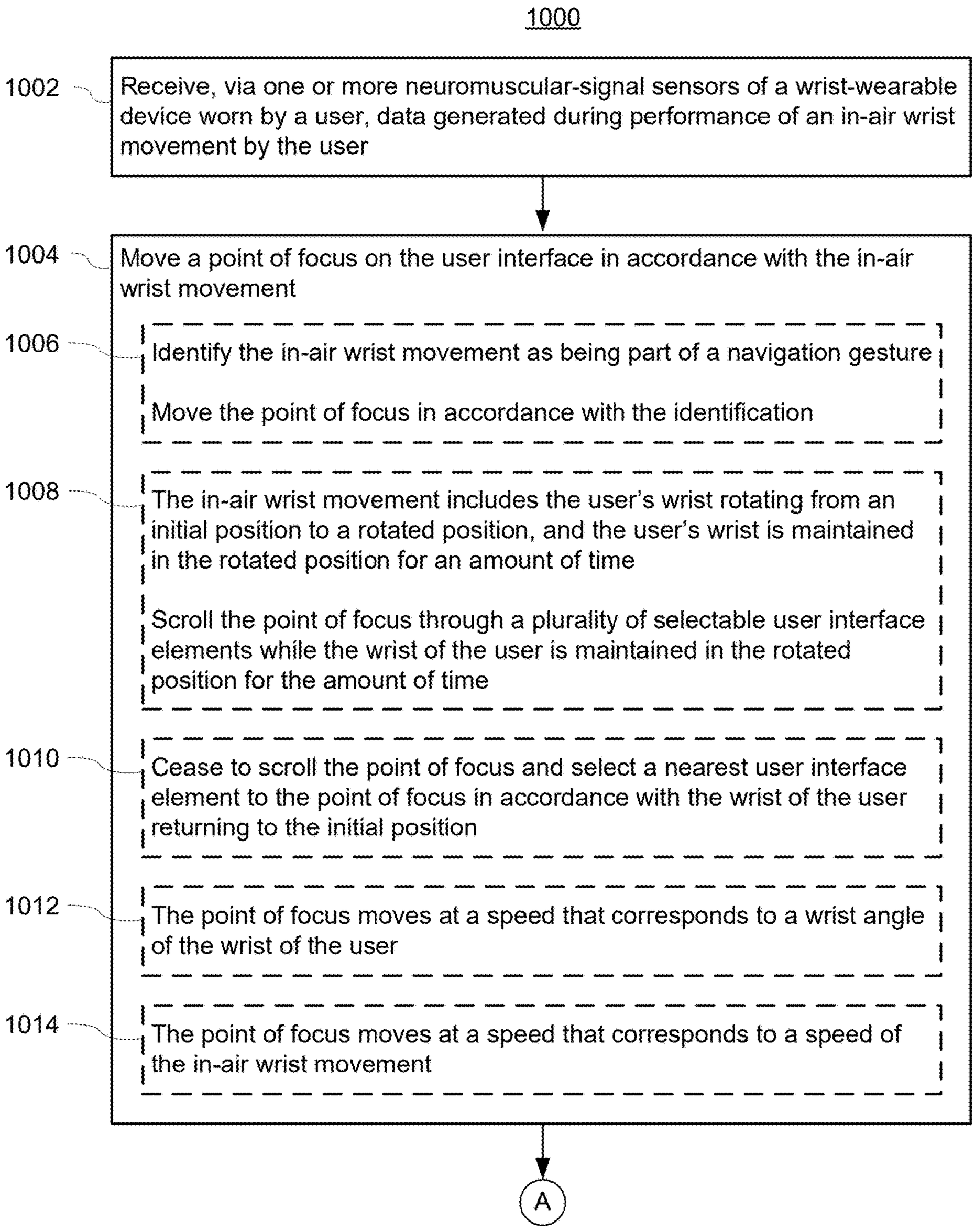

1000
1002
Receive, via one or more neuromuscular-signal sensors of a wrist-wearable device worn by a user, data generated during performance of an in-air wrist movement by the user
1004
Move a point of focus on the user interface in accordance with the in-air wrist movement
1006
Identify the in-air wrist movement as being part of a navigation gesture
Move the point of focus in accordance with the identification
1008
The in-air wrist movement includes the user's wrist rotating from an initial position to a rotated position, and the user's wrist is maintained in the rotated position for an amount of time
Scroll the point of focus through a plurality of selectable user interface elements while the wrist of the user is maintained in the rotated position for the amount of time
1010
Cease to scroll the point of focus and select a nearest user interface element to the point of focus in accordance with the wrist of the user returning to the initial position
1012
The point of focus moves at a speed that corresponds to a wrist angle of the wrist of the user
1014
The point of focus moves at a speed that corresponds to a speed of the in-air wrist movement
A

Figure 10A

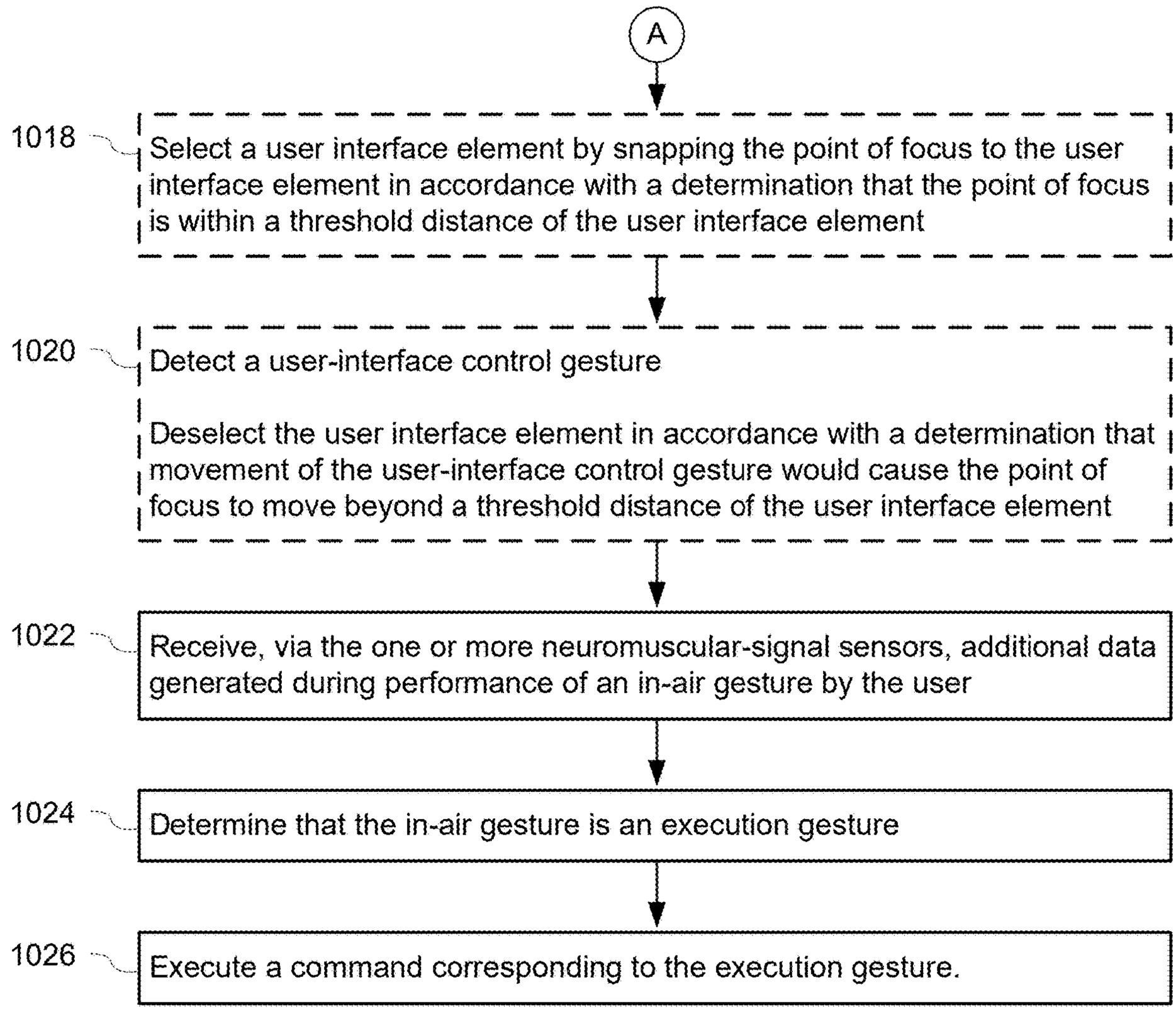

A
1018
Select a user interface element by snapping the point of focus to the user interface element in accordance with a determination that the point of focus is within a threshold distance of the user interface element
1020
Detect a user-interface control gesture
Deselect the user interface element in accordance with a determination that movement of the user-interface control gesture would cause the point of focus to move beyond a threshold distance of the user interface element
1022
Receive, via the one or more neuromuscular-signal sensors, additional data generated during performance of an in-air gesture by the user
1024
Determine that the in-air gesture is an execution gesture
1026
Execute a command corresponding to the execution gesture.

Figure 10B

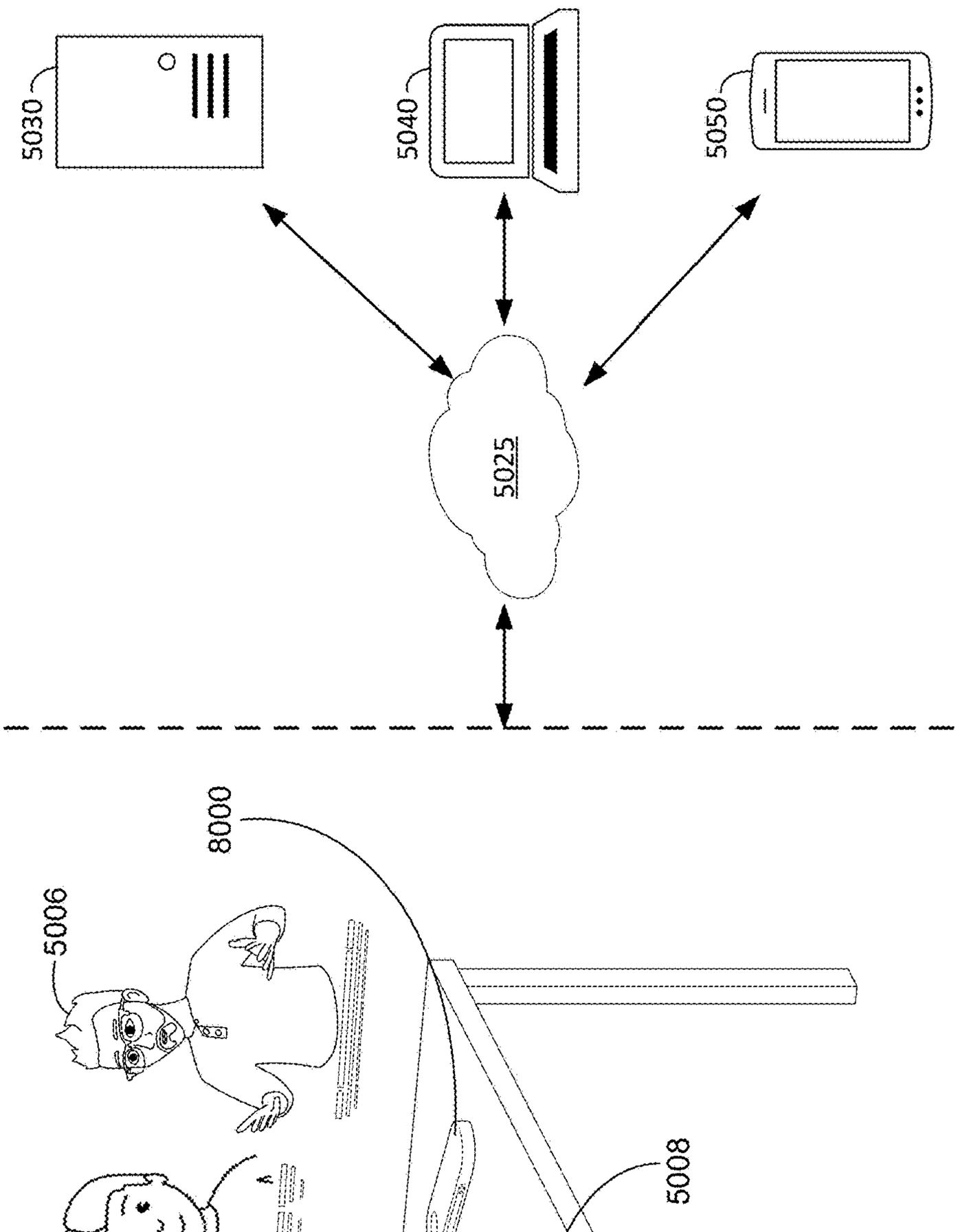

5030
5040
5050
5025
AR system 5000a
8000
5006
5008
5004
7000
5002
6000

FIG. 11A

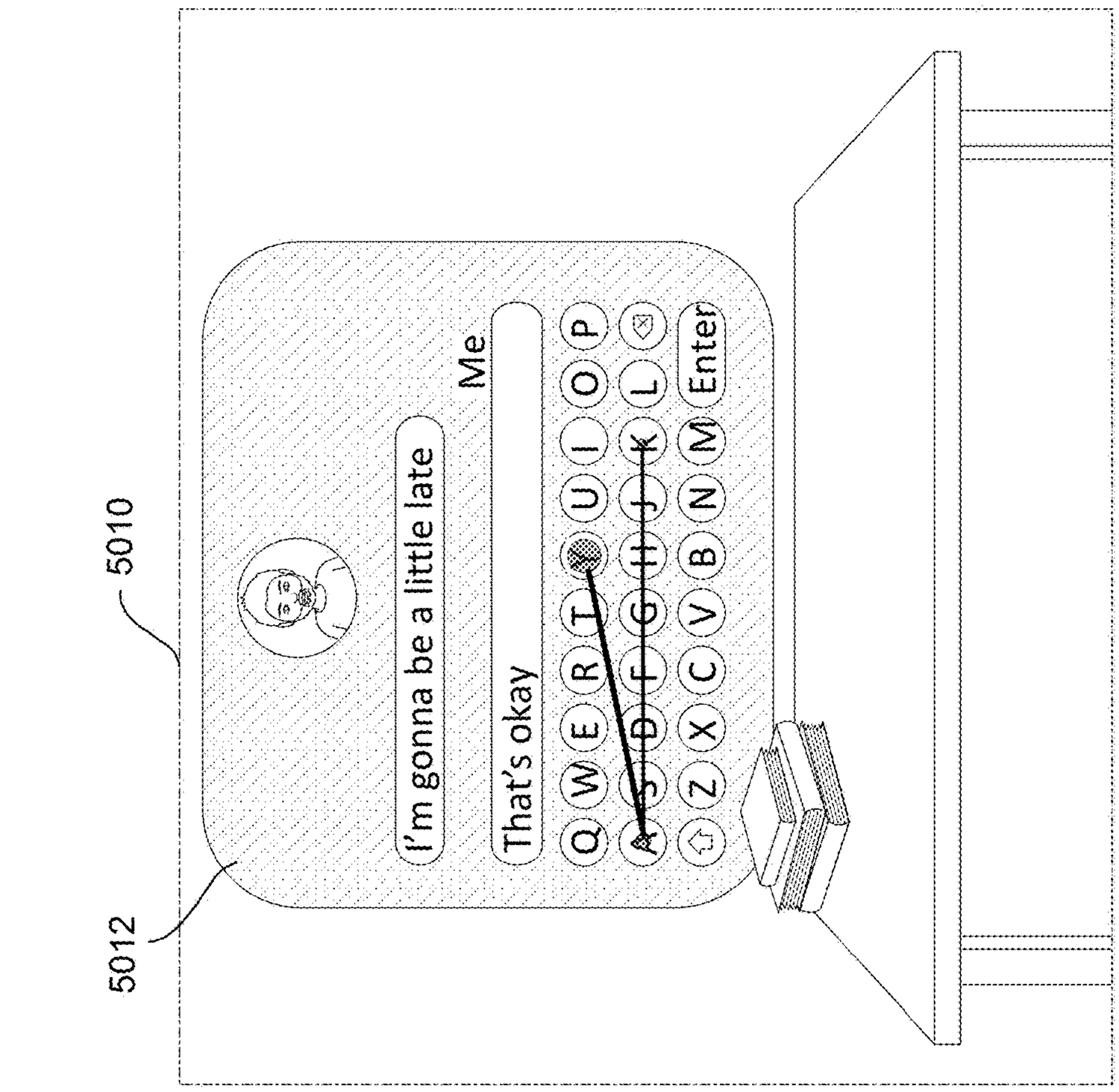

5010
5012
I'm gonna be a little late
That's okay
Me
Enter
8000
AR system 5000b
7000
5002
6000

FIG. 11B

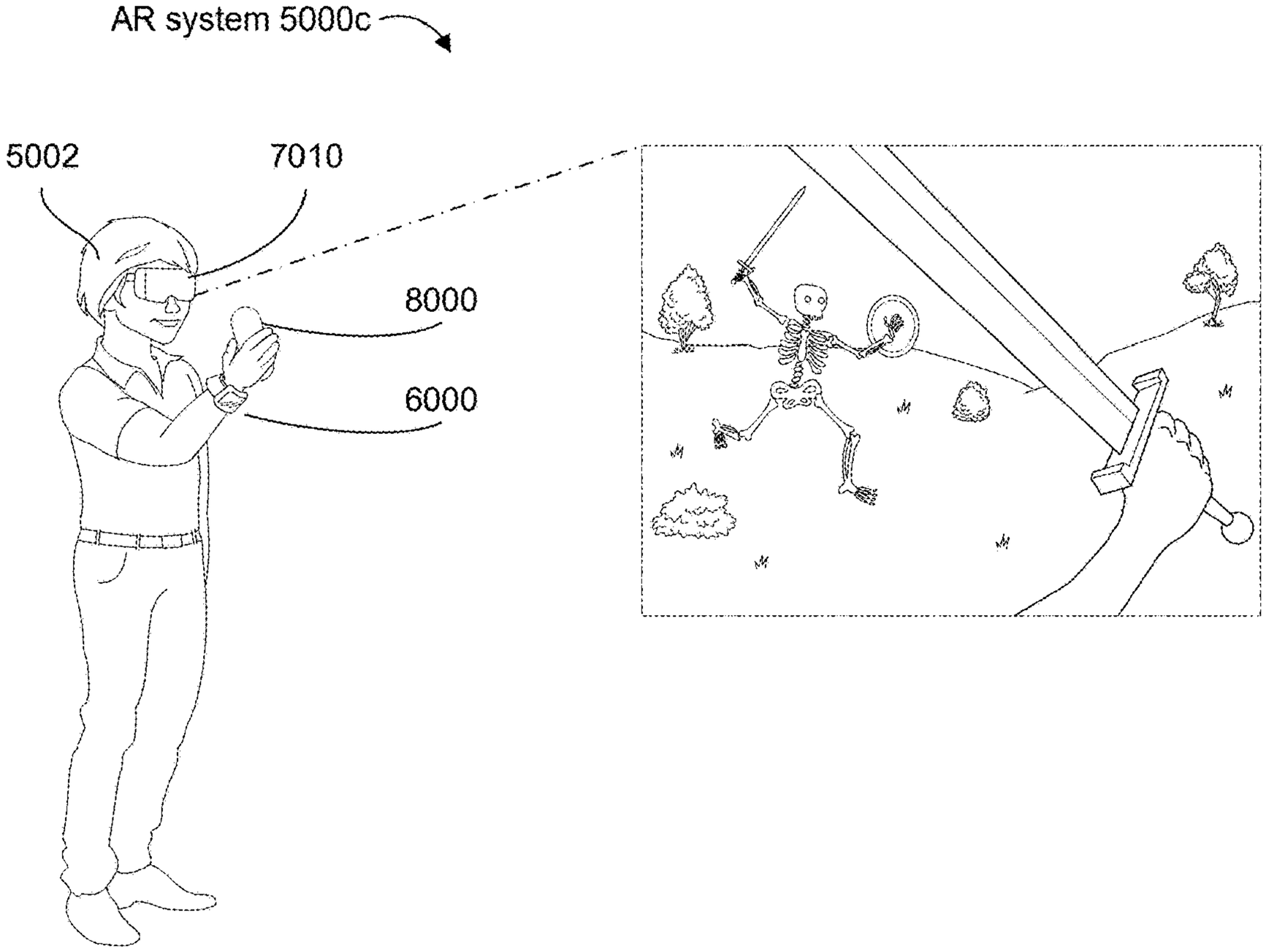


FIG. 11C-1

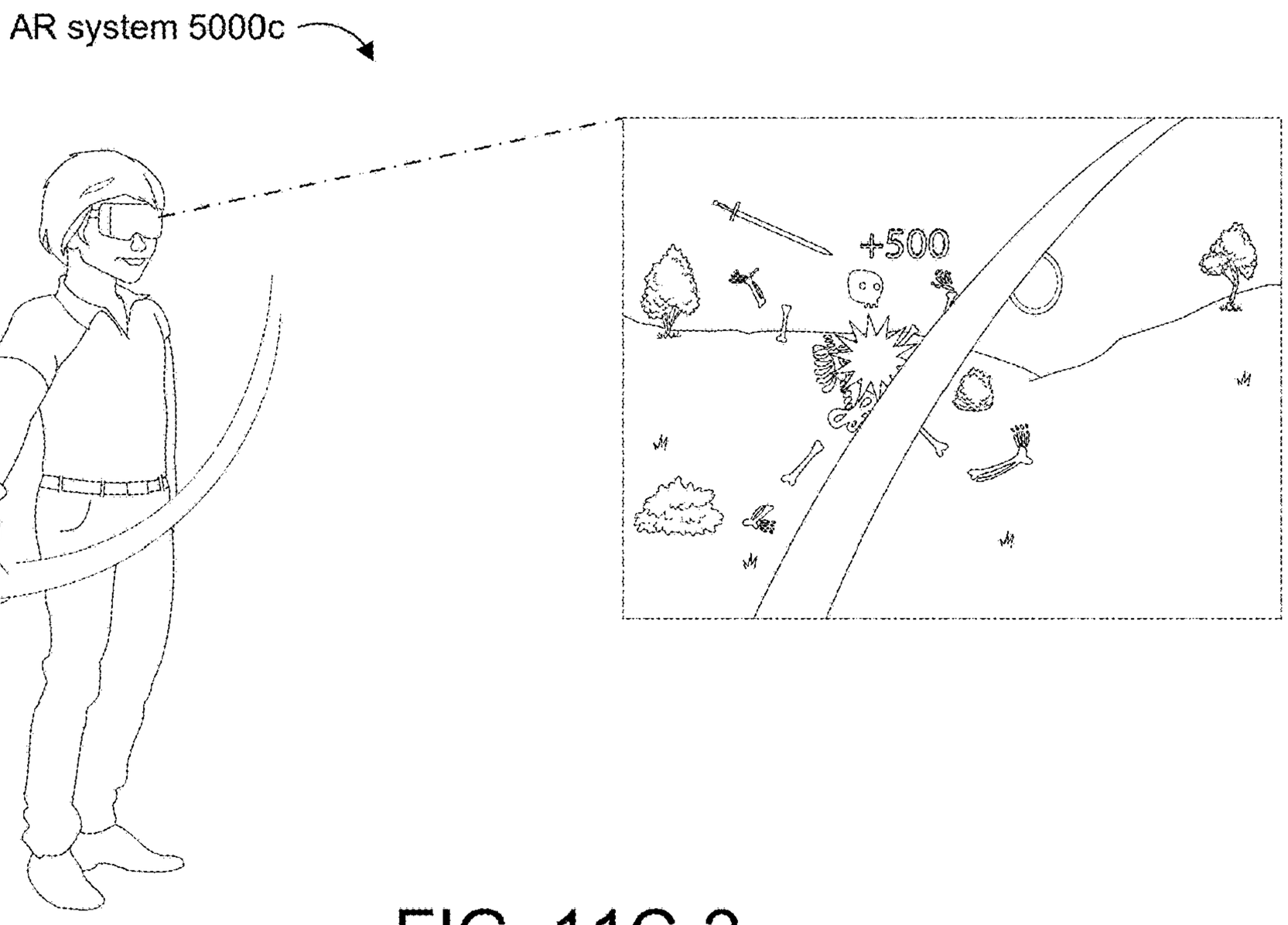


FIG. 11C-2

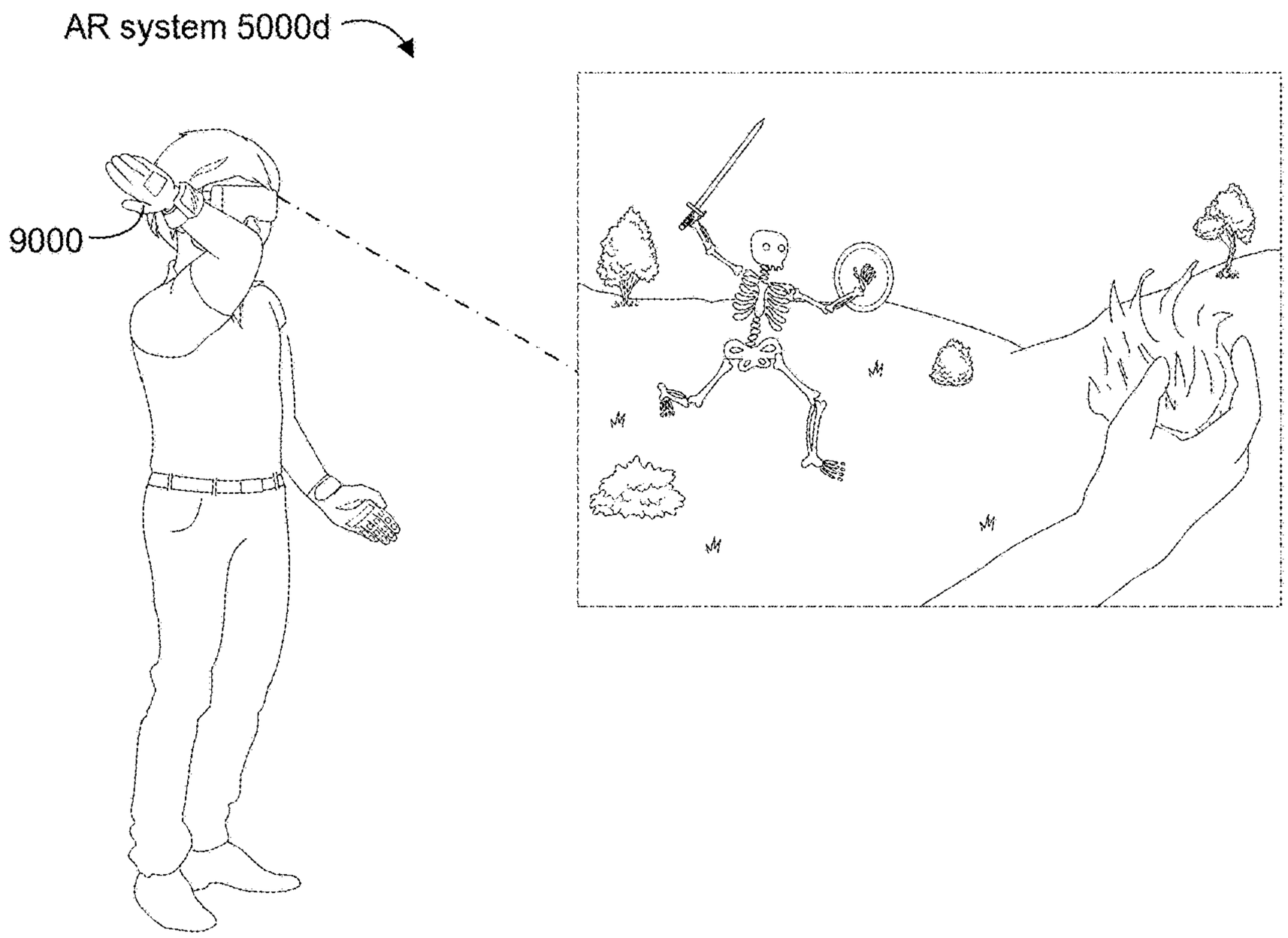


FIG. 11D-1

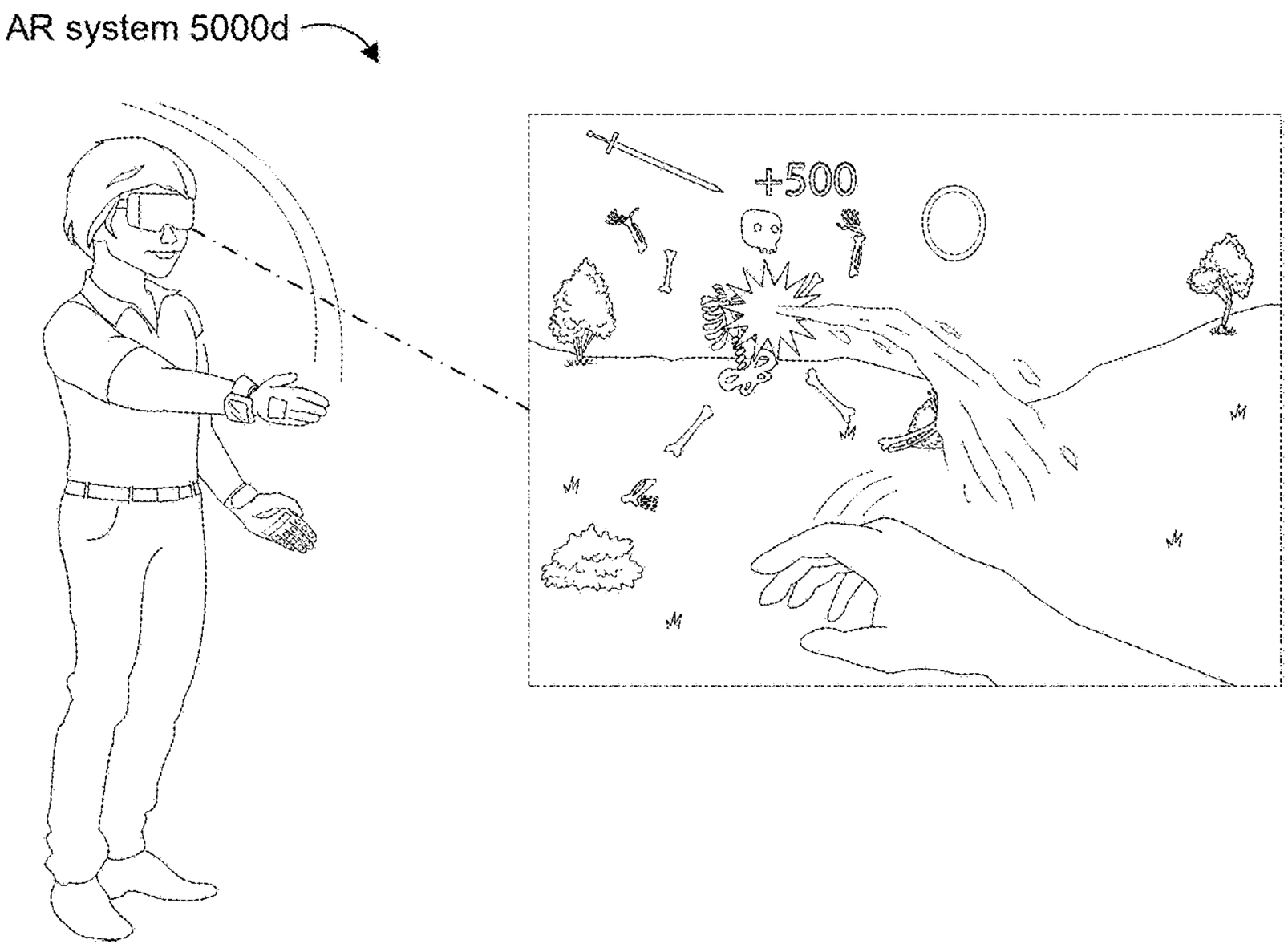


FIG. 11D-2

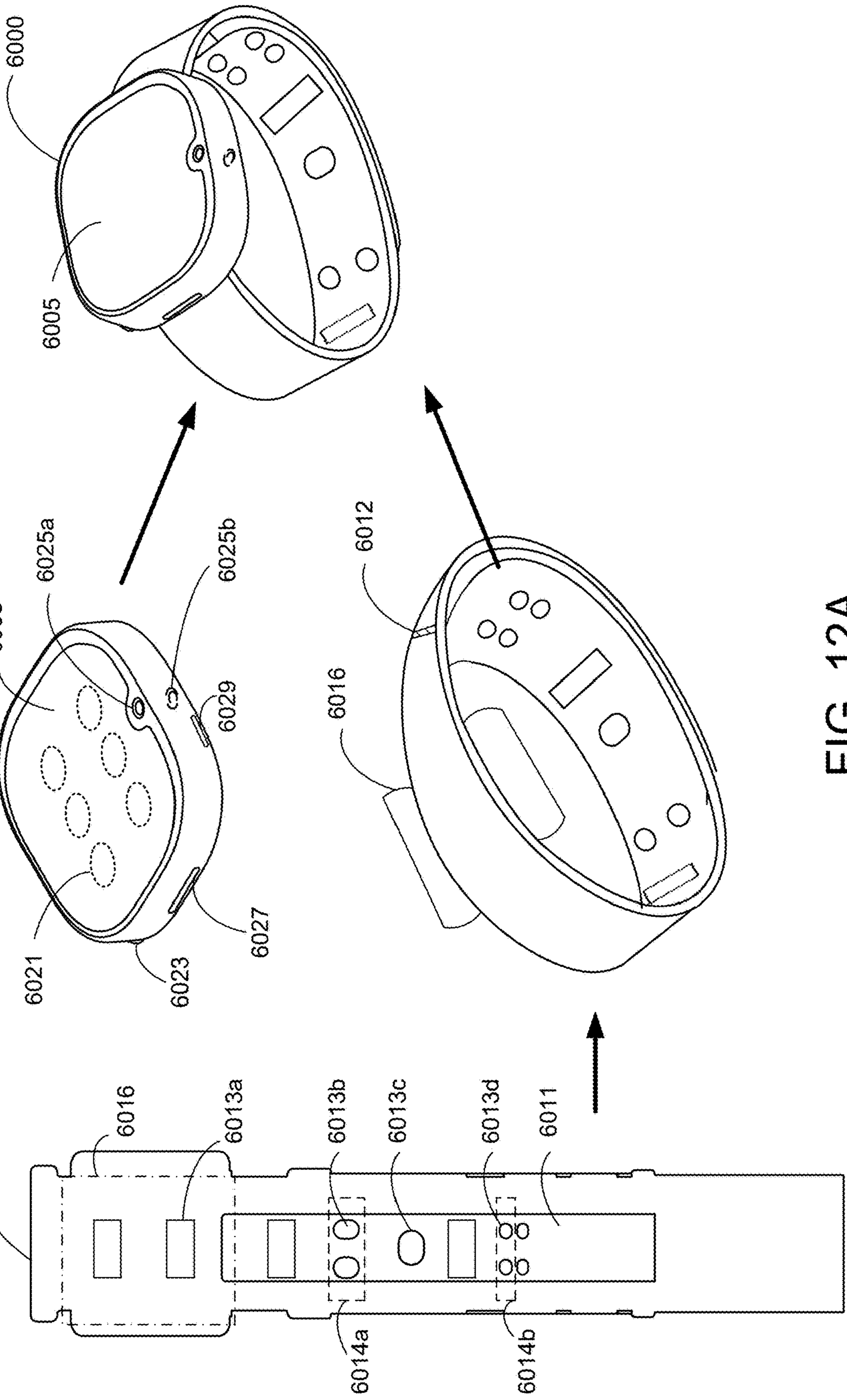

6000
6005
6020
6005
6025a
6025b
6029
6027
6021
6023
6012
6016
6010
6016
6013a
6013b
6013c
6013d
6011
6014a
6014b

FIG. 12A

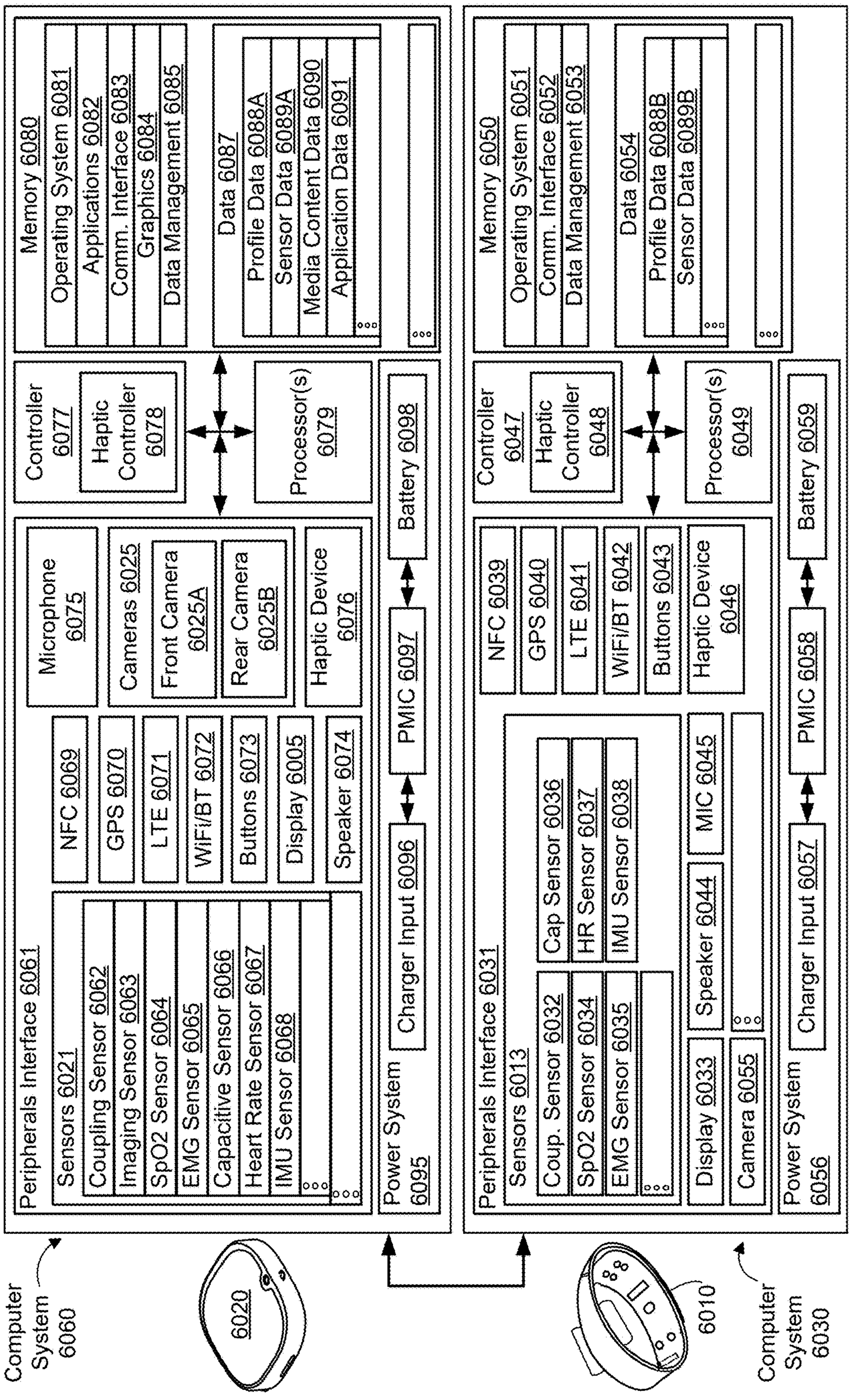

Computer System 6060
Memory 6080
Operating System 6081
Applications 6082
Comm. Interface 6083
Graphics 6084
Data Management 6085
Data 6087
Profile Data 6088A
Sensor Data 6089A
Media Content Data 6090
Application Data 6091
Controller 6077
Haptic Controller 6078
Processor(s) 6079
Microphone 6075
Cameras 6025
Front Camera 6025A
Rear Camera 6025B
Haptic Device 6076
NFC 6069
GPS 6070
LTE 6071
WiFi/BT 6072
Buttons 6073
Display 6005
Speaker 6074
PMIC 6097
Battery 6098
Peripherals Interface 6061
Sensors 6021
Coupling Sensor 6062
Imaging Sensor 6063
SpO2 Sensor 6064
EMG Sensor 6065
Capacitive Sensor 6066
Heart Rate Sensor 6067
IMU Sensor 6068
Power System 6095
Charger Input 6096
6020
Computer System 6030
Memory 6050
Operating System 6051
Comm. Interface 6052
Data Management 6053
Data 6054
Profile Data 6088B
Sensor Data 6089B
Controller 6047
Haptic Controller 6048
Processor(s) 6049
NFC 6039
GPS 6040
LTE 6041
WiFi/BT 6042
Buttons 6043
Haptic Device 6046
PMIC 6058
Battery 6059
Peripherals Interface 6031
Sensors 6013
Coup. Sensor 6032
SpO2 Sensor 6034
EMG Sensor 6035
Cap Sensor 6036
HR Sensor 6037
IMU Sensor 6038
Display 6033
Camera 6055
MIC 6045
Speaker 6044
Power System 6056
Charger Input 6057
6010

FIG. 12B

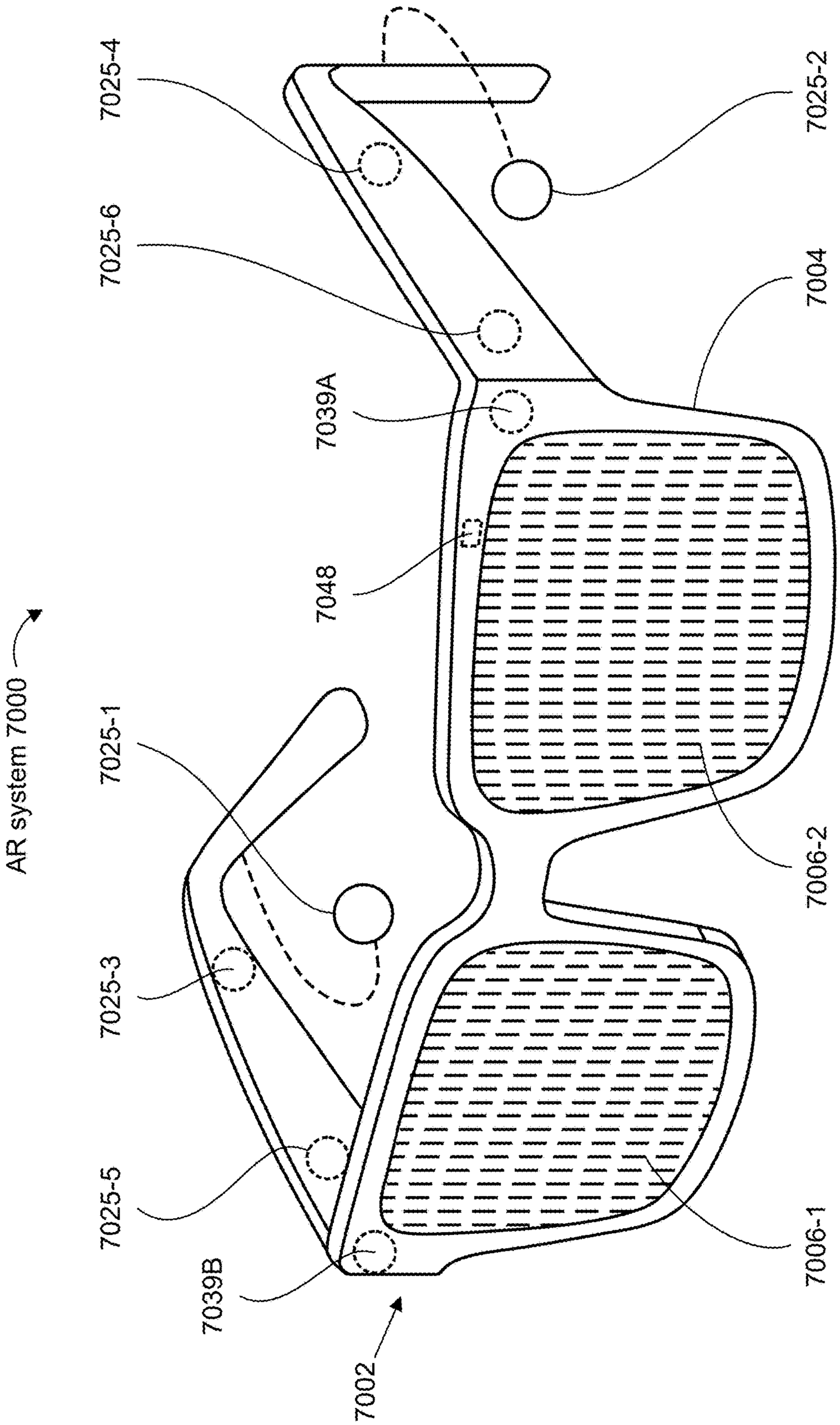

AR system 7000
7025-4
7025-6
7025-1
7025-3
7025-5
7039B
7002
7039A
7048
7025-2
7004
7006-2
7006-1

FIG. 13A

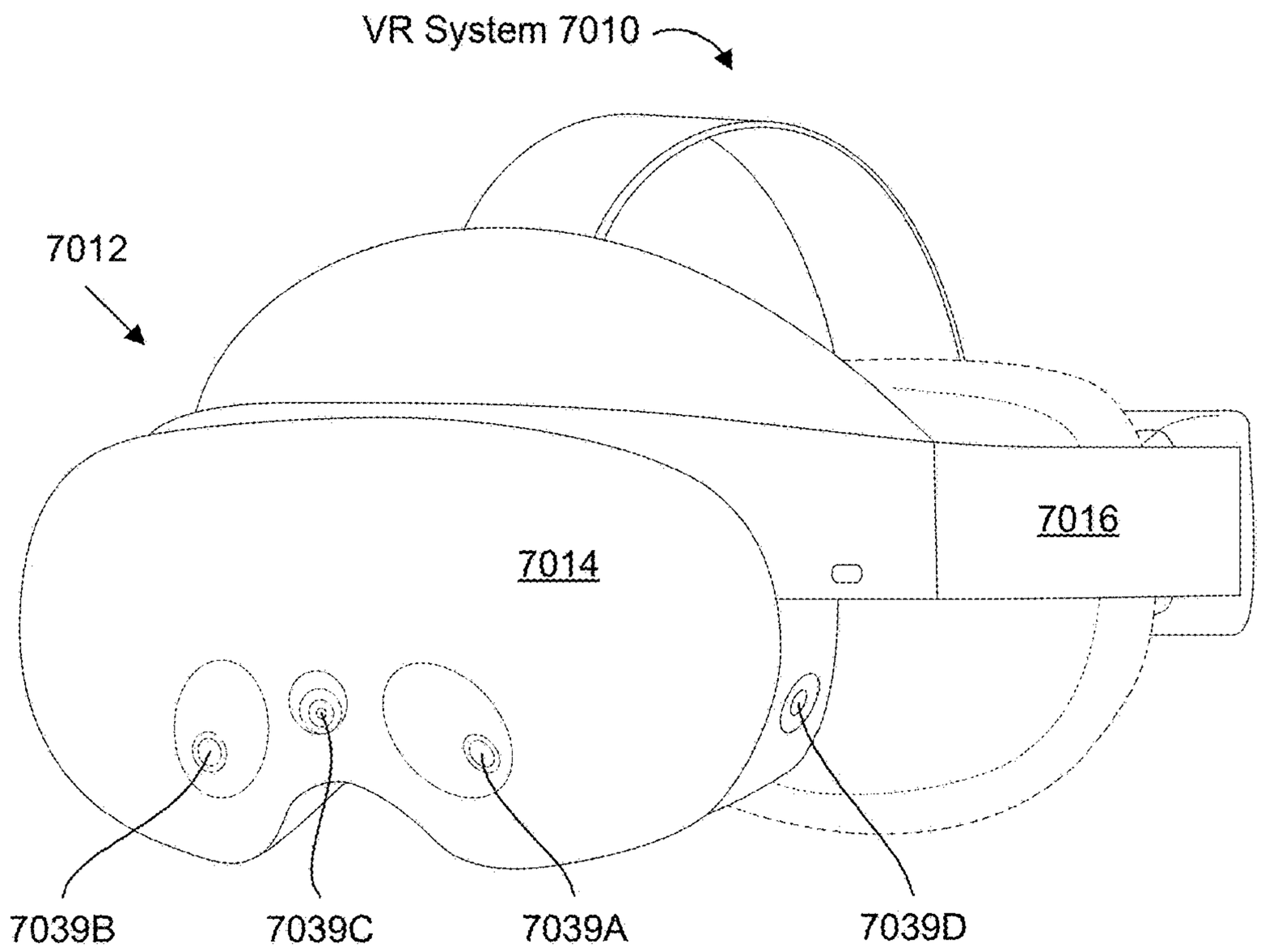


FIG. 13B-1

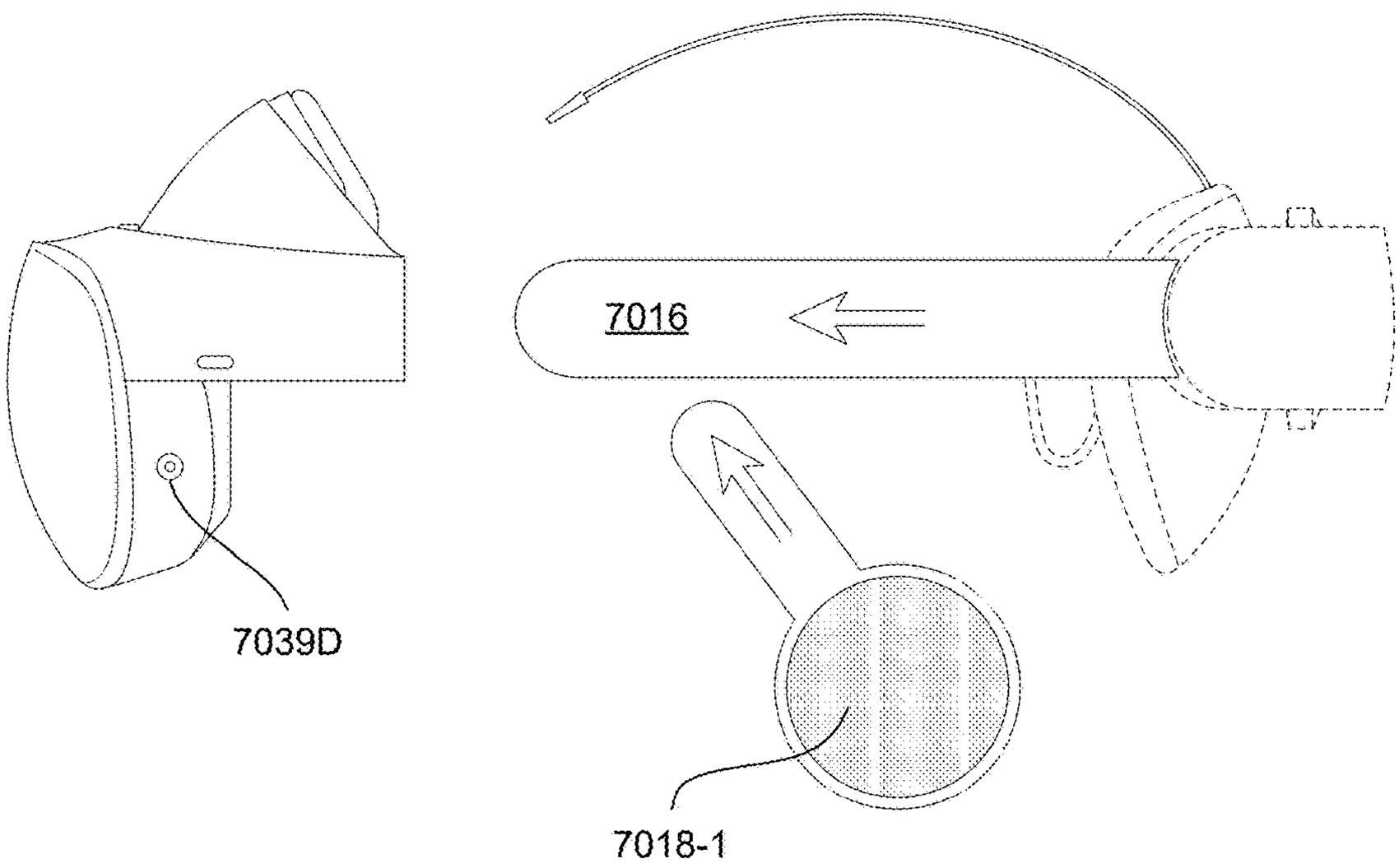


FIG. 13B-2

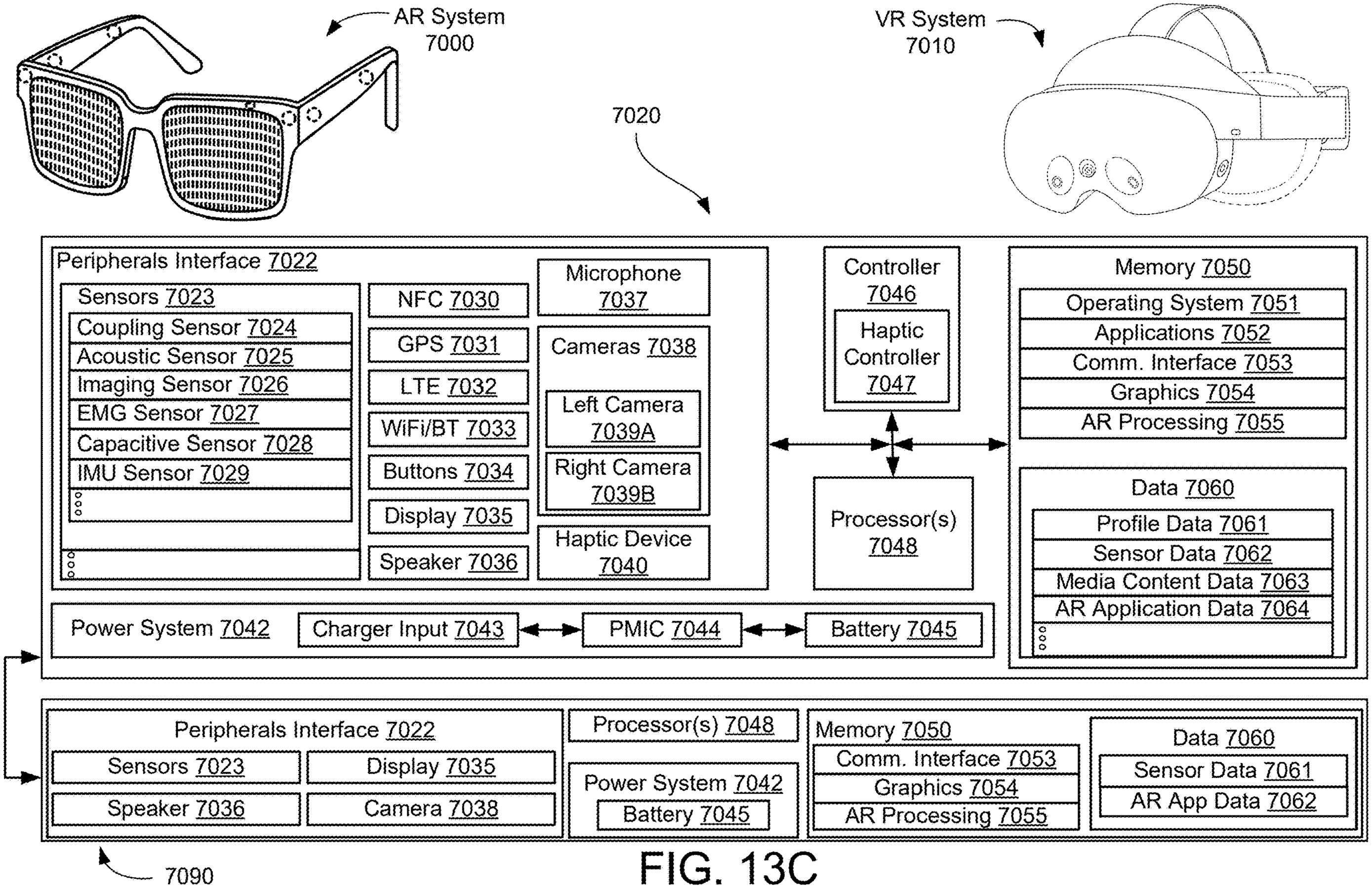
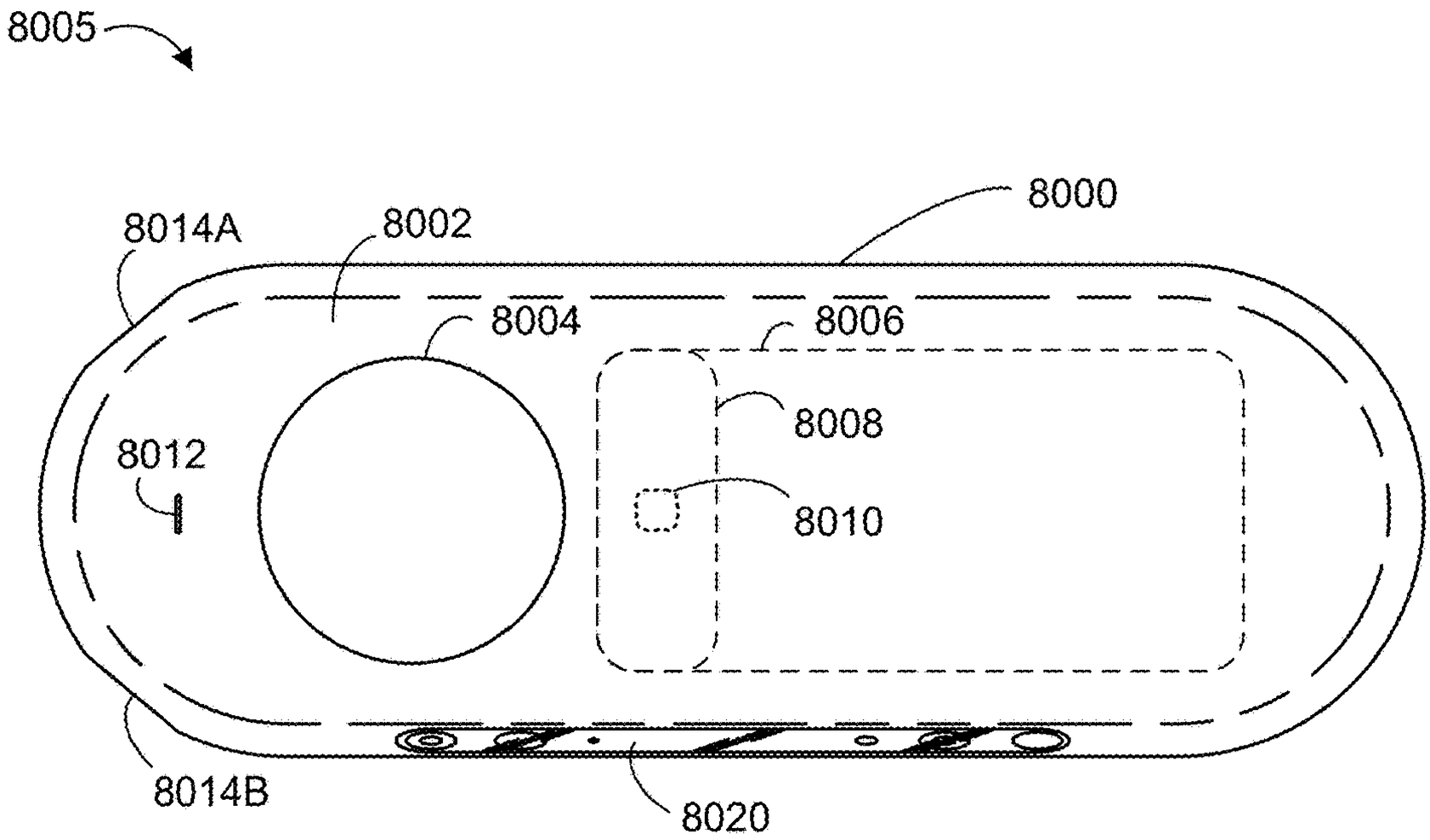

AR System
7000
VR System
7010
7020
Peripherals Interface 7022
Sensors 7023
Coupling Sensor 7024
Acoustic Sensor 7025
Imaging Sensor 7026
EMG Sensor 7027
Capacitive Sensor 7028
IMU Sensor 7029
NFC 7030
GPS 7031
LTE 7032
WiFi/BT 7033
Buttons 7034
Display 7035
Speaker 7036
Microphone 7037
Cameras 7038
Left Camera 7039A
Right Camera 7039B
Haptic Device 7040
Controller 7046
Haptic Controller 7047
Processor(s) 7048
Memory 7050
Operating System 7051
Applications 7052
Comm. Interface 7053
Graphics 7054
AR Processing 7055
Data 7060
Profile Data 7061
Sensor Data 7062
Media Content Data 7063
AR Application Data 7064
Power System 7042
Charger Input 7043
PMIC 7044
Battery 7045
Peripherals Interface 7022
Sensors 7023
Display 7035
Speaker 7036
Camera 7038
Processor(s) 7048
Power System 7042
Battery 7045
Memory 7050
Comm. Interface 7053
Graphics 7054
AR Processing 7055
Data 7060
Sensor Data 7061
AR App Data 7062
7090

FIG. 13C


8005
8000
8014A
8002
8004
8006
8008
8012
8010
8014B
8020

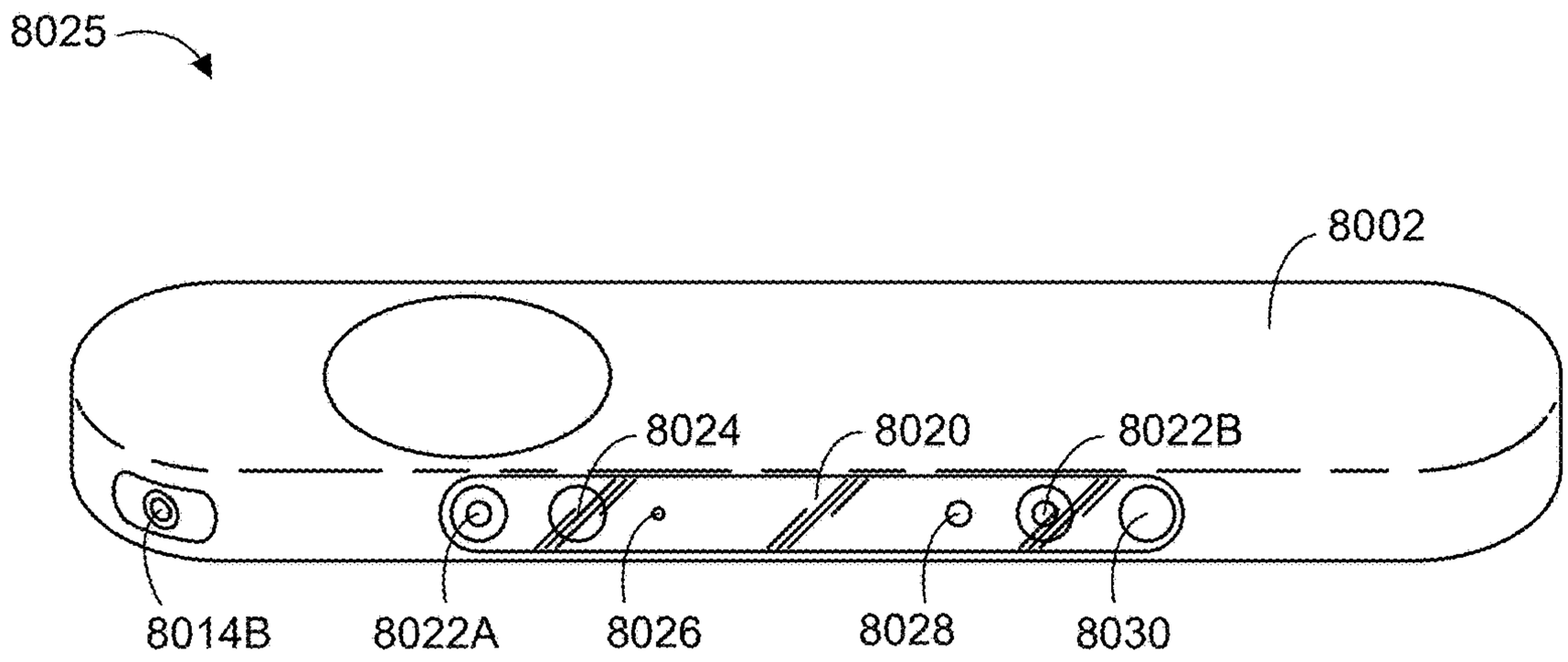

8025
8002
8024
8020
8022B
8014B
8022A
8026
8028
8030

FIG. 14A

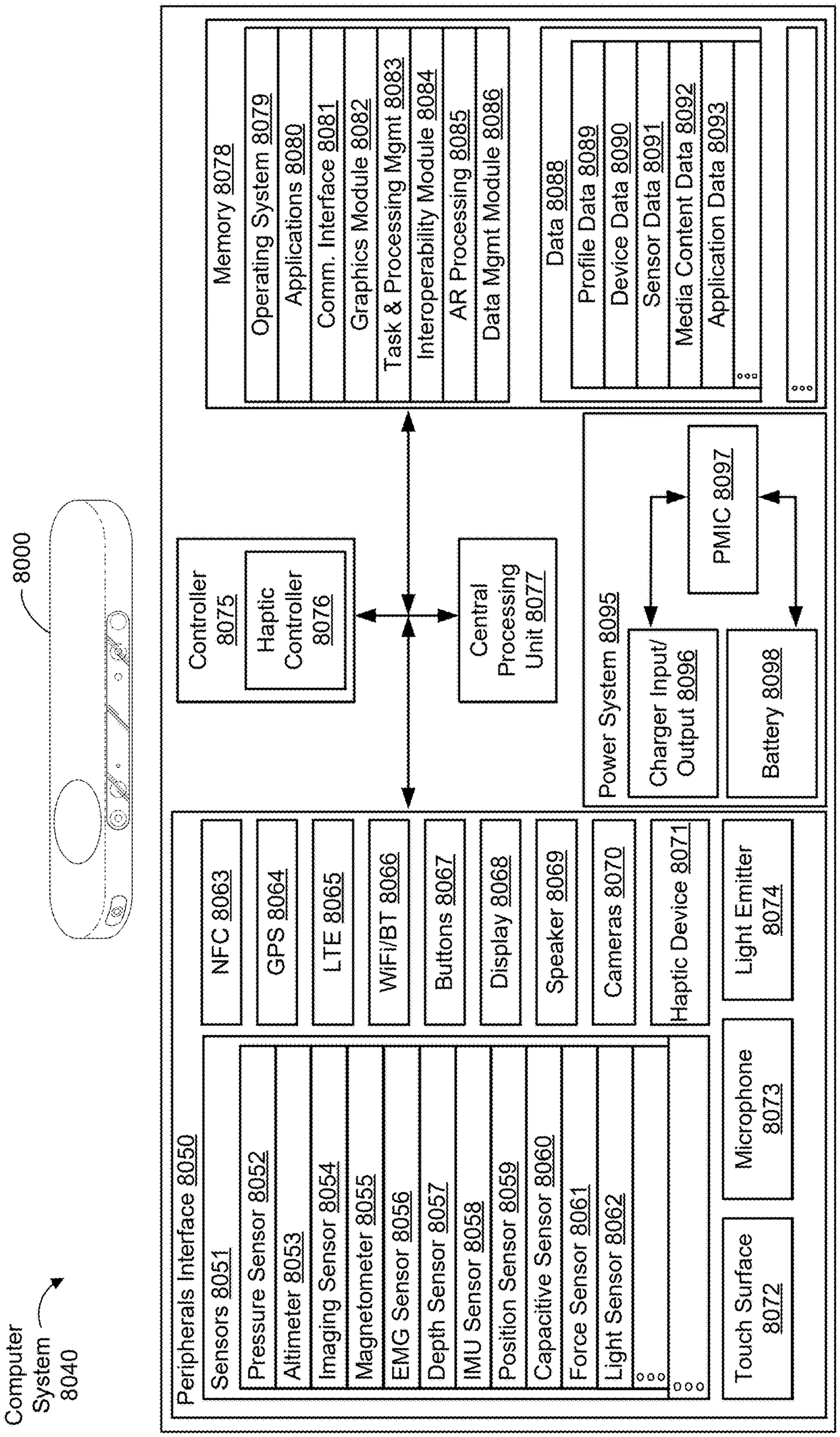

8000
Computer System 8040
Memory 8078
Operating System 8079
Applications 8080
Comm. Interface 8081
Graphics Module 8082
Task & Processing Mgmt 8083
Interoperability Module 8084
AR Processing 8085
Data Mgmt Module 8086
Data 8088
Profile Data 8089
Device Data 8090
Sensor Data 8091
Media Content Data 8092
Application Data 8093
Controller 8075
Haptic Controller 8076
Central Processing Unit 8077
Power System 8095
Charger Input/ Output 8096
PMIC 8097
Battery 8098
NFC 8063
GPS 8064
LTE 8065
WiFi/BT 8066
Buttons 8067
Display 8068
Speaker 8069
Cameras 8070
Haptic Device 8071
Light Emitter 8074
Peripherals Interface 8050
Sensors 8051
Pressure Sensor 8052
Altimeter 8053
Imaging Sensor 8054
Magnetometer 8055
EMG Sensor 8056
Depth Sensor 8057
IMU Sensor 8058
Position Sensor 8059
Capacitive Sensor 8060
Force Sensor 8061
Light Sensor 8062
Touch Surface 8072
Microphone 8073

FIG. 14B

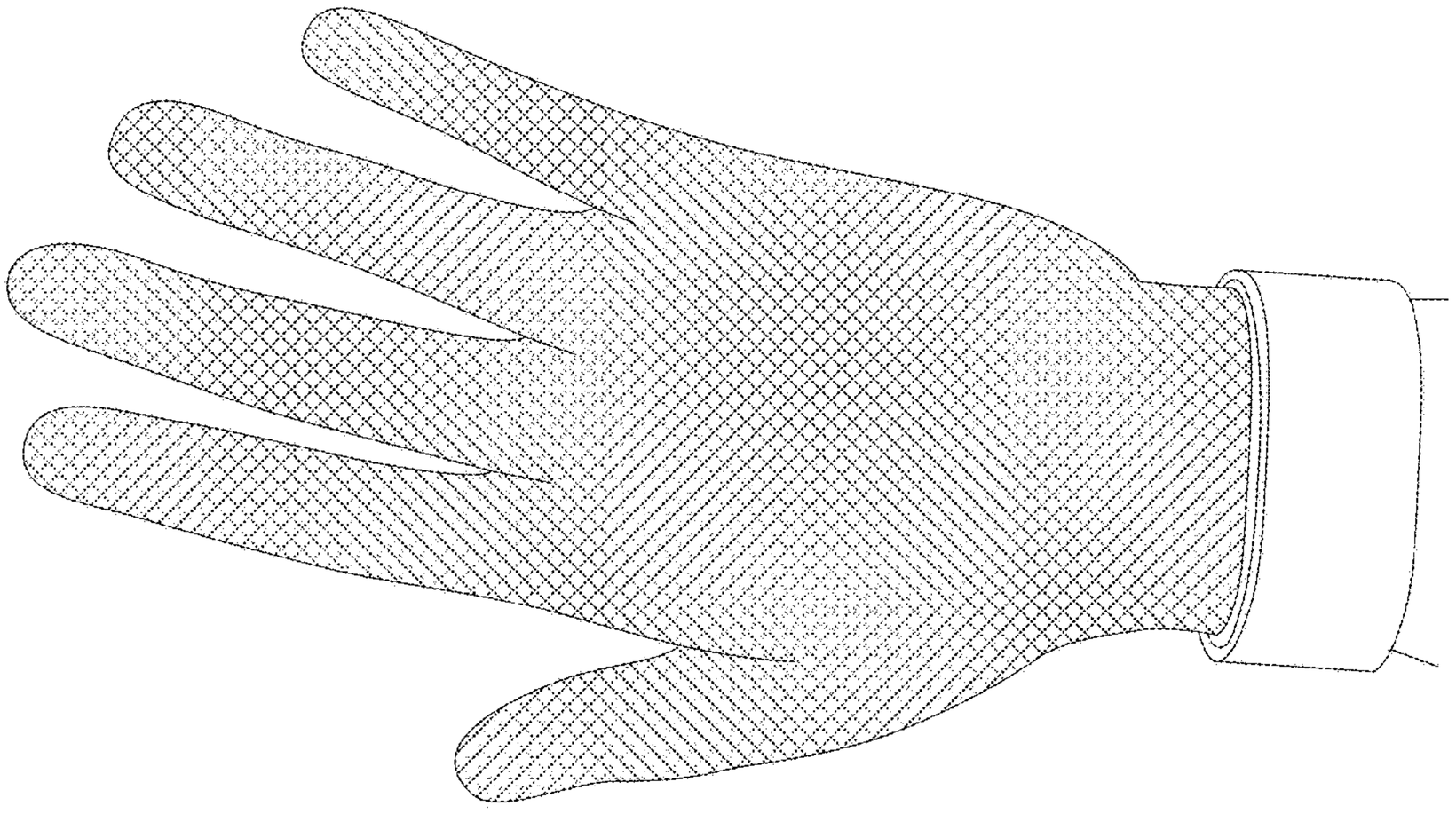


FIG. 15B

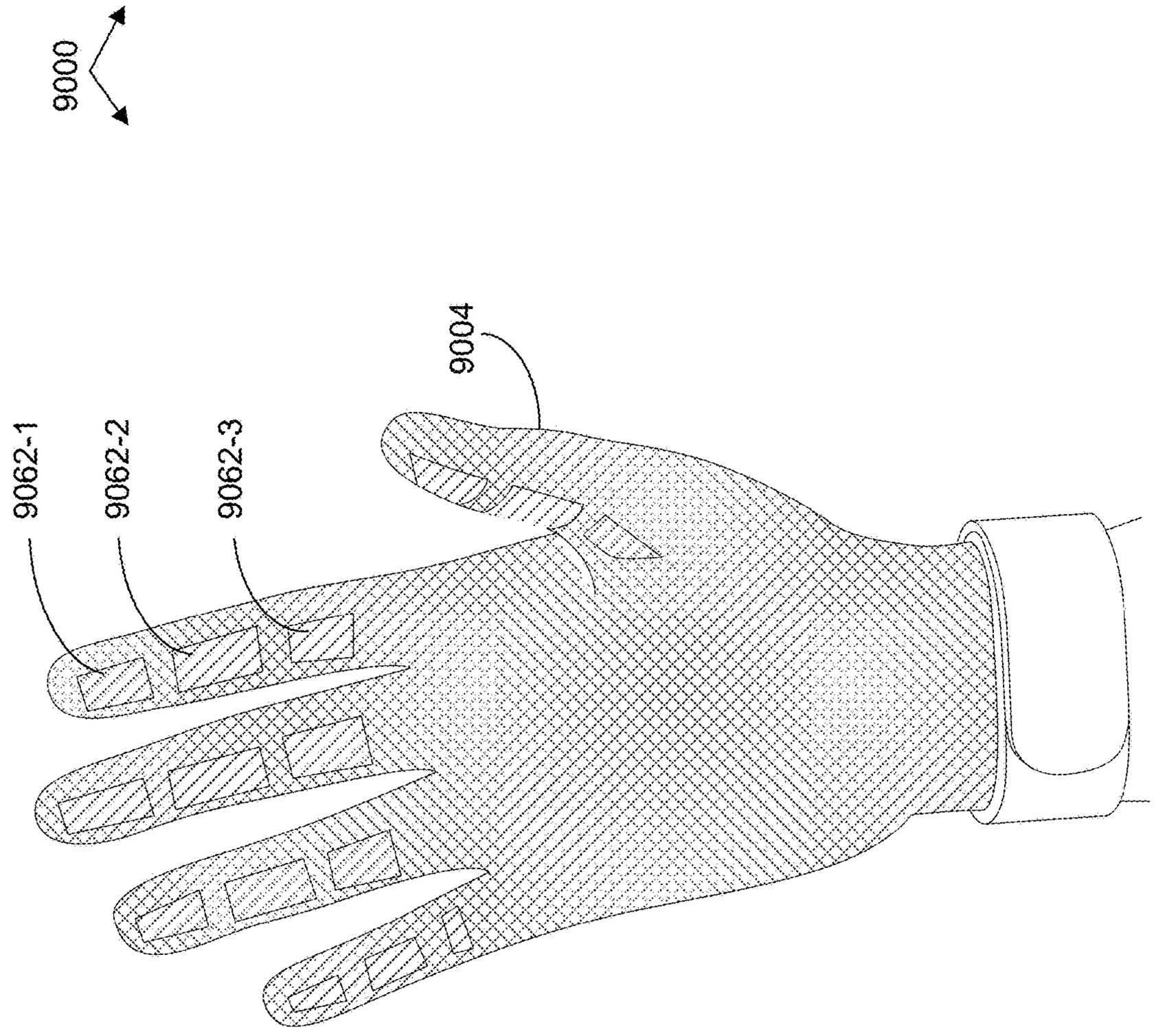
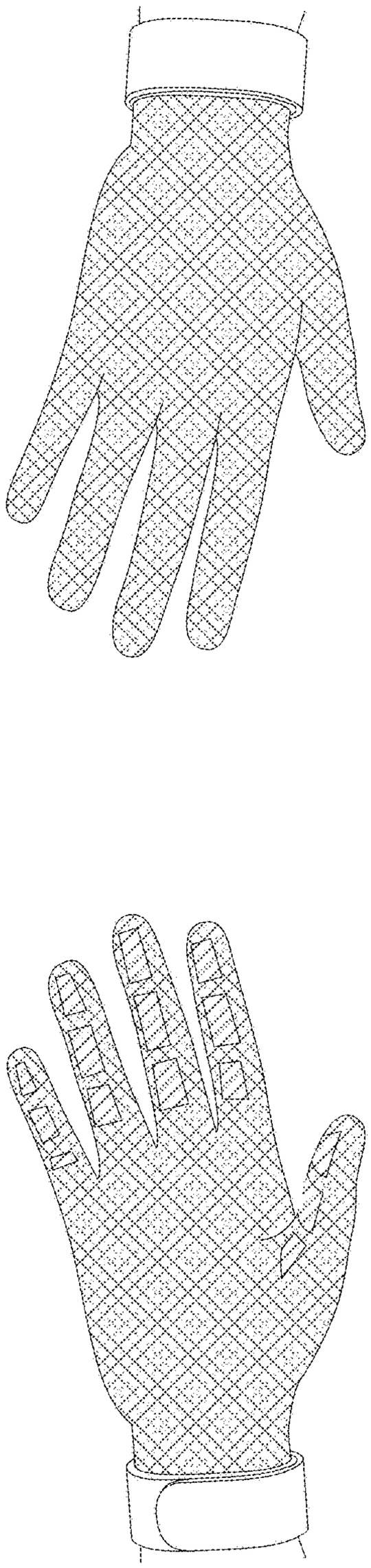


FIG. 15A



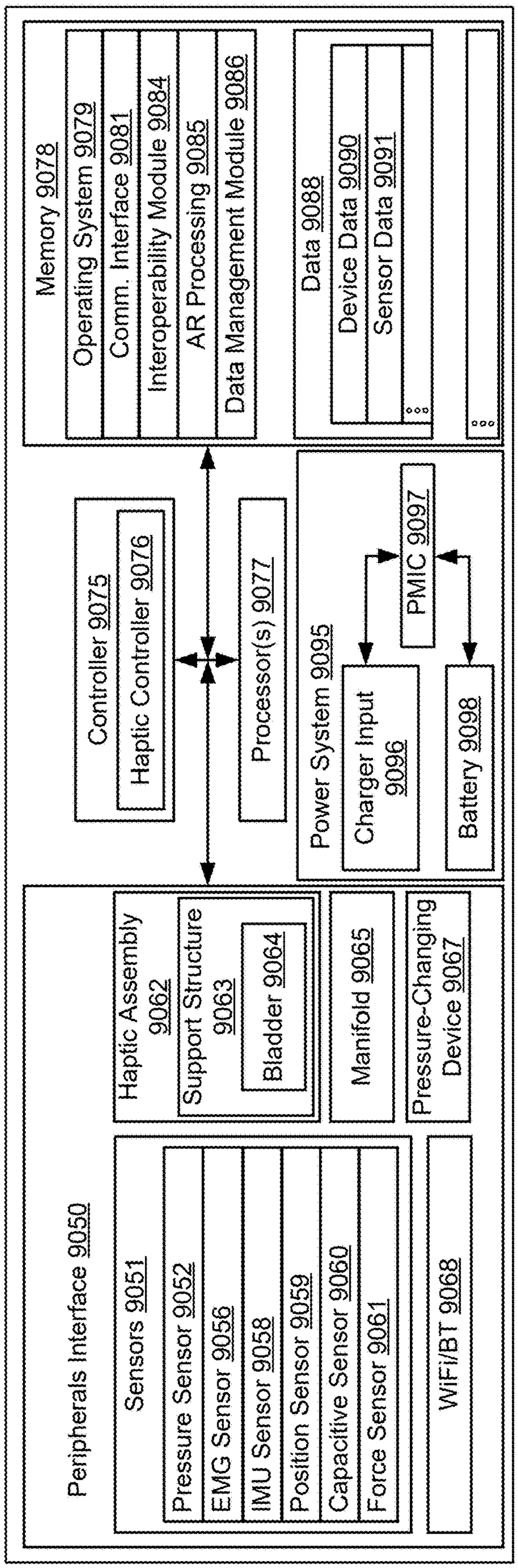

Memory 9078
Operating System 9079
Comm. Interface 9081
Interoperability Module 9084
AR Processing 9085
Data Management Module 9086
Data 9088
Device Data 9090
Sensor Data 9091
Controller 9075
Haptic Controller 9076
Processor(s) 9077
Power System 9095
Charger Input 9096
PMIC 9097
Battery 9098
Haptic Assembly 9062
Support Structure 9063
Bladder 9064
Manifold 9065
Pressure-Changing Device 9067
Peripherals Interface 9050
Sensors 9051
Pressure Sensor 9052
EMG Sensor 9056
IMU Sensor 9058
Position Sensor 9059
Capacitive Sensor 9060
Force Sensor 9061
WiFi/BT 9068
Computer System 9040

FIG. 15C

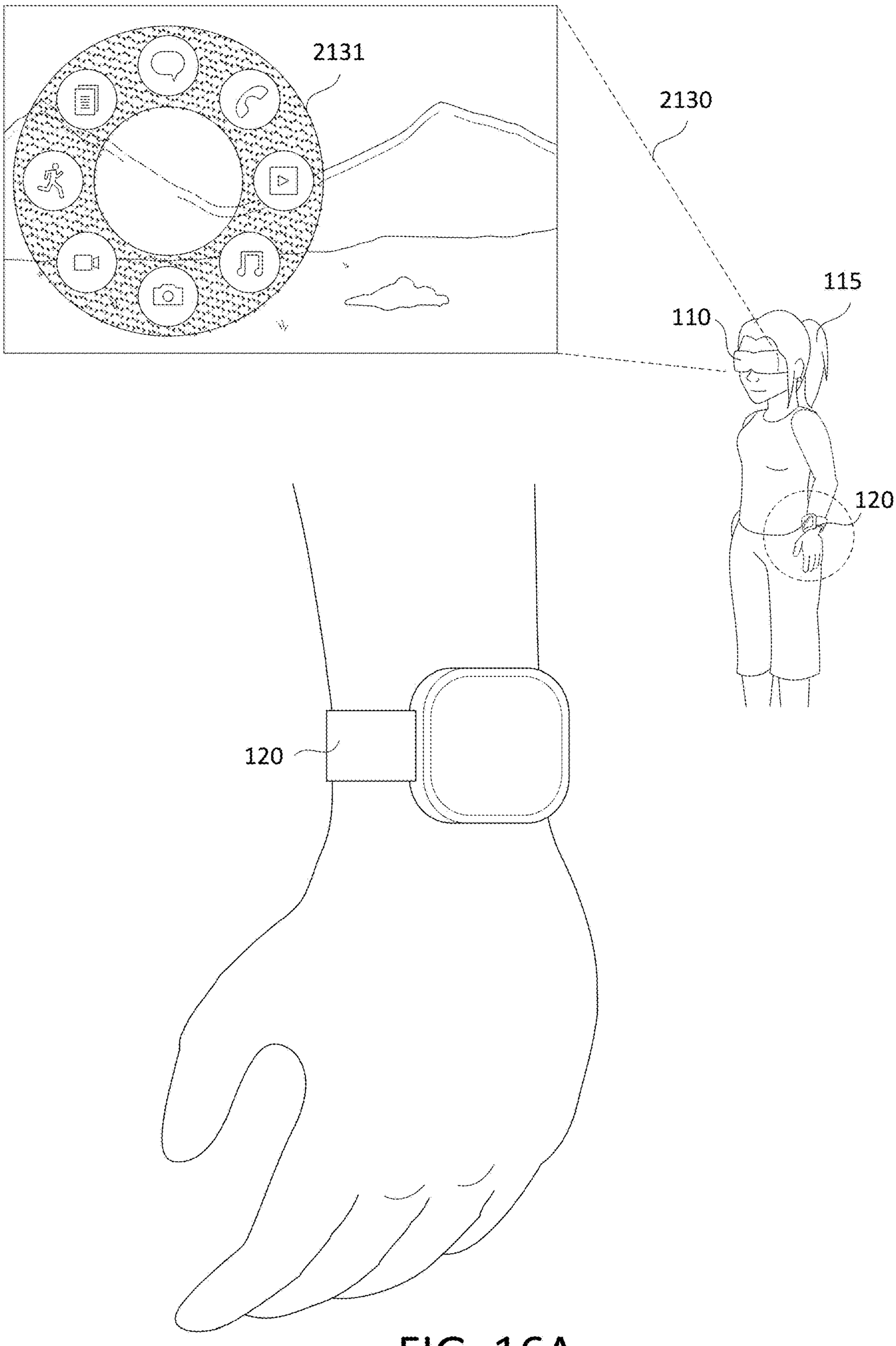


FIG. 16A

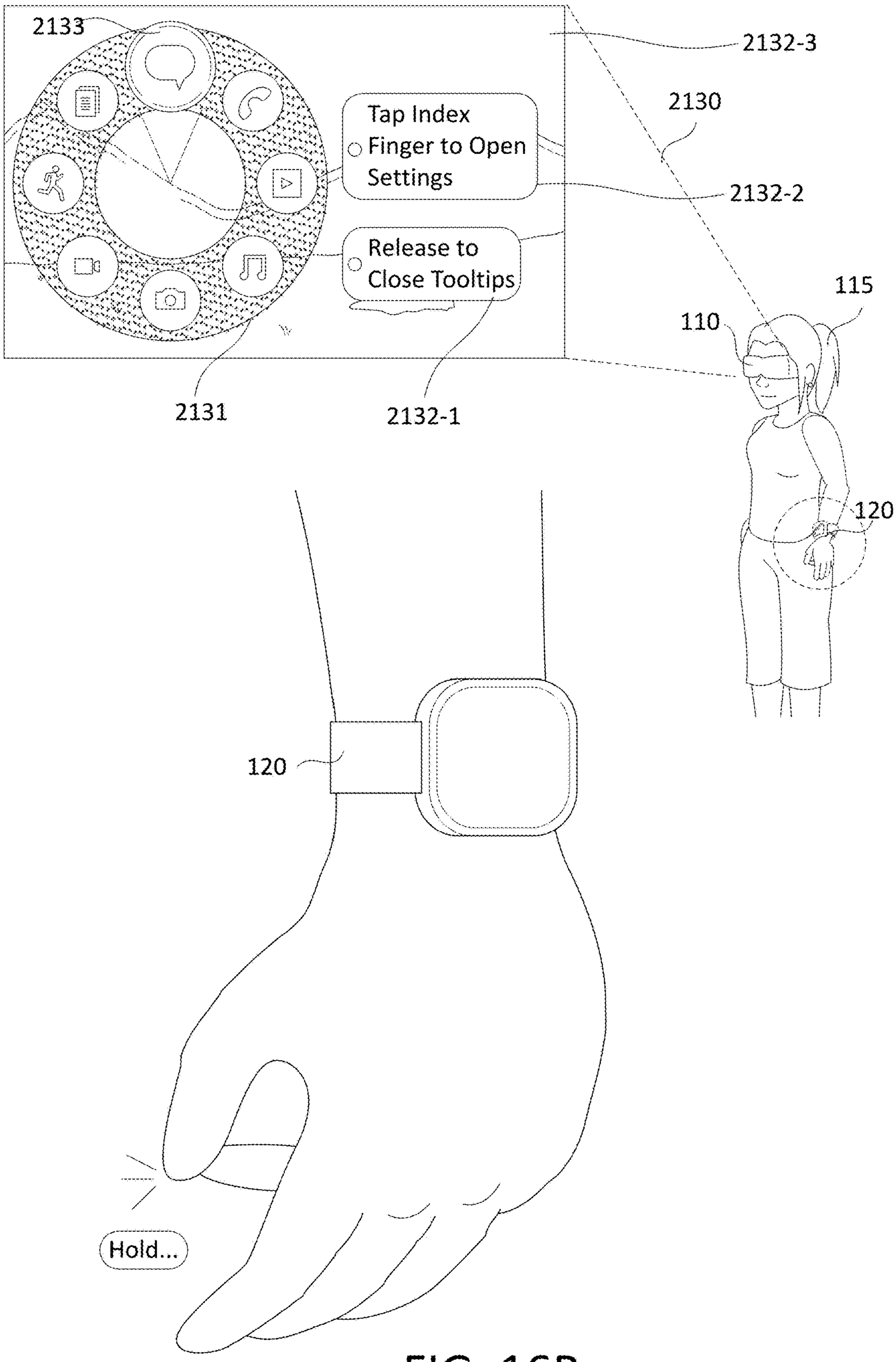

2133
2132-3
2130
Tap Index Finger to Open Settings
2132-2
Release to Close Tooltips
115
110
2131
2132-1
120
120
Hold...

FIG. 16B

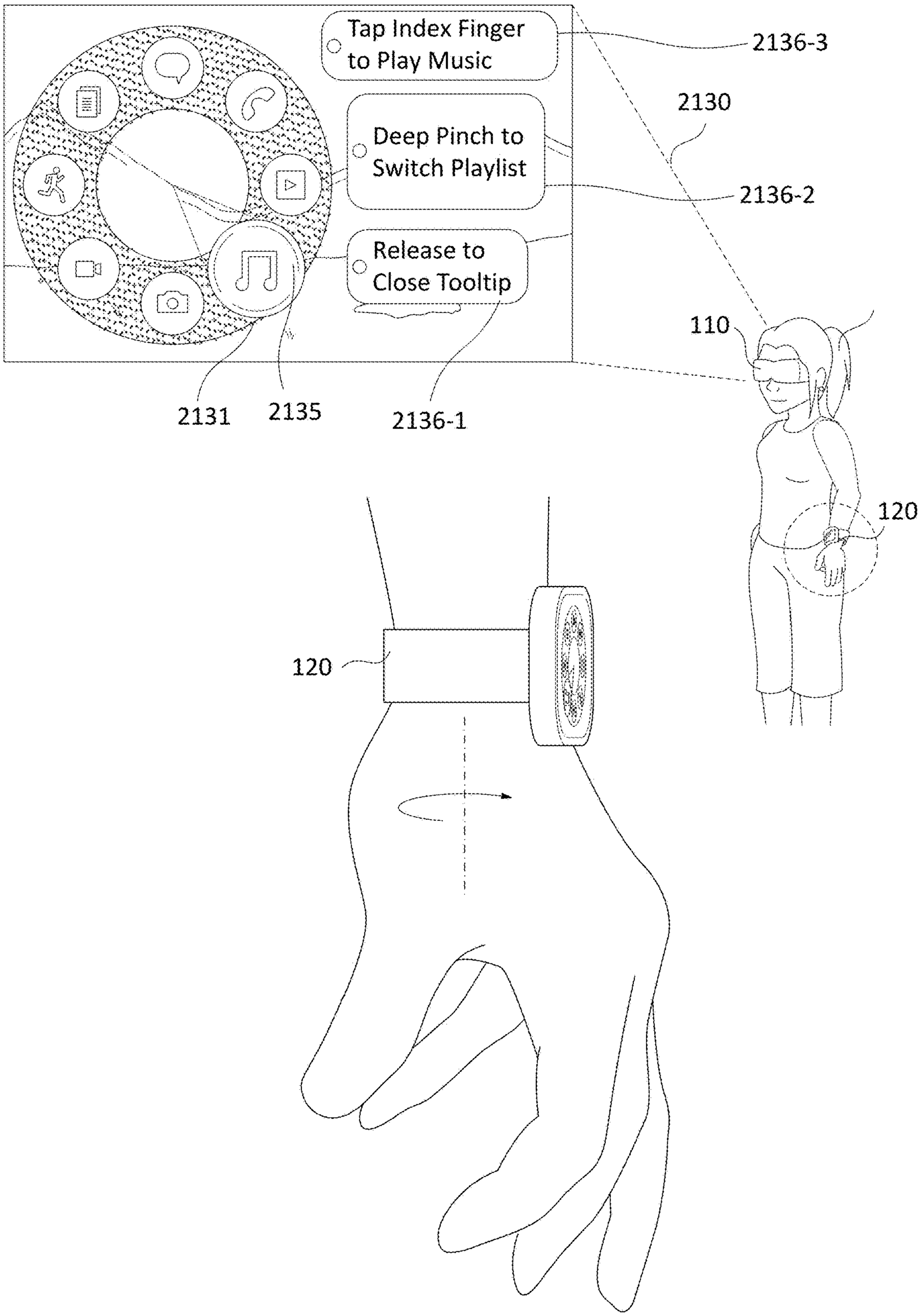

Tap Index Finger to Play Music
Deep Pinch to Switch Playlist
Release to Close Tooltip
2136-3
2130
2136-2
110
120
2131
2135
2136-1
120

FIG. 16C

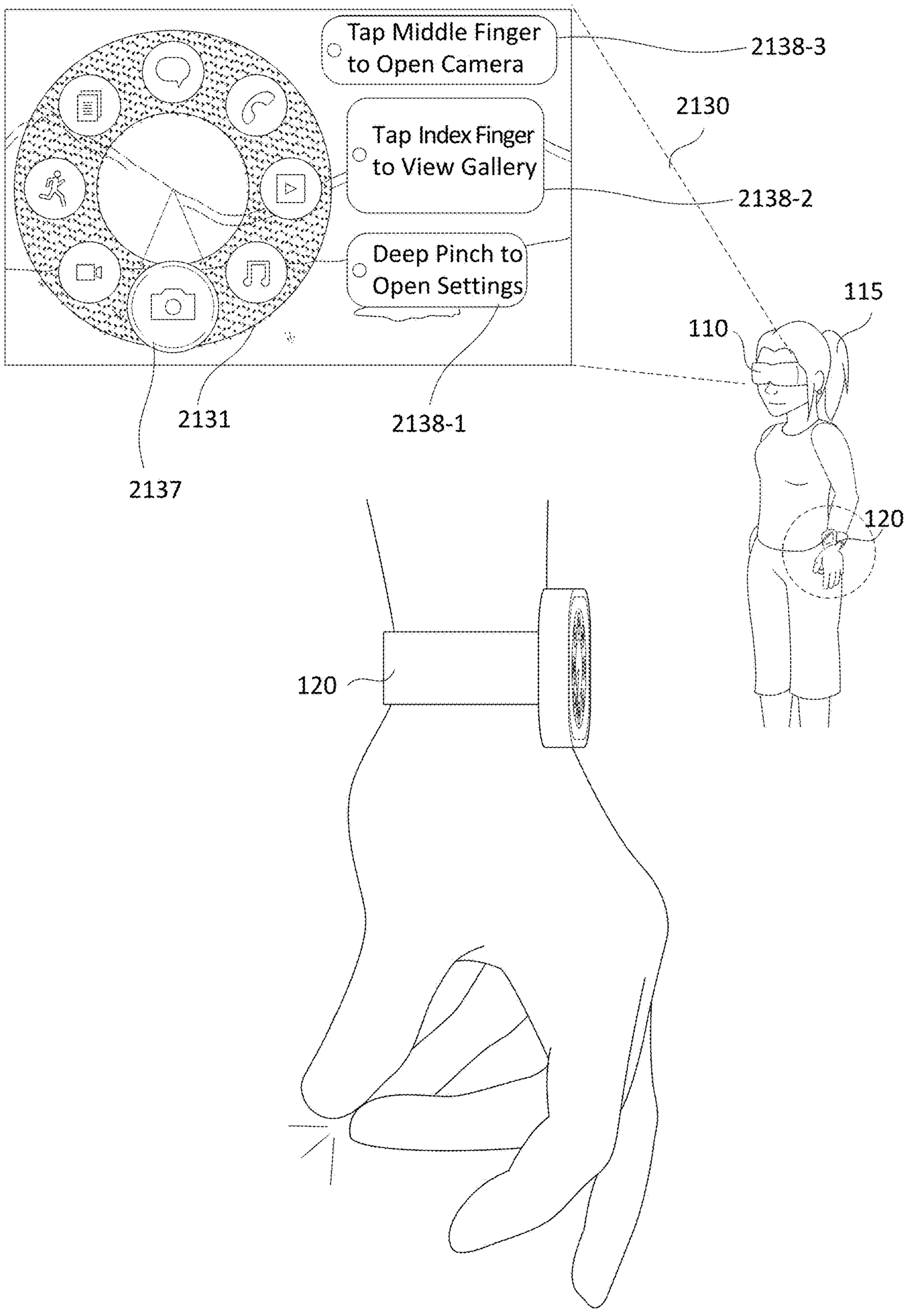

Tap Middle Finger to Open Camera
2138-3
2130
Tap Index Finger to View Gallery
2138-2
Deep Pinch to Open Settings
115
110
2131
2138-1
2137
120
120

FIG. 16D

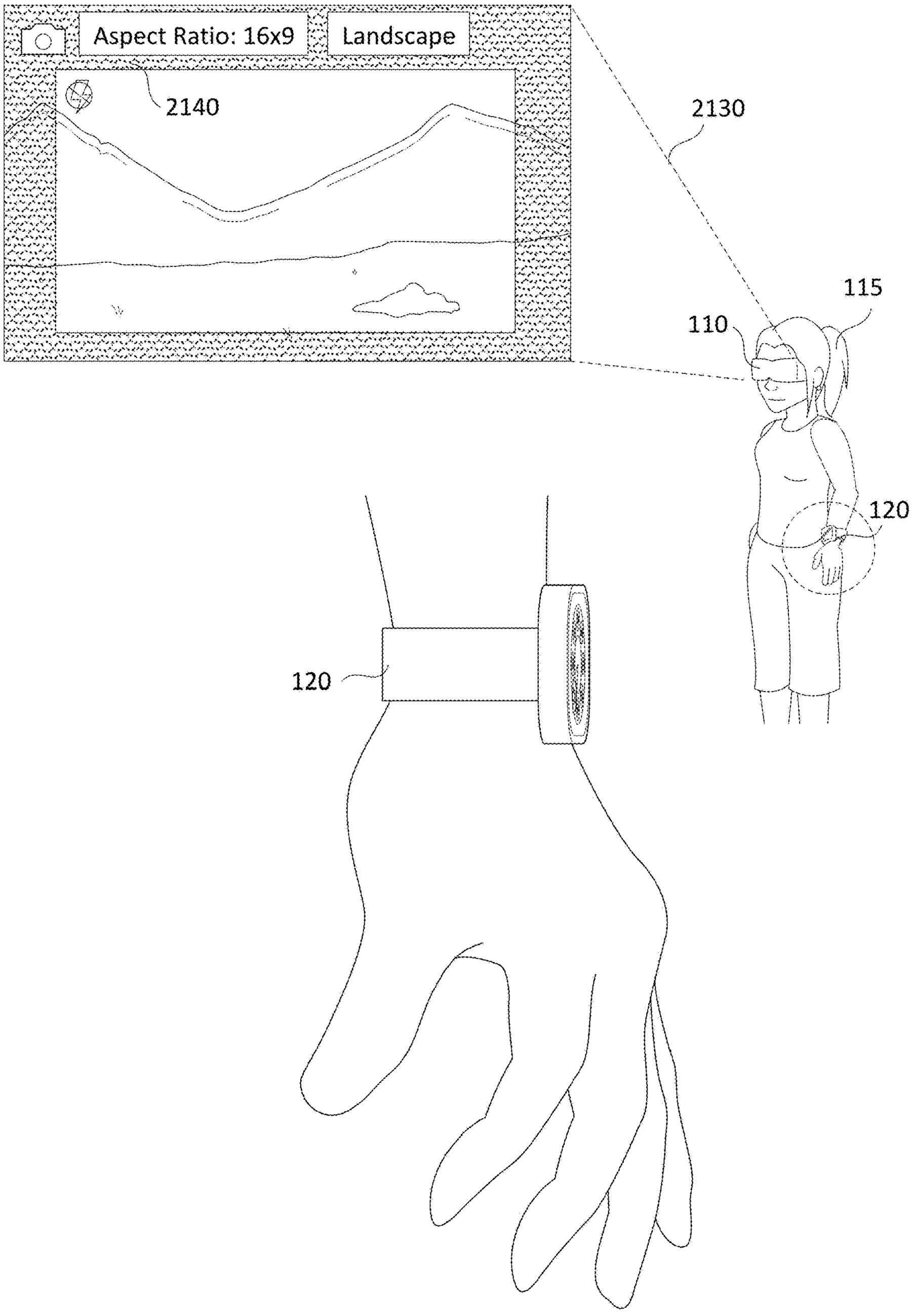


FIG. 16E

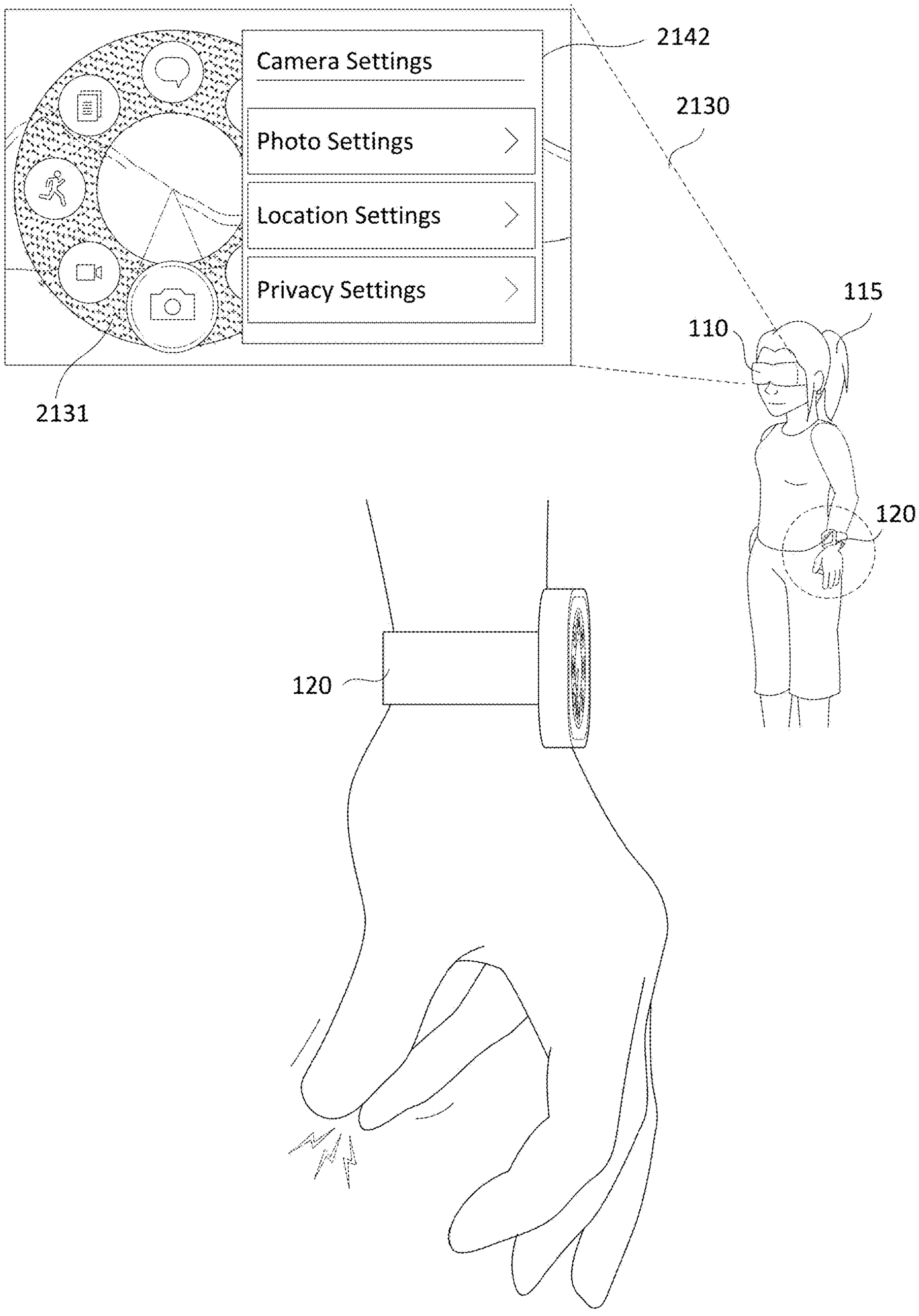

Camera Settings
Photo Settings
Location Settings
Privacy Settings
2142
2130
2131
115
110
120
120

FIG. 16F

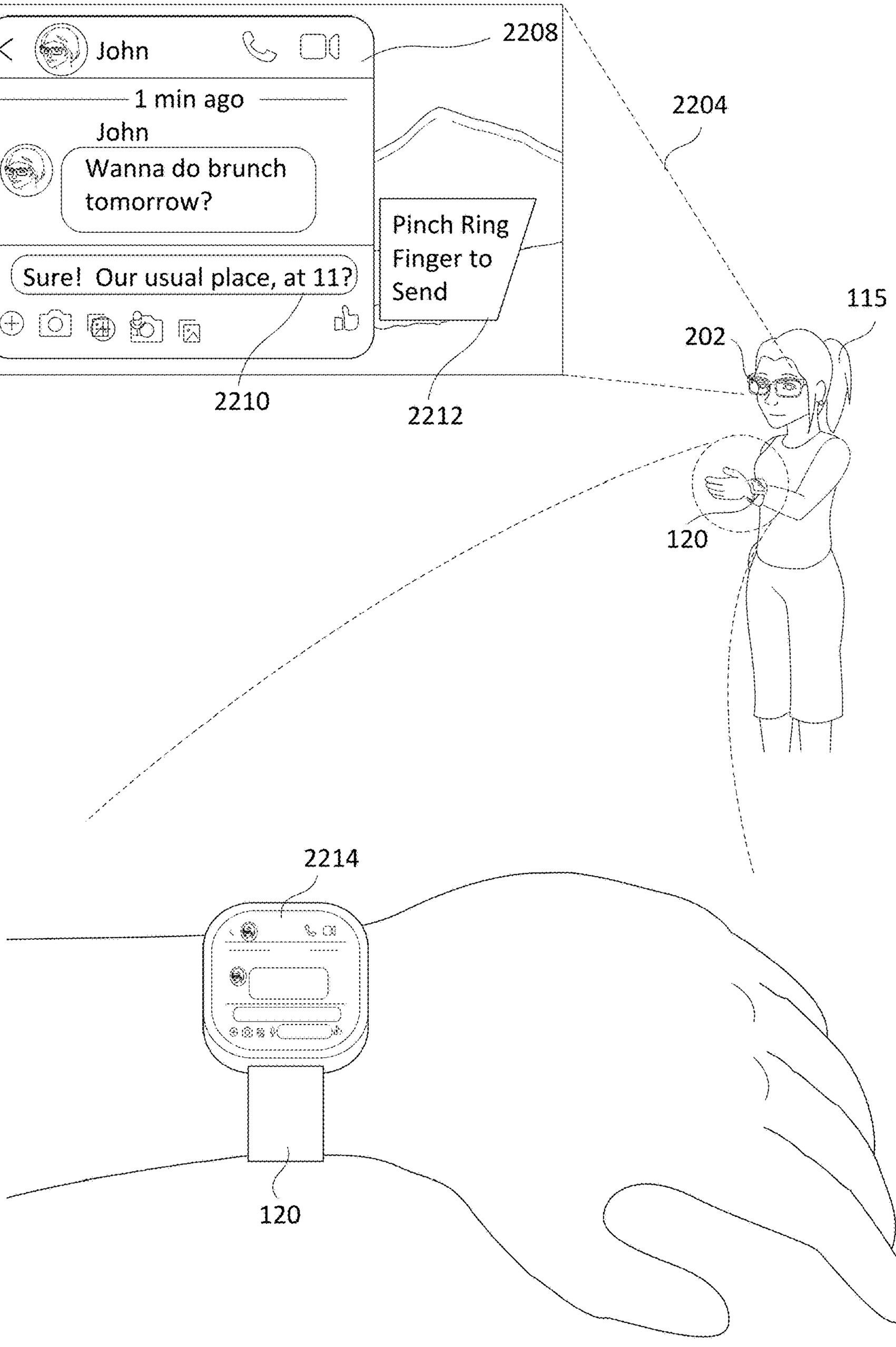

John
1 min ago
John
Wanna do brunch tomorrow?
Sure! Our usual place, at 11?
Pinch Ring Finger to Send
2208
2204
115
202
120
2210
2212
2214
120

FIG. 17A

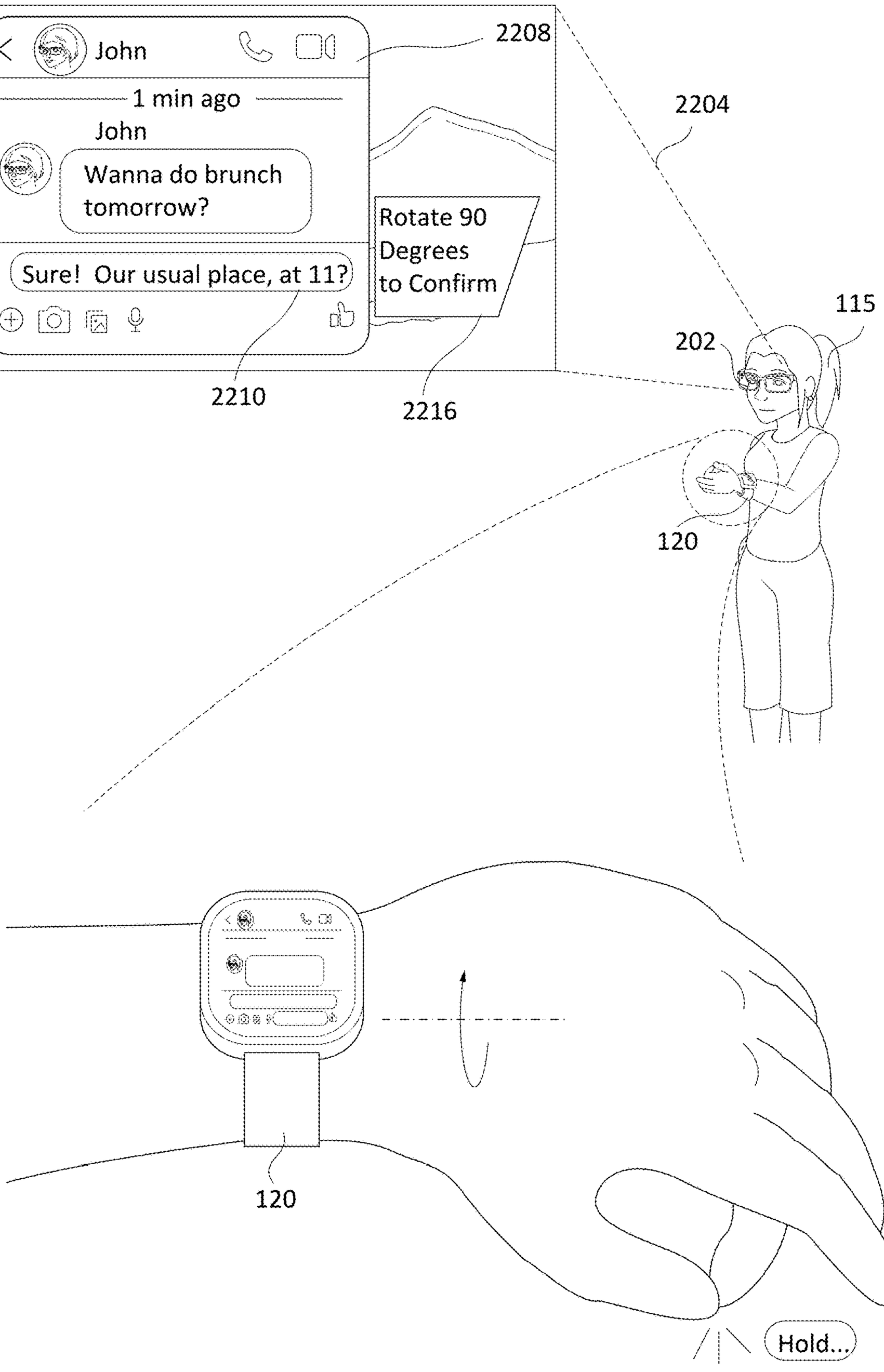

John
1 min ago
John
Wanna do brunch tomorrow?
Sure! Our usual place, at 11?
Rotate 90 Degrees to Confirm
2208
2204
115
202
120
2210
2216
120
Hold...

FIG. 17B

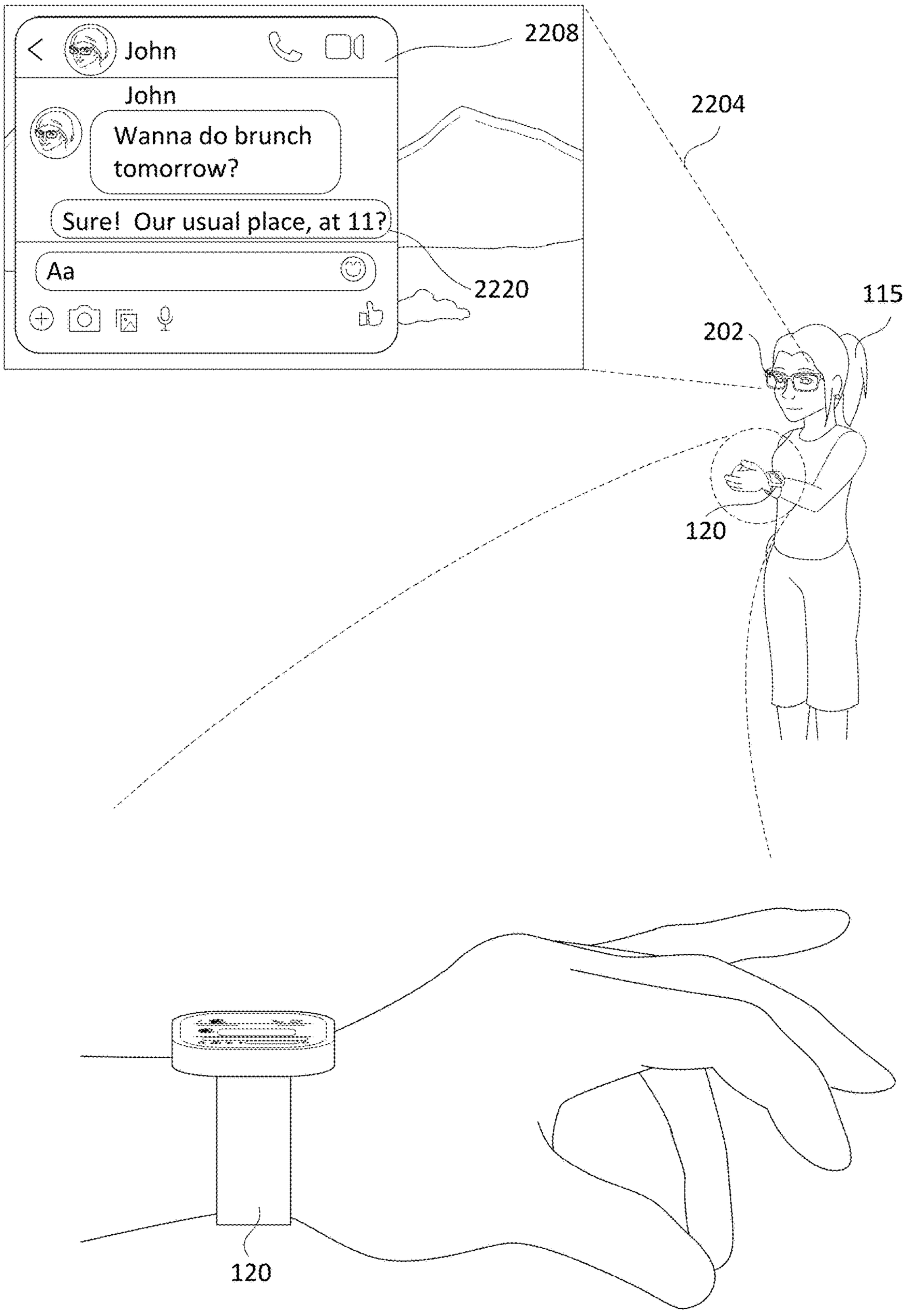

John
John
Wanna do brunch tomorrow?
Sure! Our usual place, at 11?
Aa
2208
2204
2220
115
202
120
120

FIG. 17C

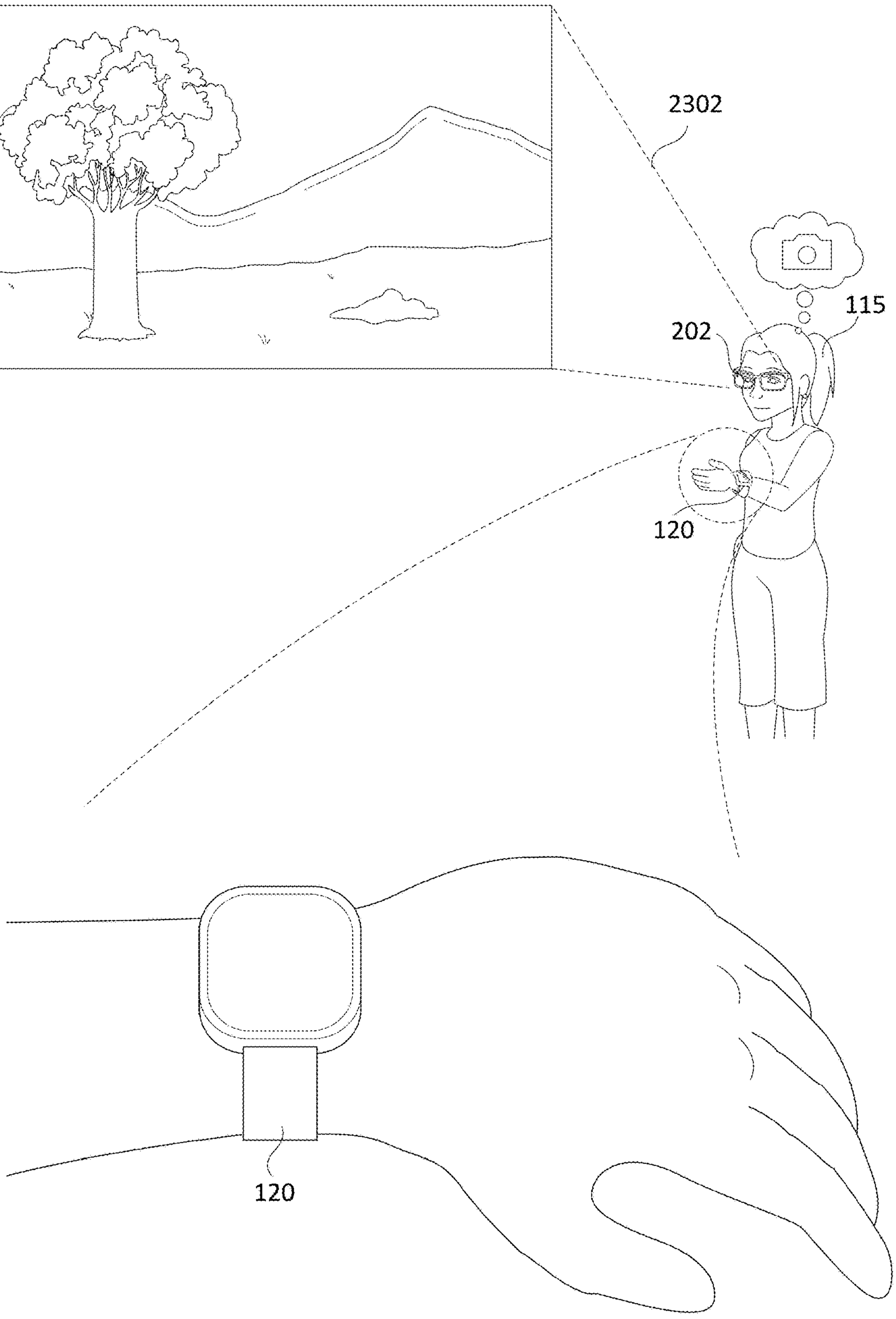


FIG. 18A

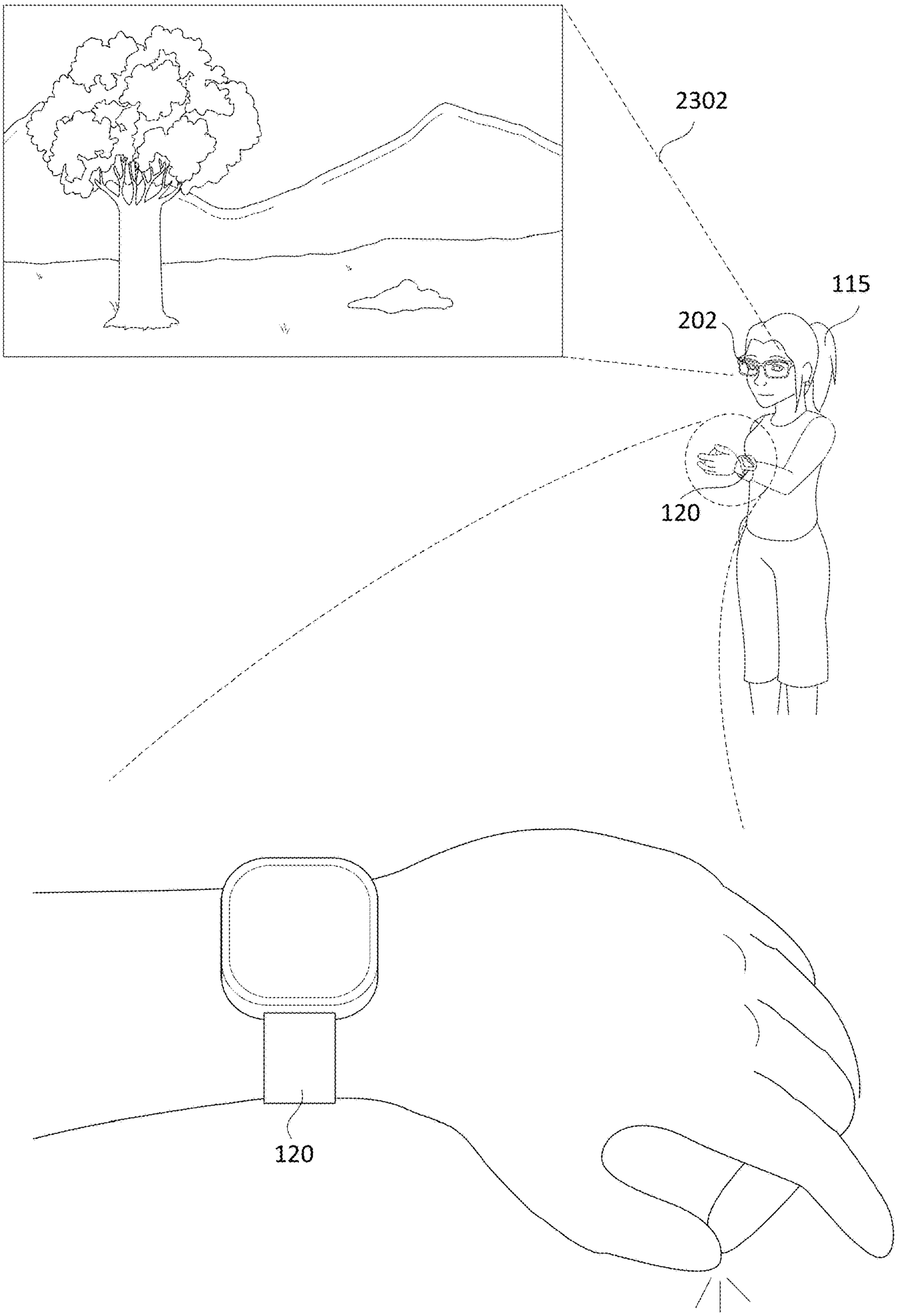


FIG. 18B

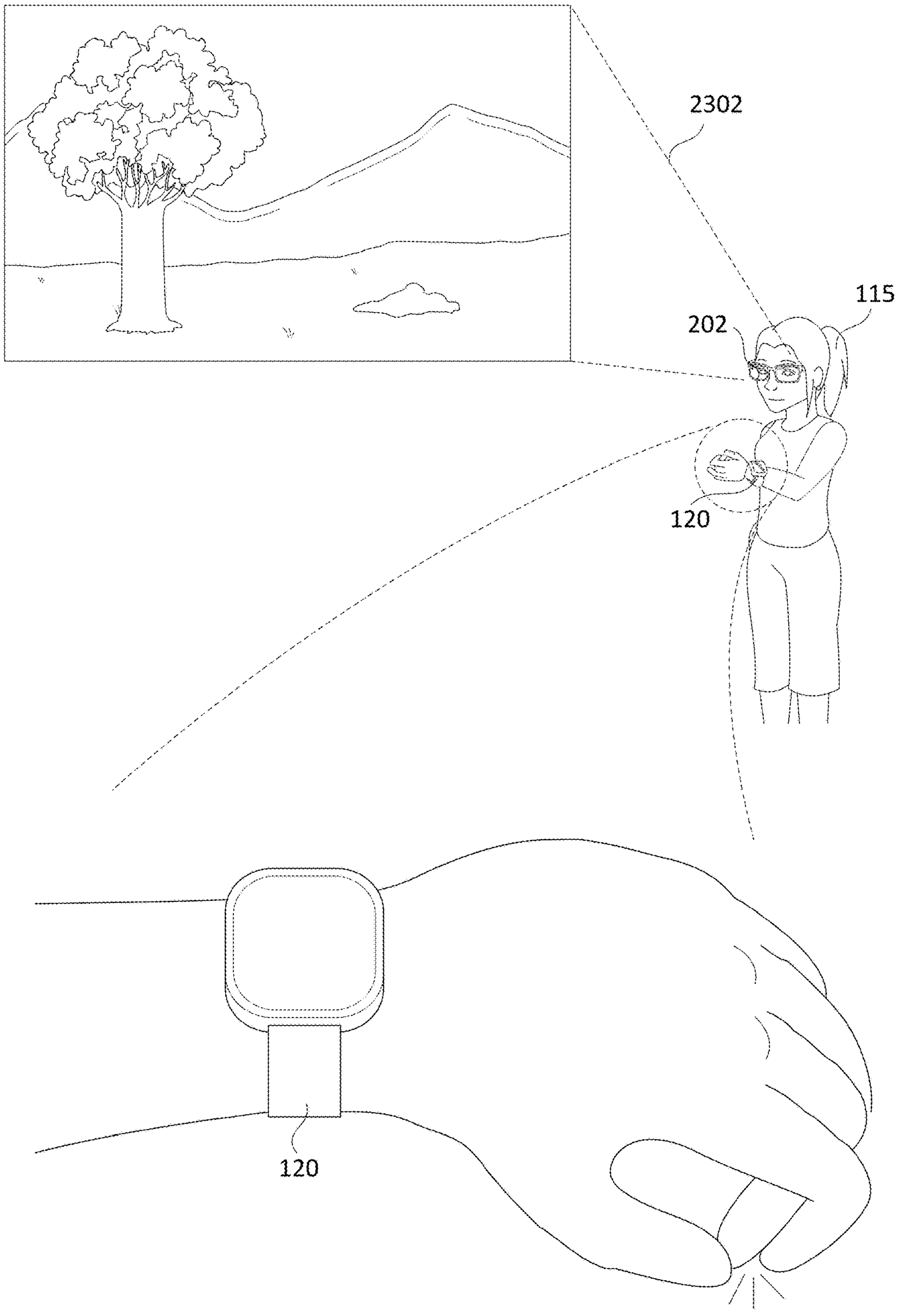


FIG. 18C

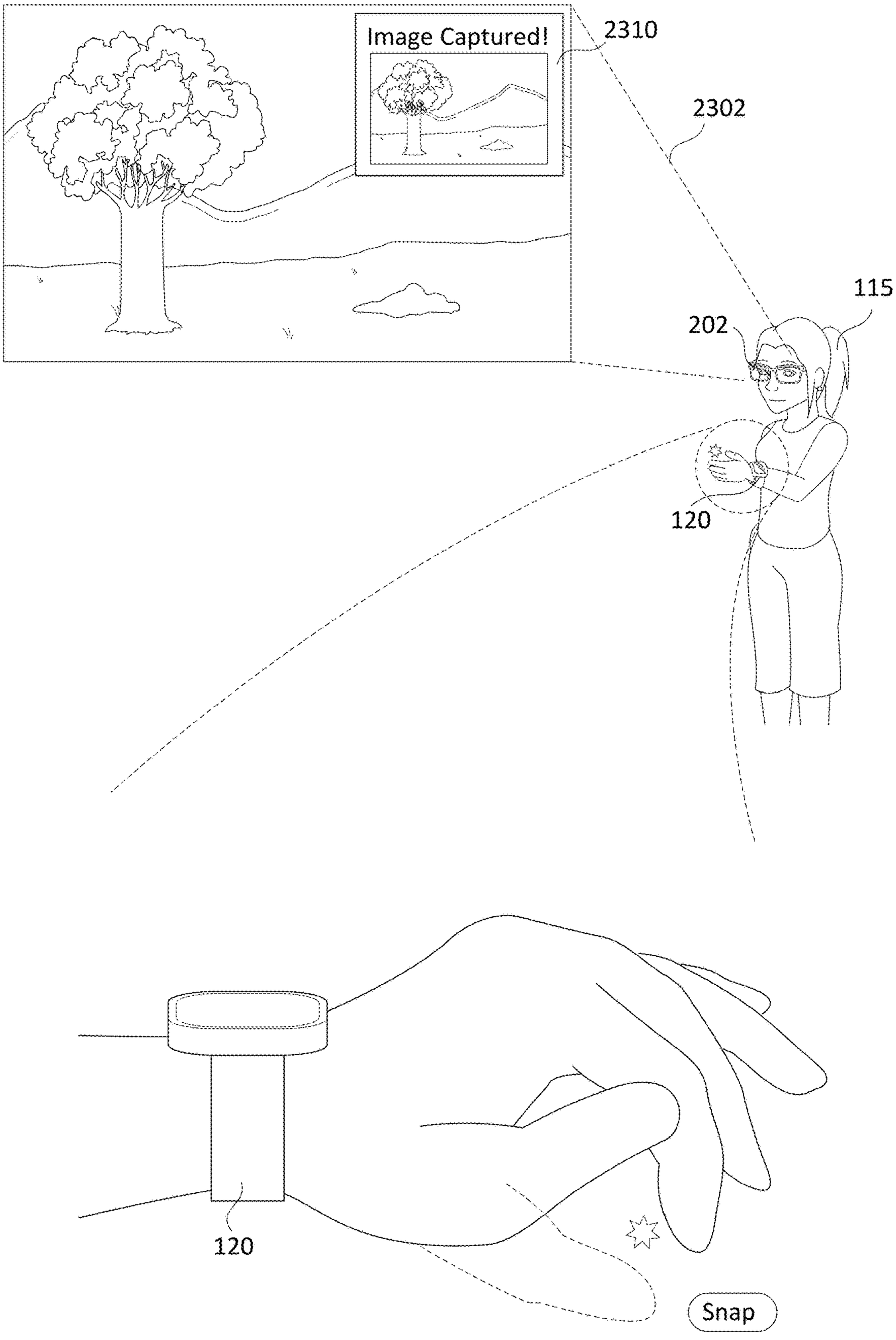


FIG. 18D

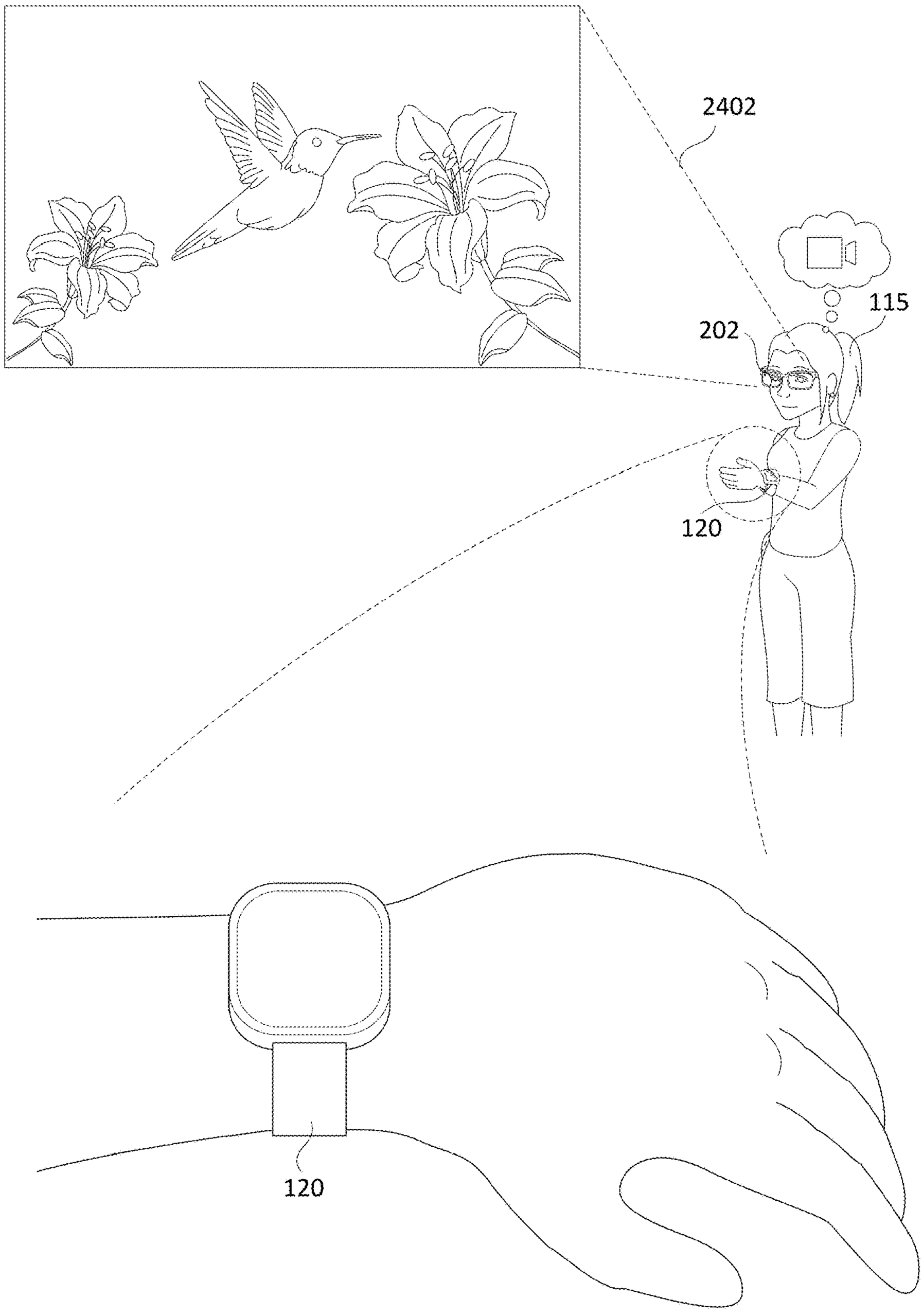


FIG. 19A

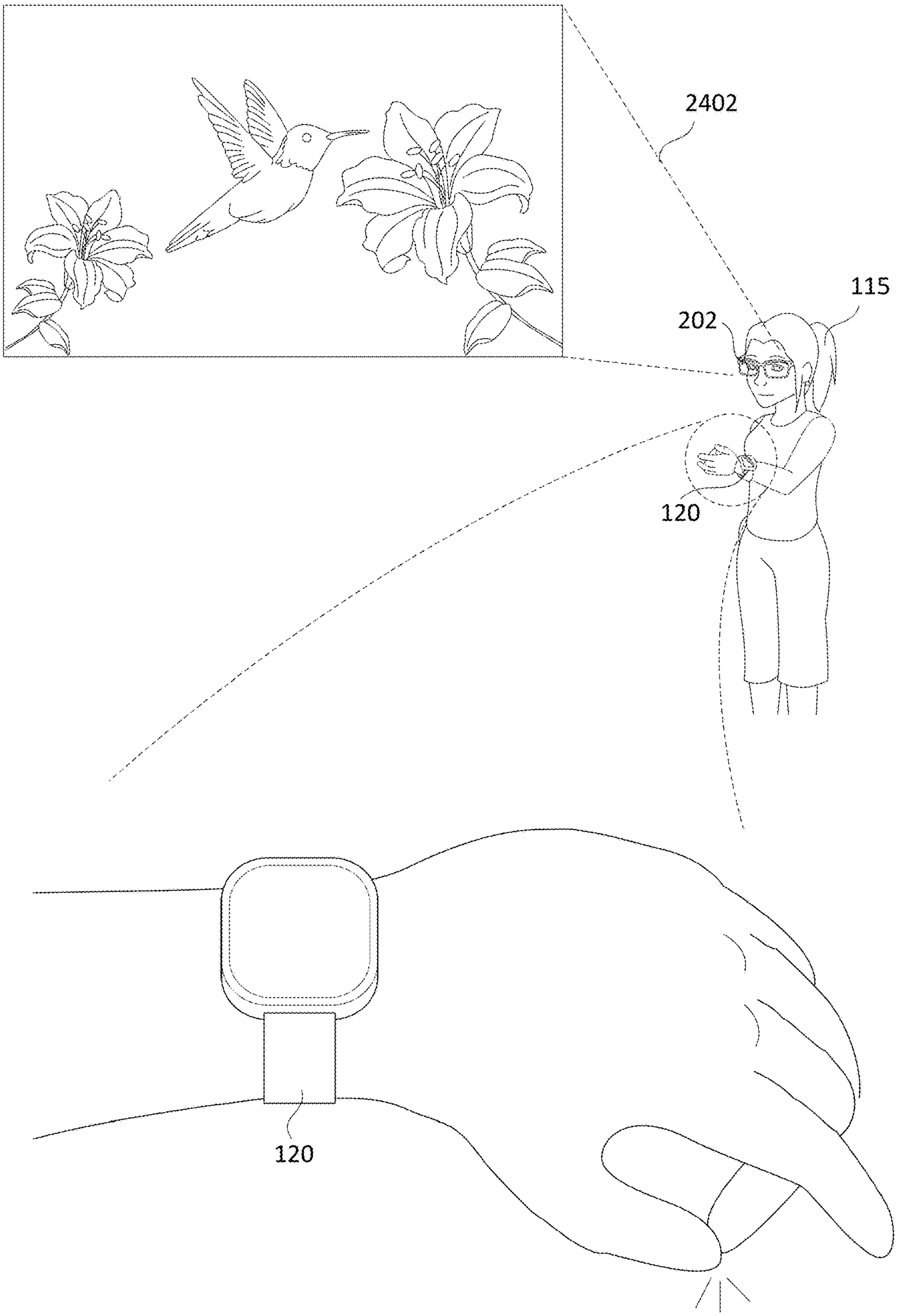


FIG. 19B

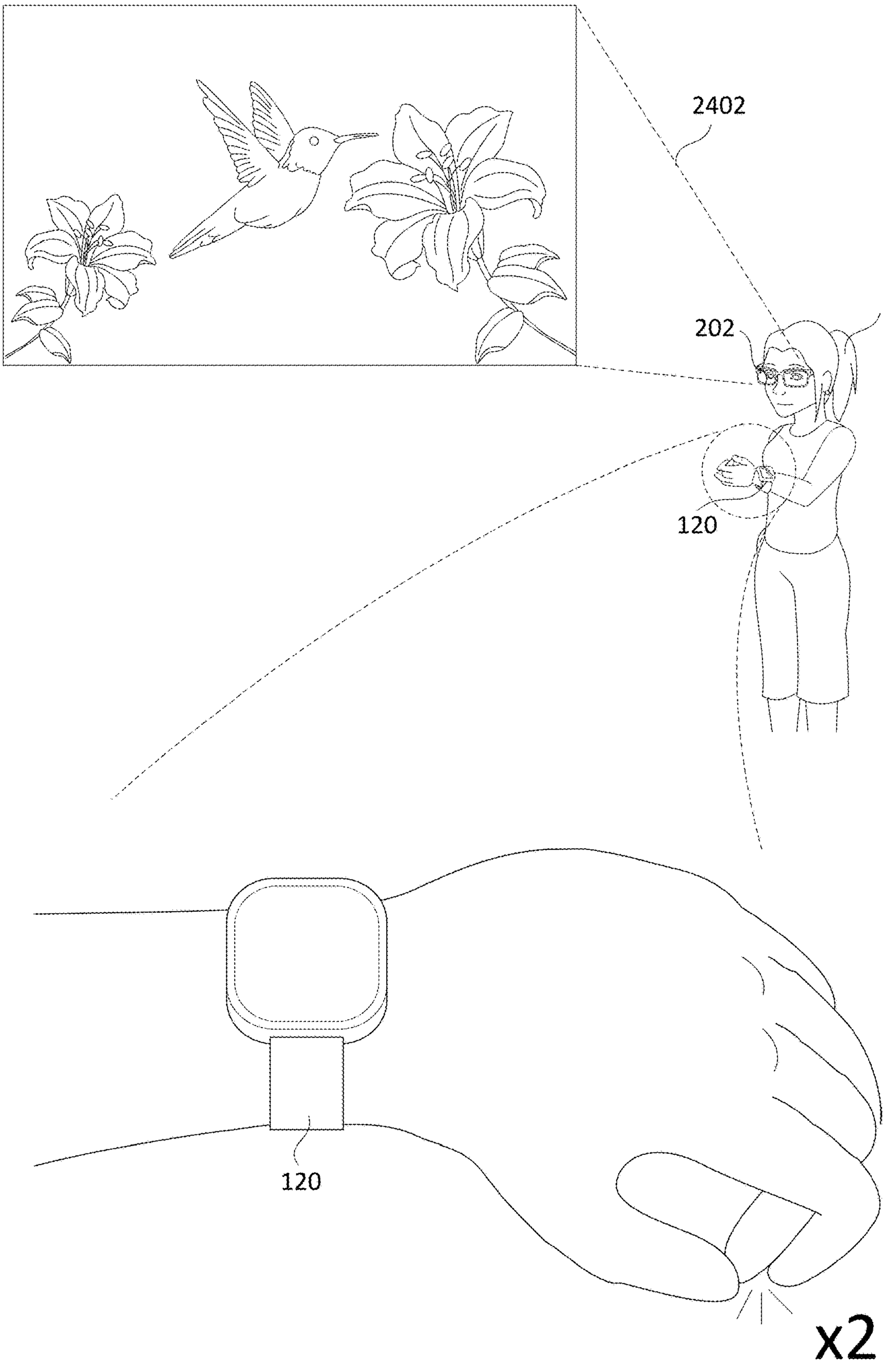


FIG. 19C

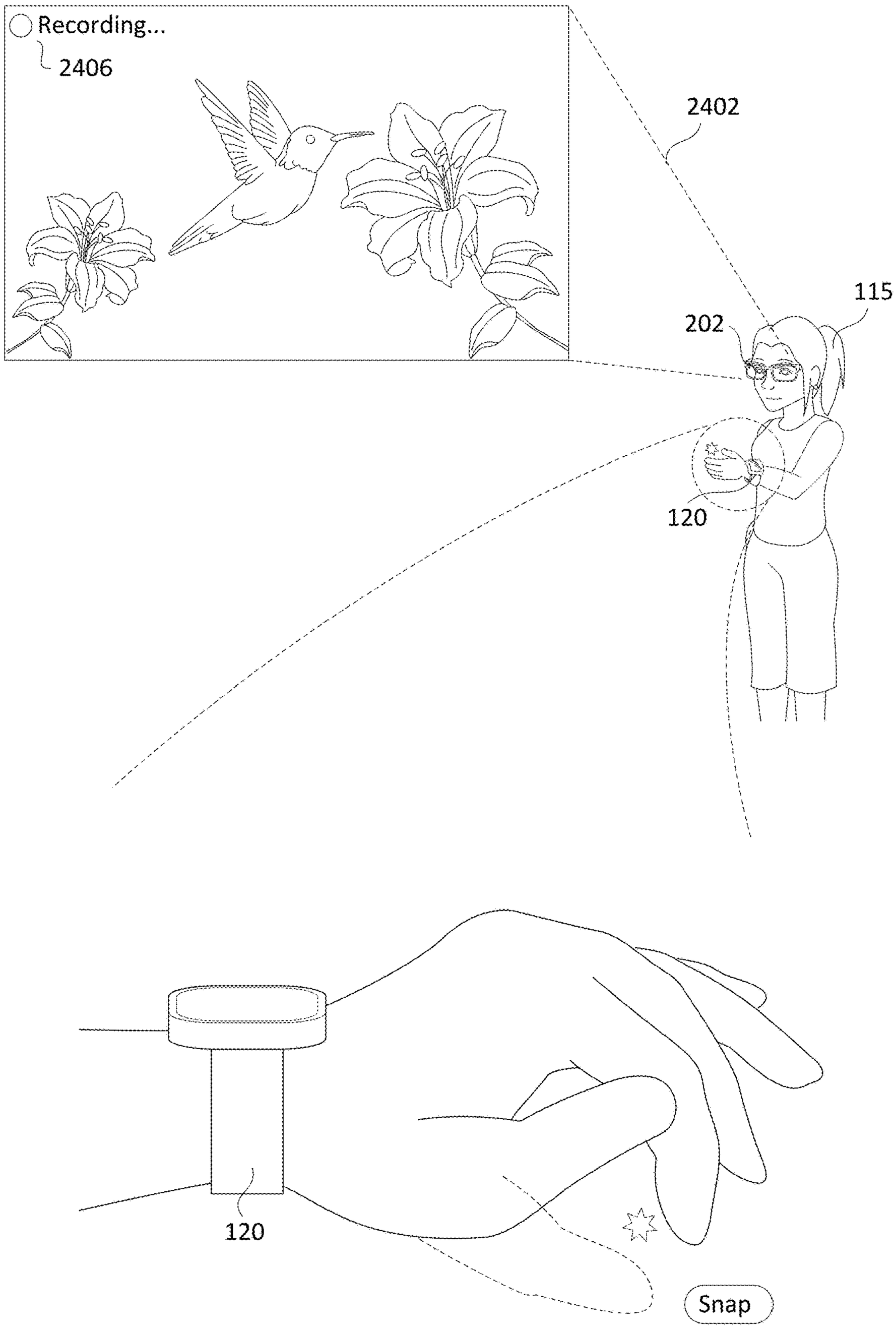


FIG. 19D

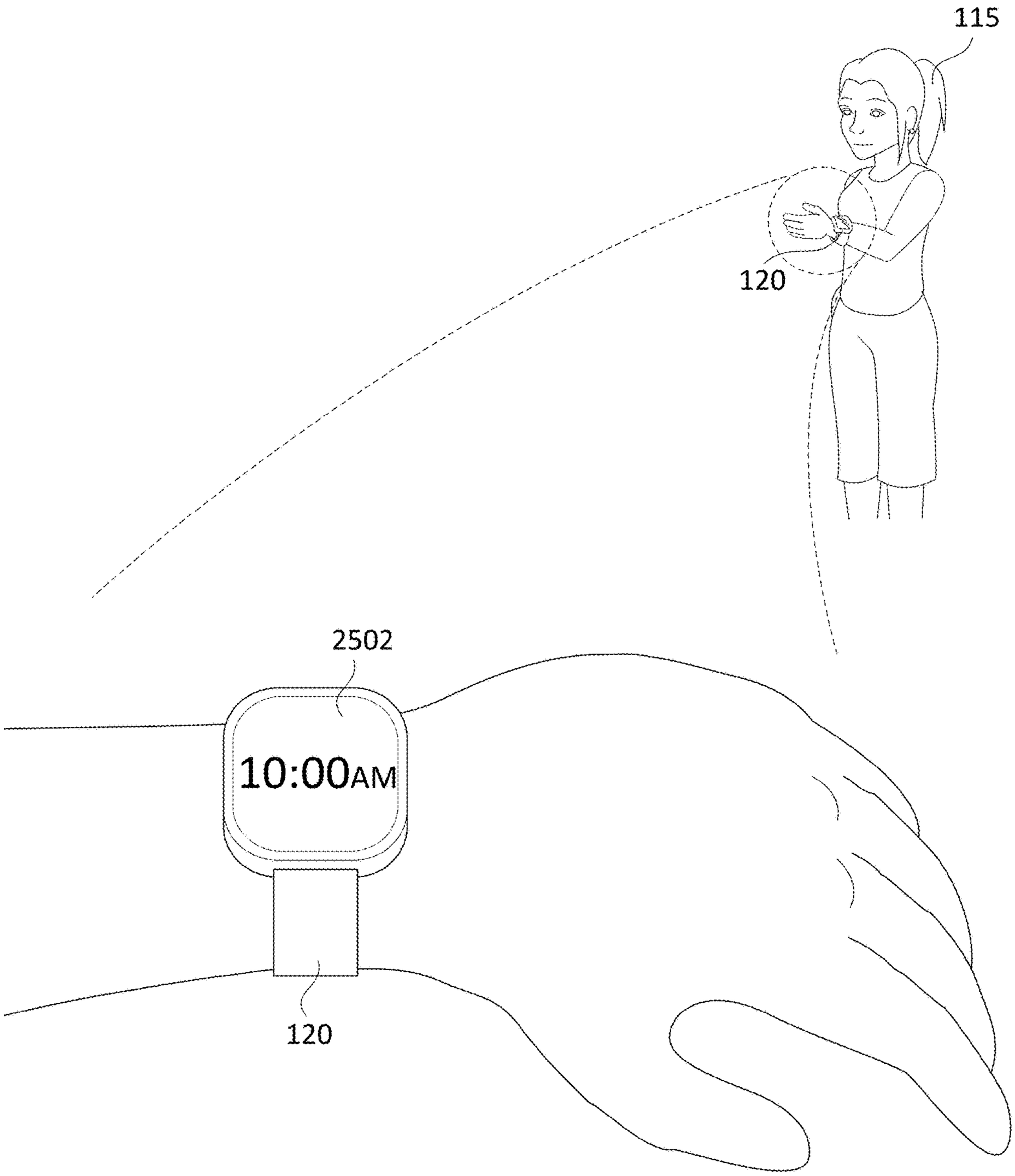


FIG. 20A

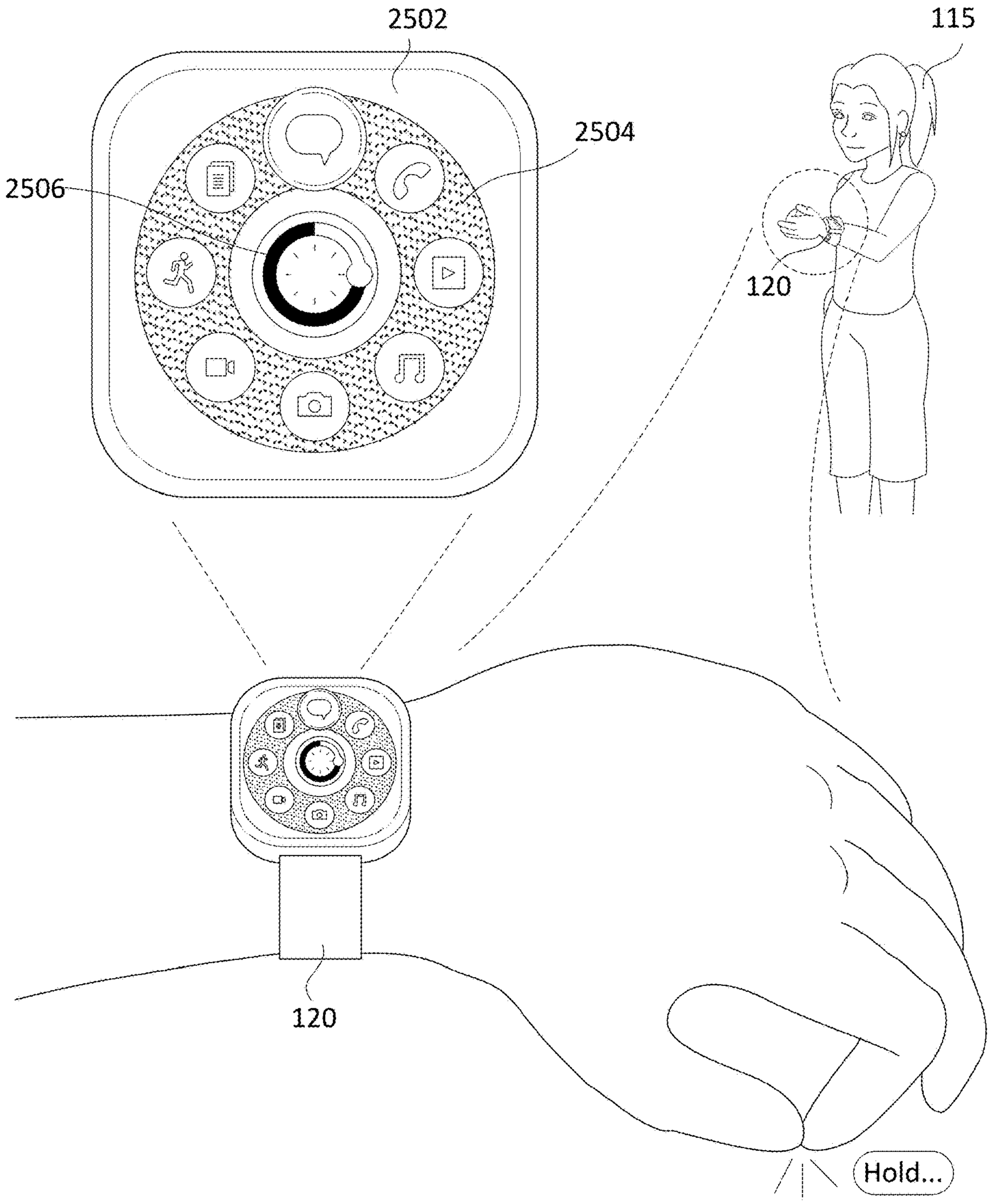


FIG. 20B

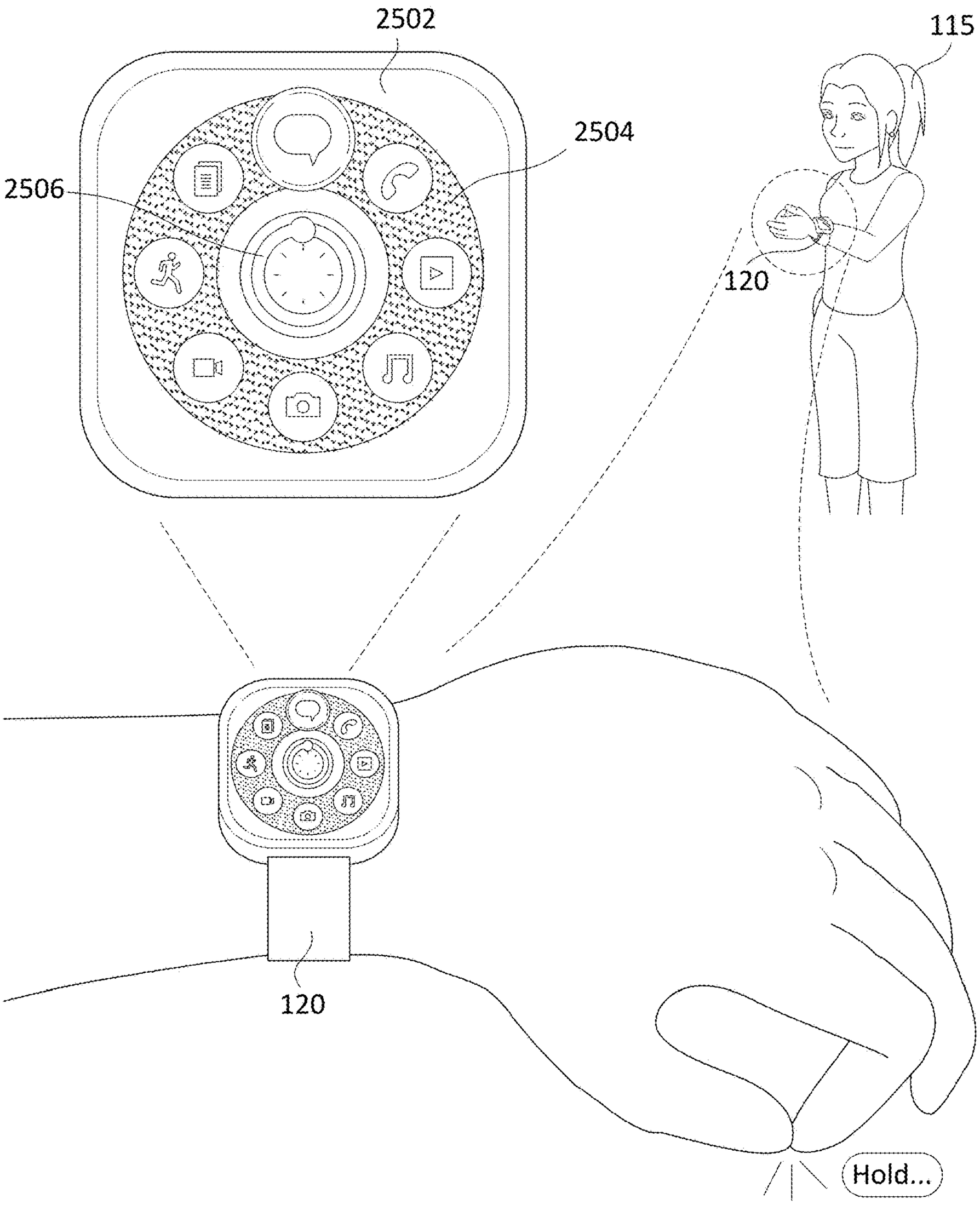


FIG. 20C

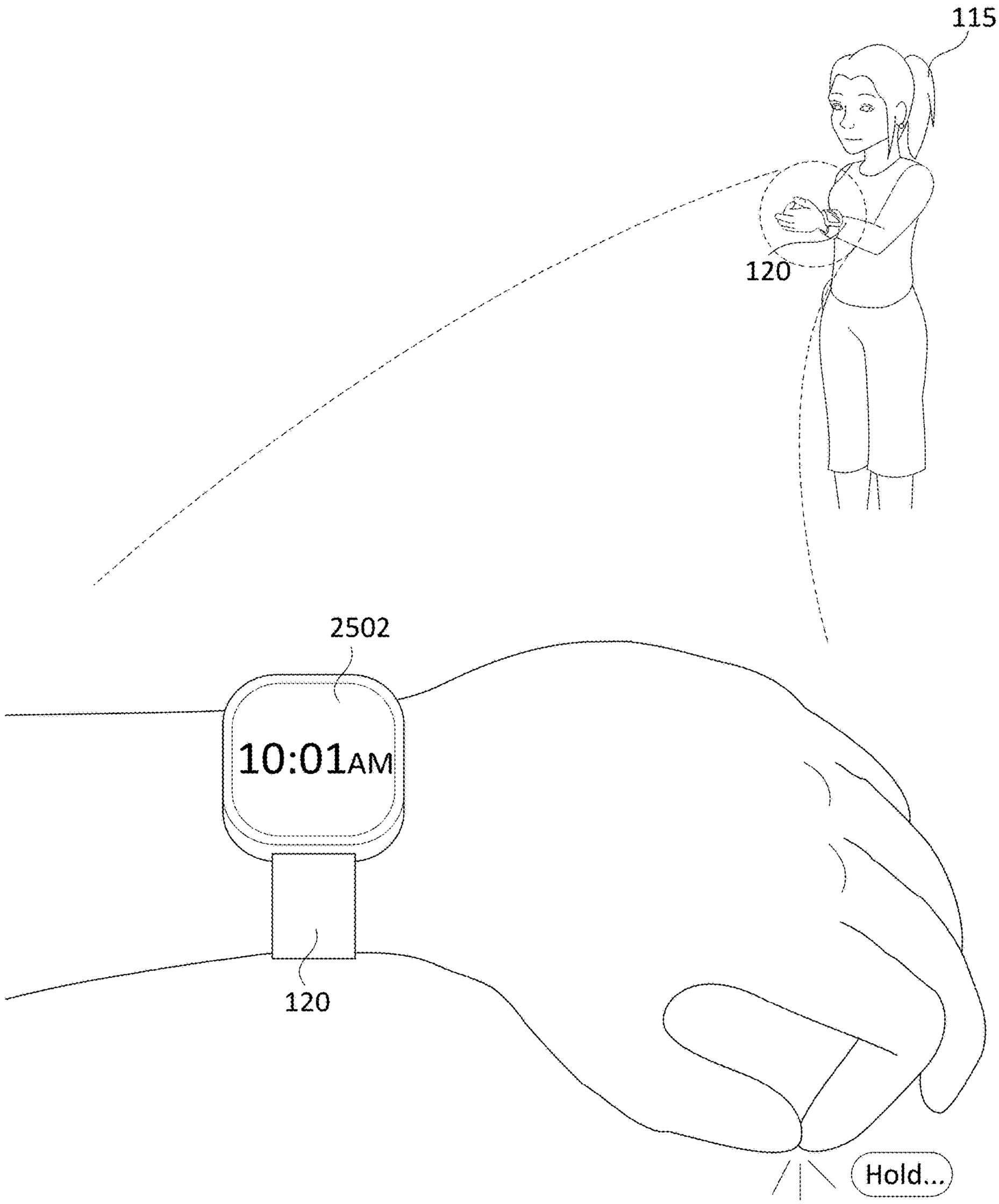


FIG. 20D

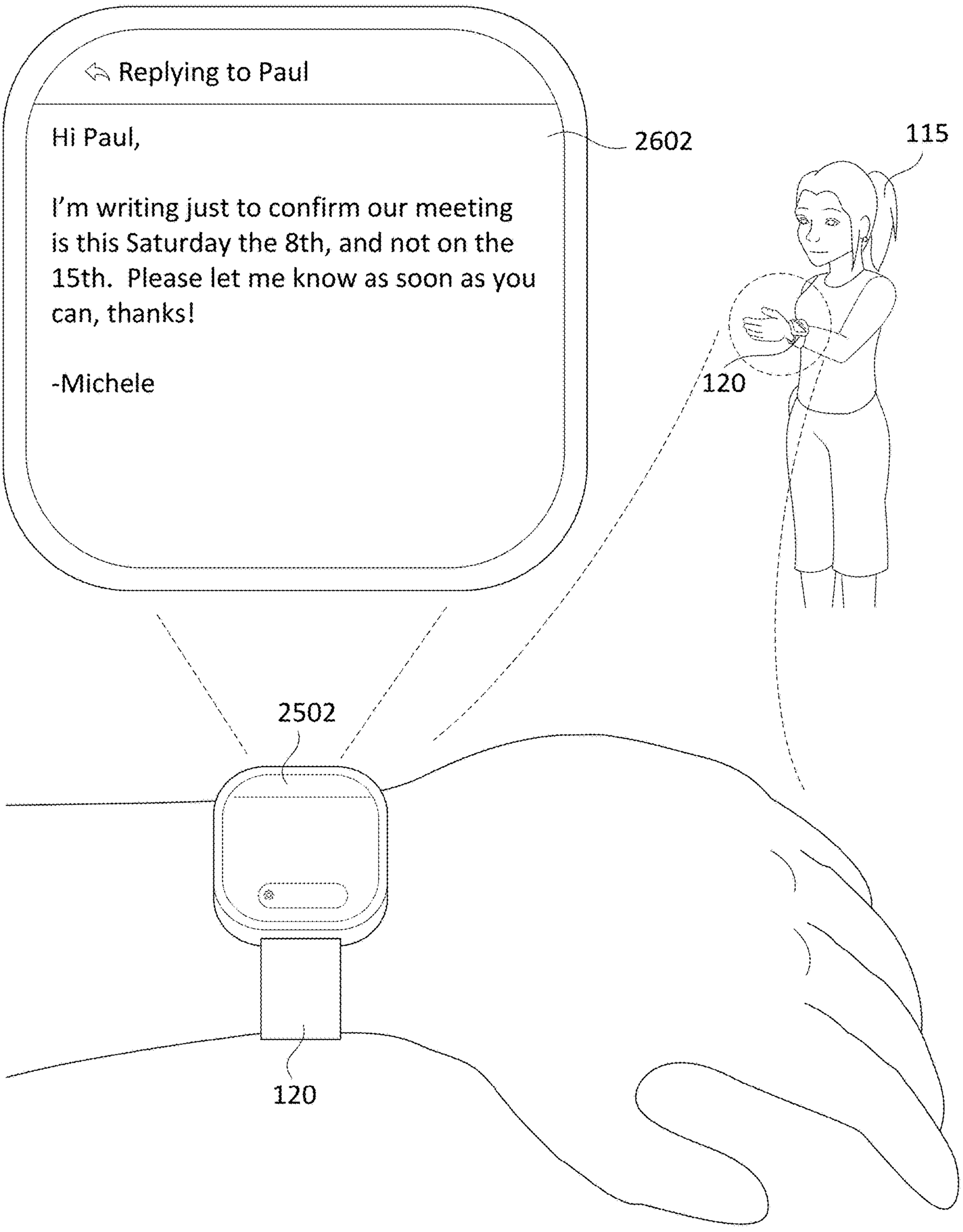

Replying to Paul
Hi Paul,
I'm writing just to confirm our meeting is this Saturday the 8th, and not on the 15th. Please let me know as soon as you can, thanks!
-Michele
2602
115
120
2502
120

FIG. 21A

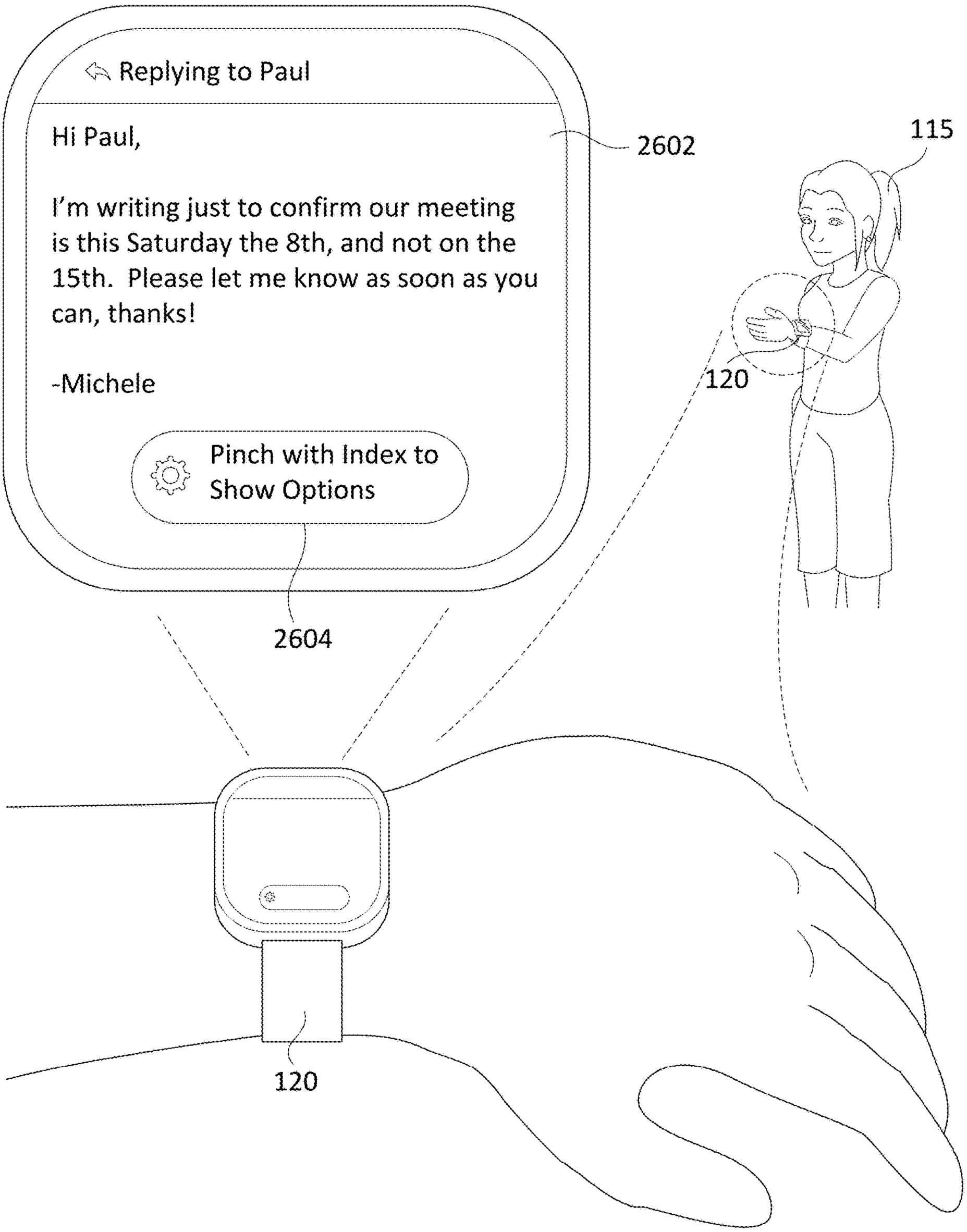

Replying to Paul
Hi Paul,
I'm writing just to confirm our meeting is this Saturday the 8th, and not on the 15th. Please let me know as soon as you can, thanks!
-Michele
Pinch with Index to Show Options
2602
2604
115
120
120

FIG. 21B

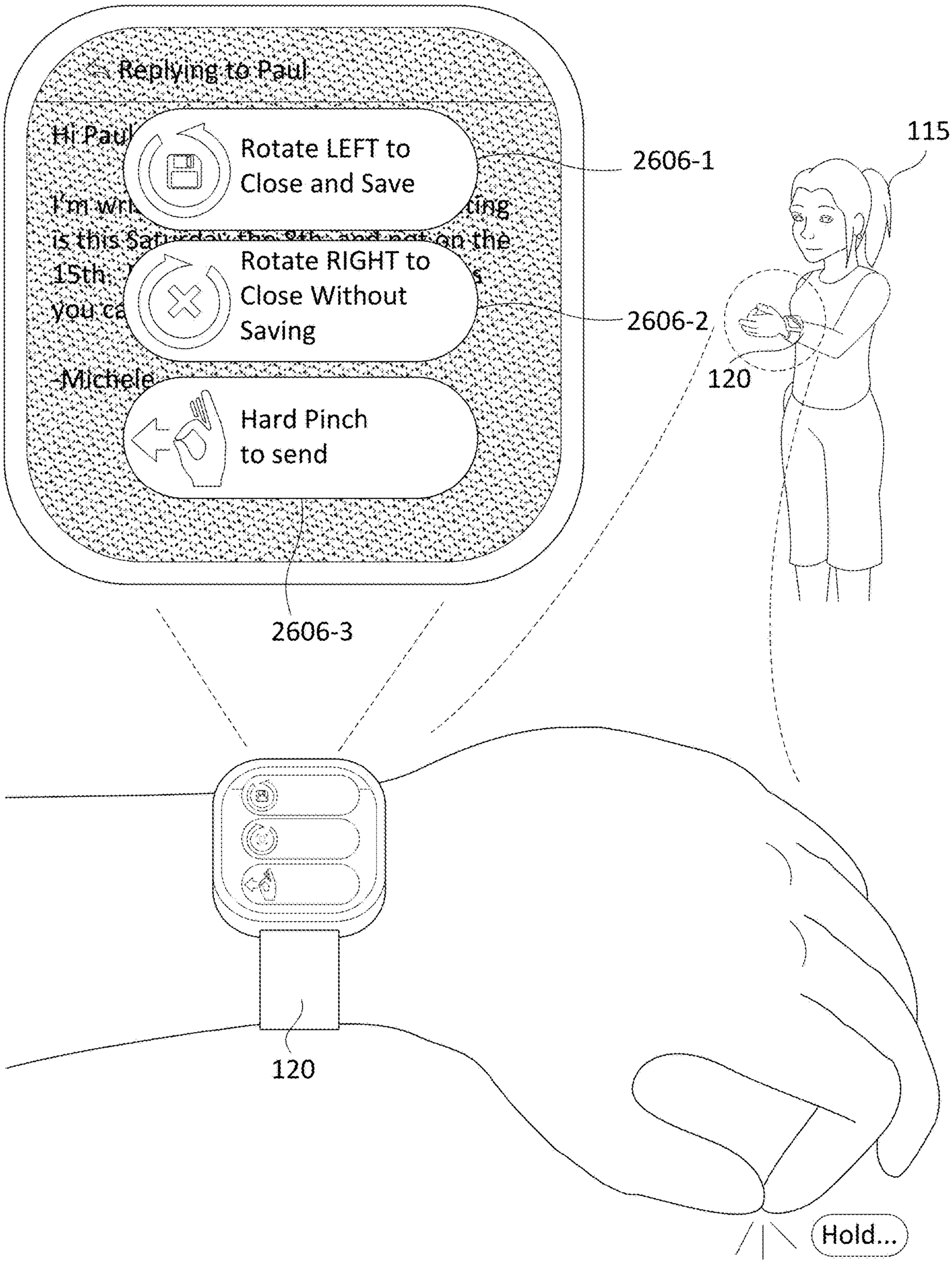

Replying to Paul
Hi Paul
I'm wri ting
is this Sat on the
15th.
you ca s
-Michele
Rotate LEFT to Close and Save
Rotate RIGHT to Close Without Saving
Hard Pinch to send
2606-1
2606-2
2606-3
115
120
120
Hold...

FIG. 21C

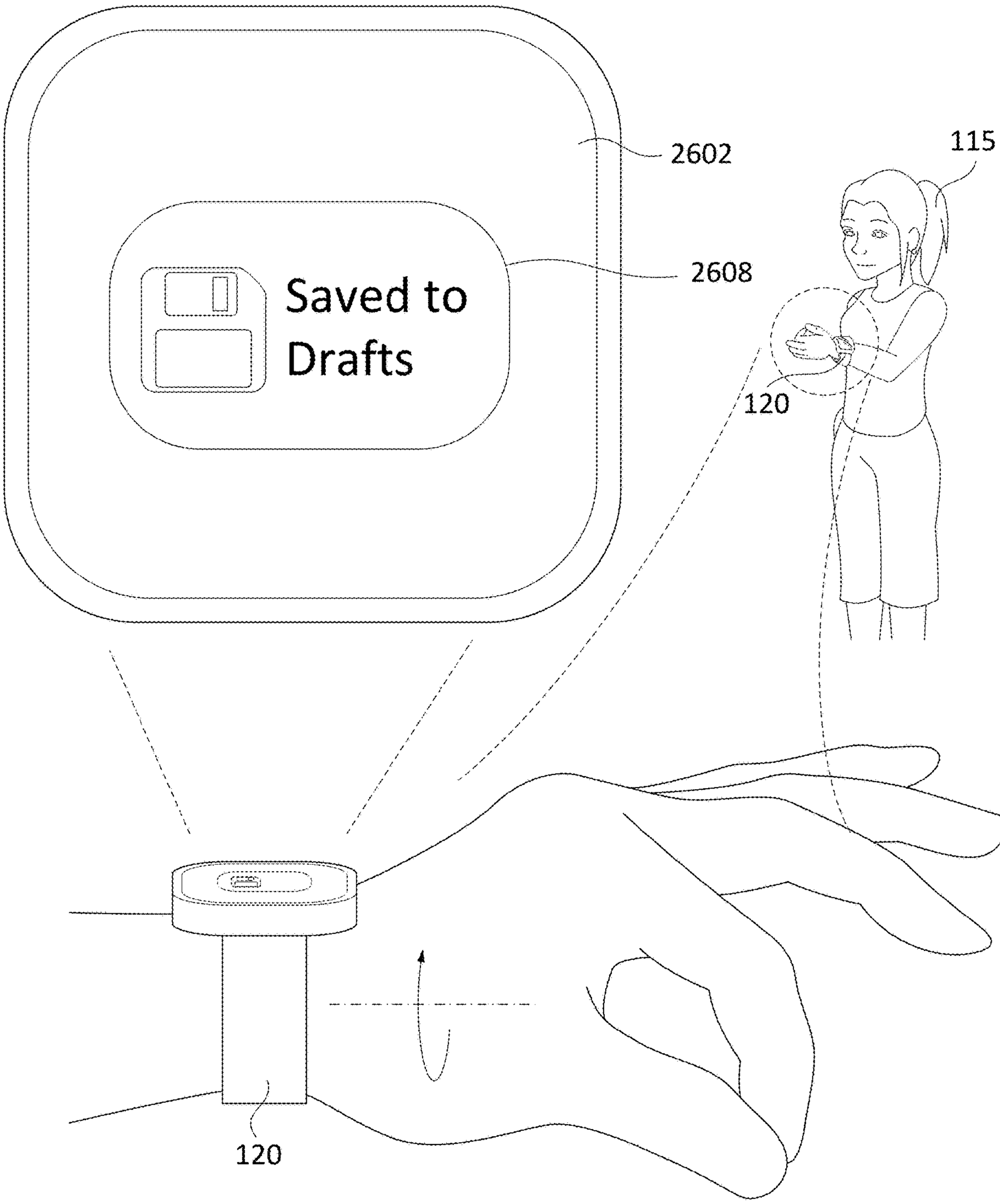


FIG. 21D

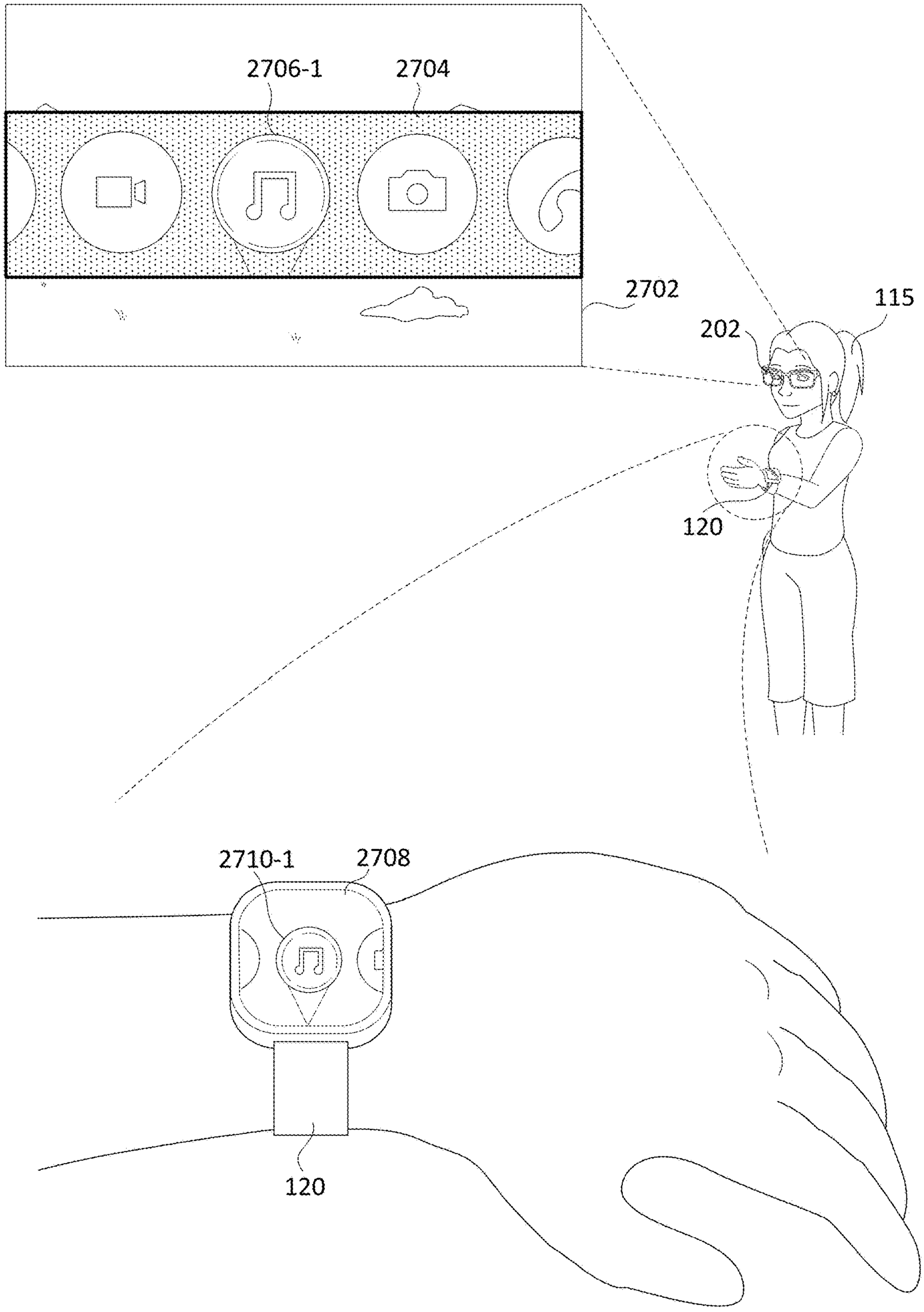


FIG. 22A

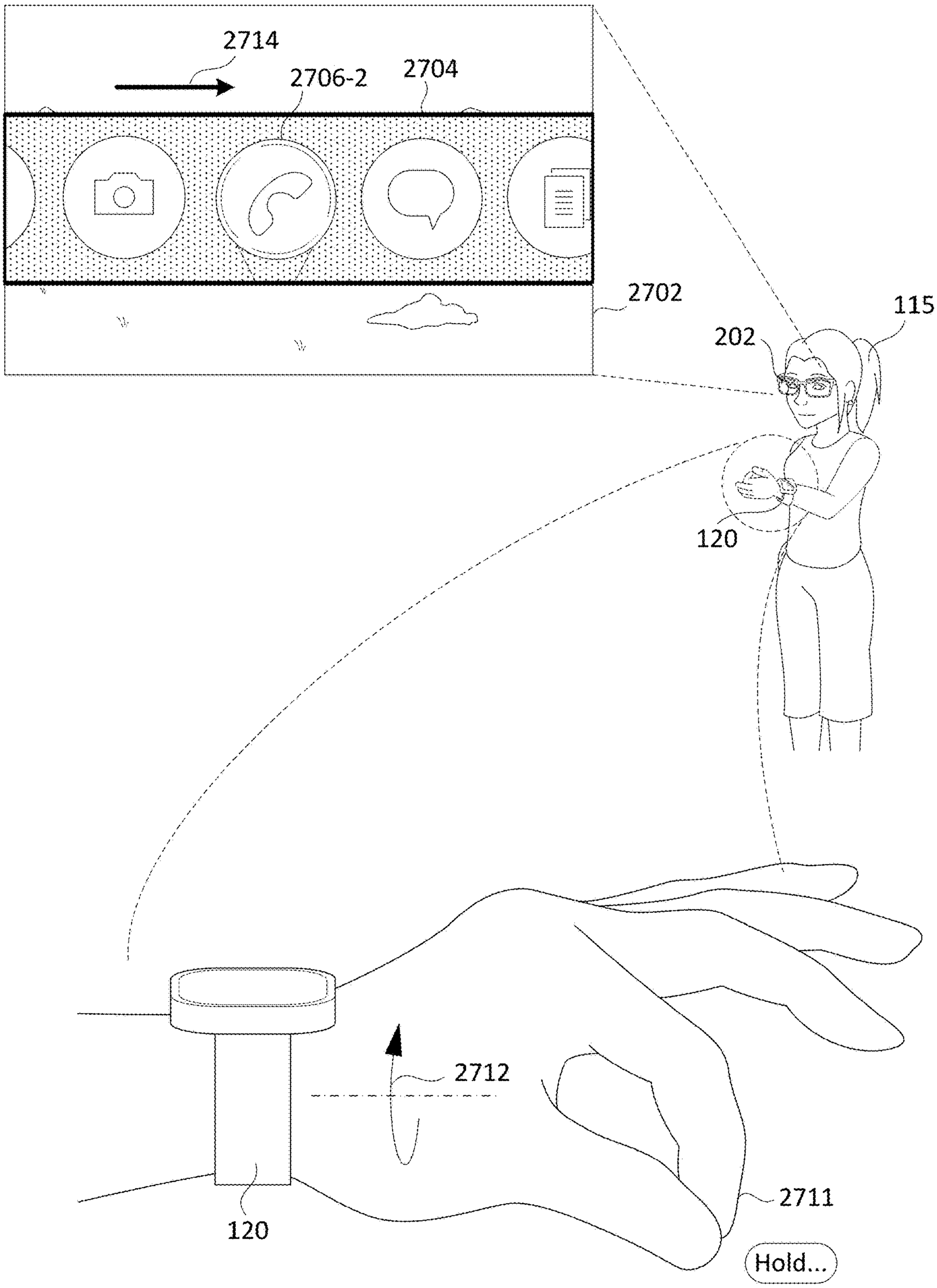


FIG. 22B

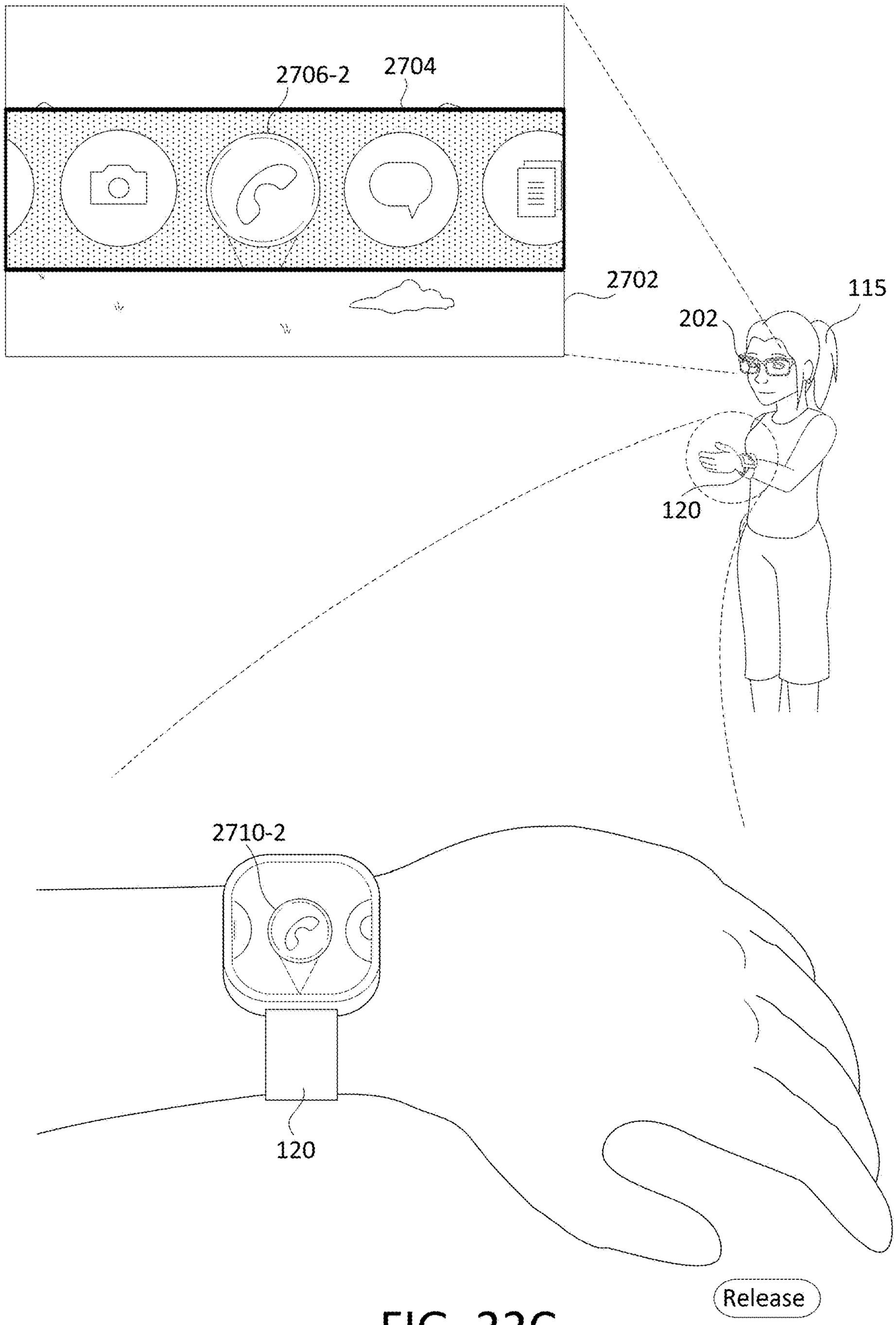


FIG. 22C

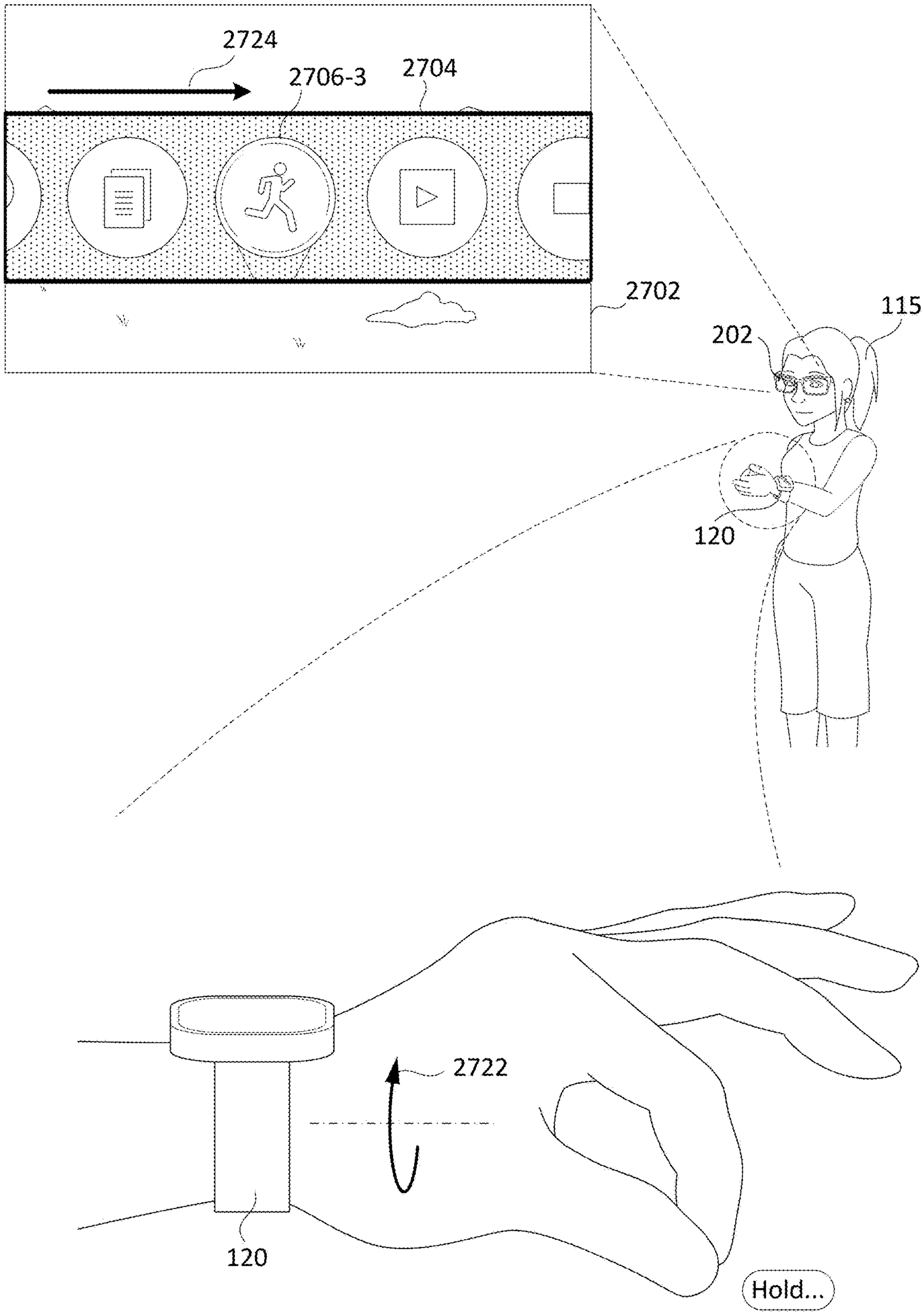


FIG. 22D

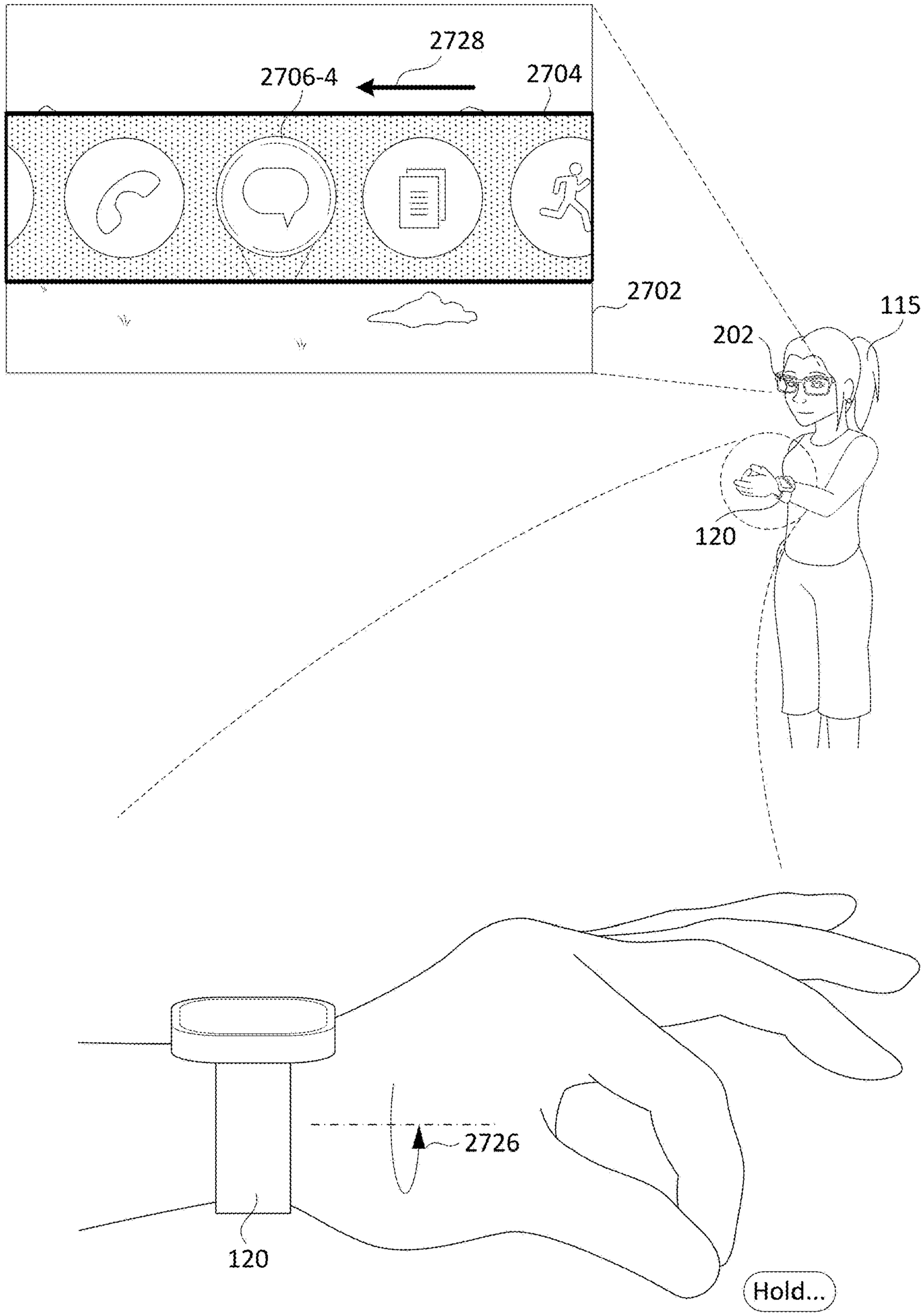


FIG. 22E

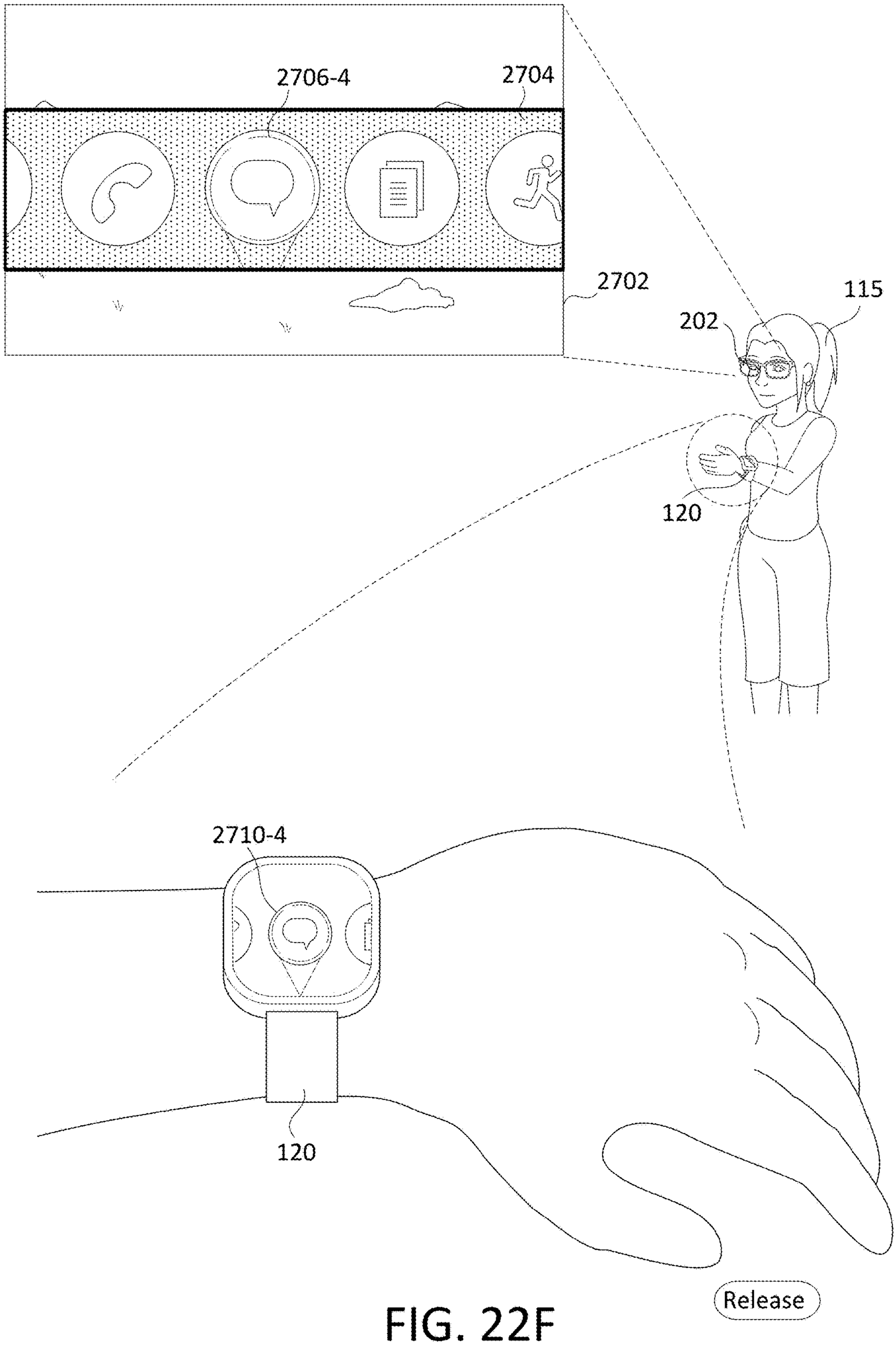


FIG. 22F

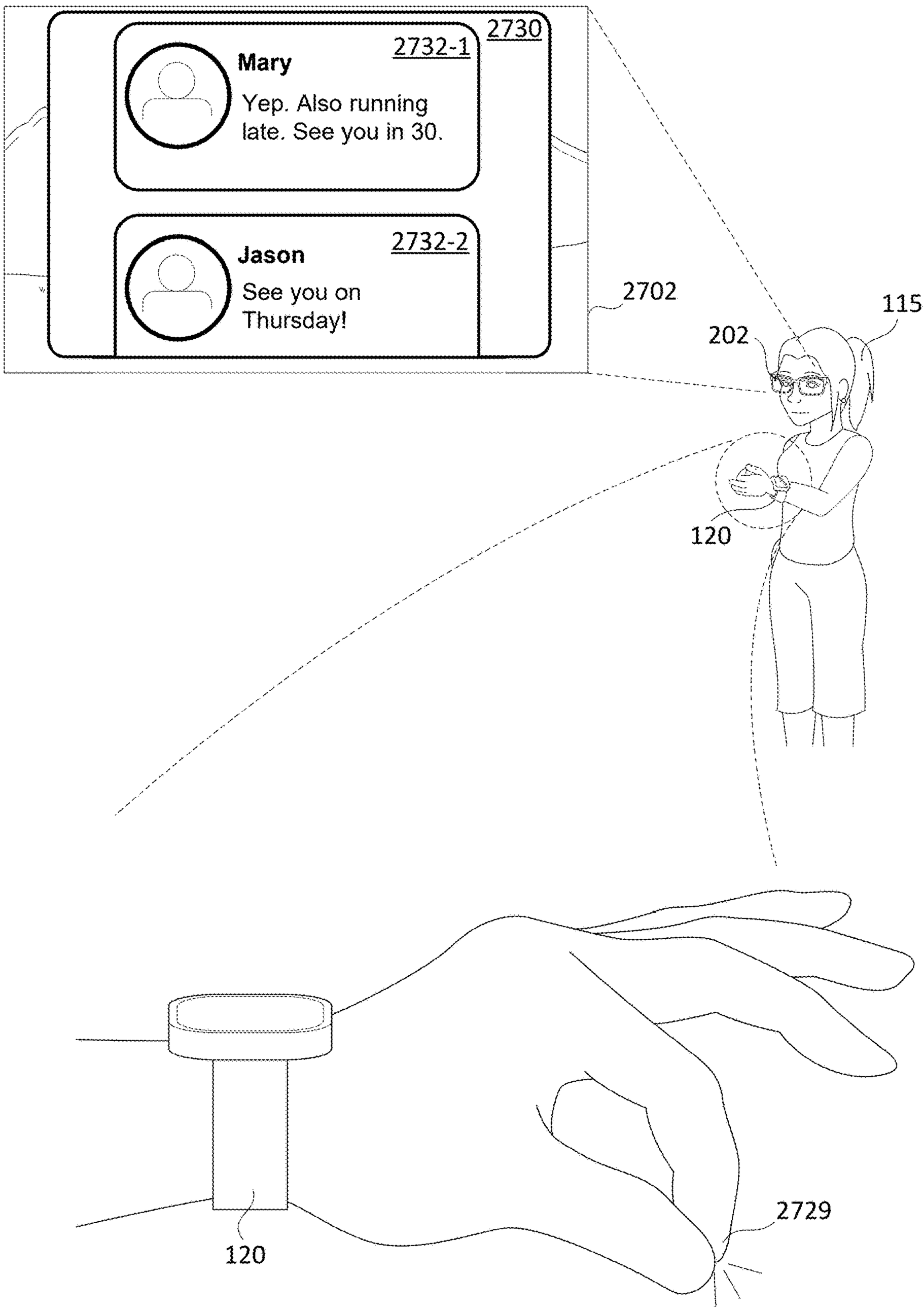

2730
2732-1
Mary
Yep. Also running late. See you in 30.
2732-2
Jason
See you on Thursday!
2702
115
202
120
120
2729

FIG. 22G

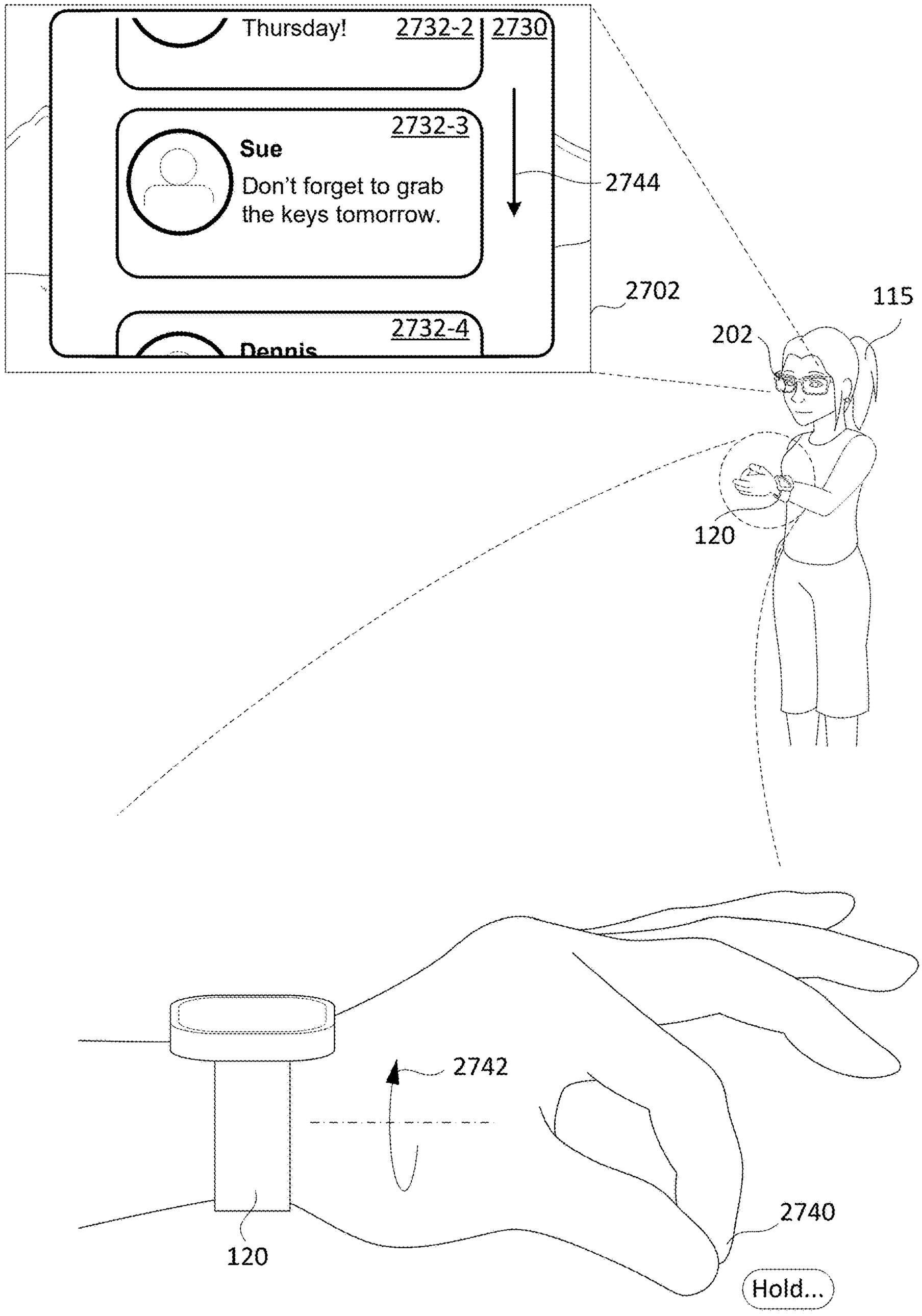

Thursday!
2732-2
2730
2732-3
Sue
Don't forget to grab the keys tomorrow.
2744
2702
2732-4
Dennis
115
202
120
2742
2740
Hold...
120

FIG. 22H

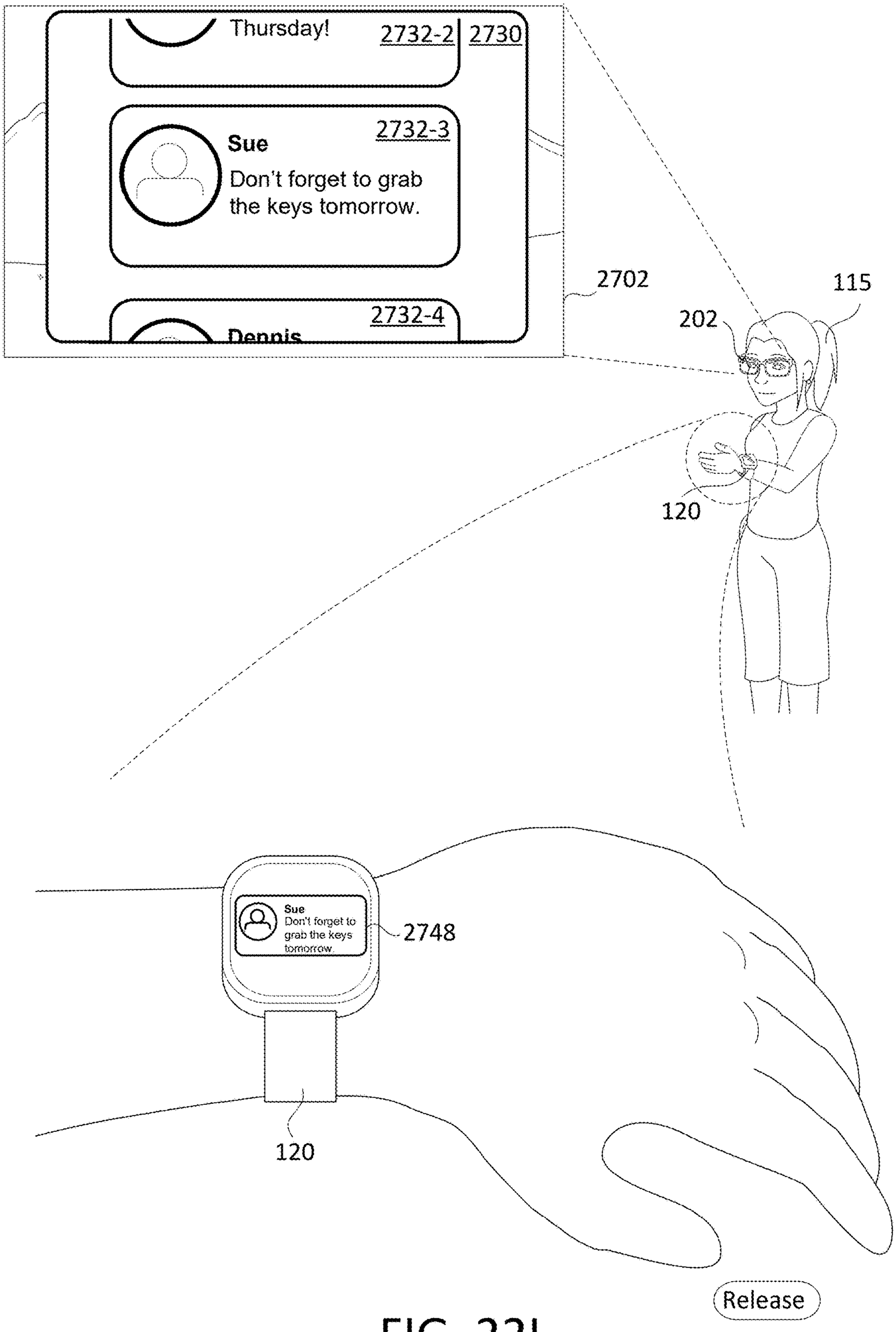

Thursday!
2732-2
2730
2732-3
Sue
Don't forget to grab the keys tomorrow.
2732-4
Dennis
2702
115
202
120
Sue
Don't forget to grab the keys tomorrow.
2748
120
Release

FIG. 22I

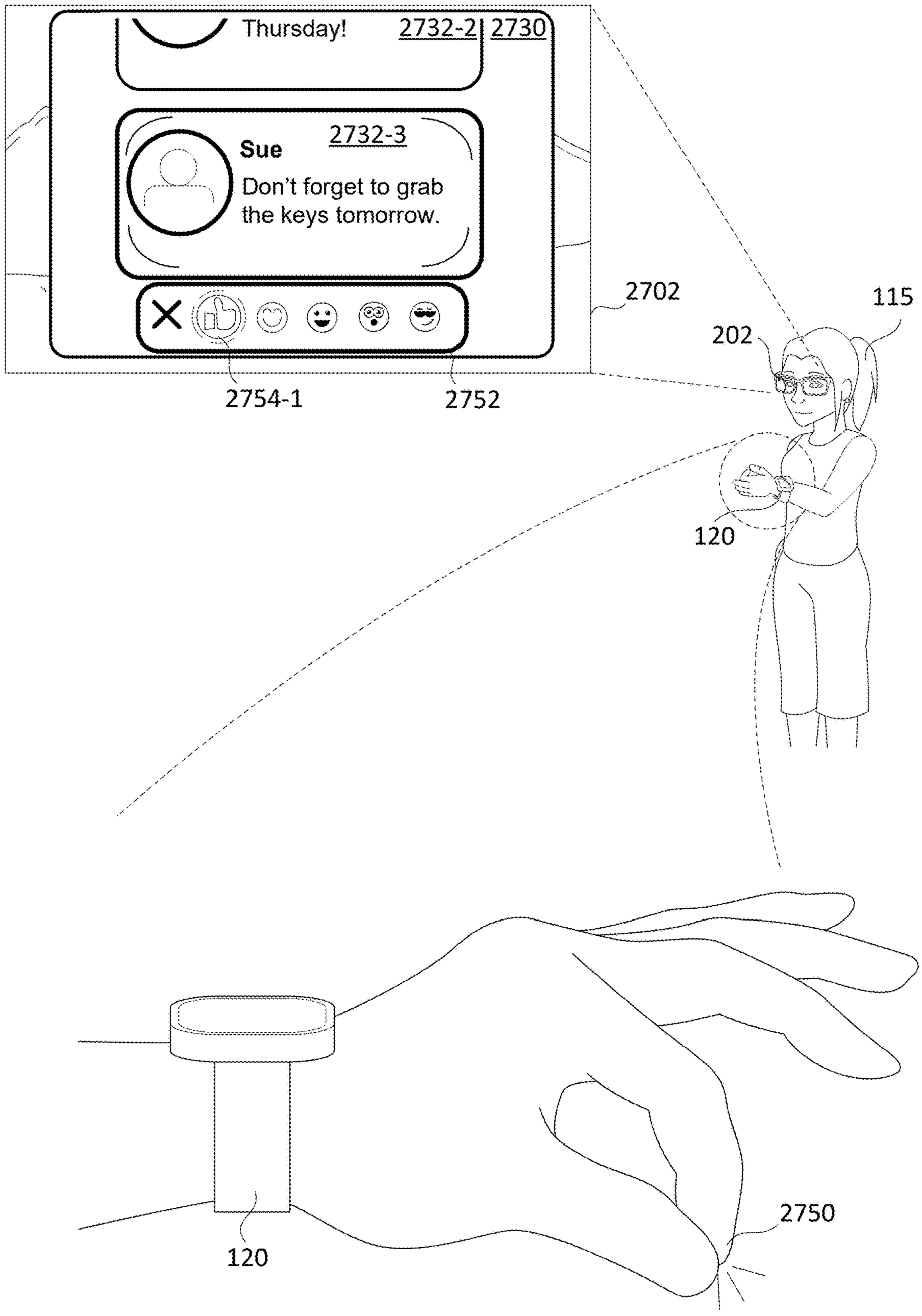

Thursday!
2732-2
2730
Sue
2732-3
Don't forget to grab the keys tomorrow.
2702
115
202
120
2754-1
2752
2750
120

FIG. 22J

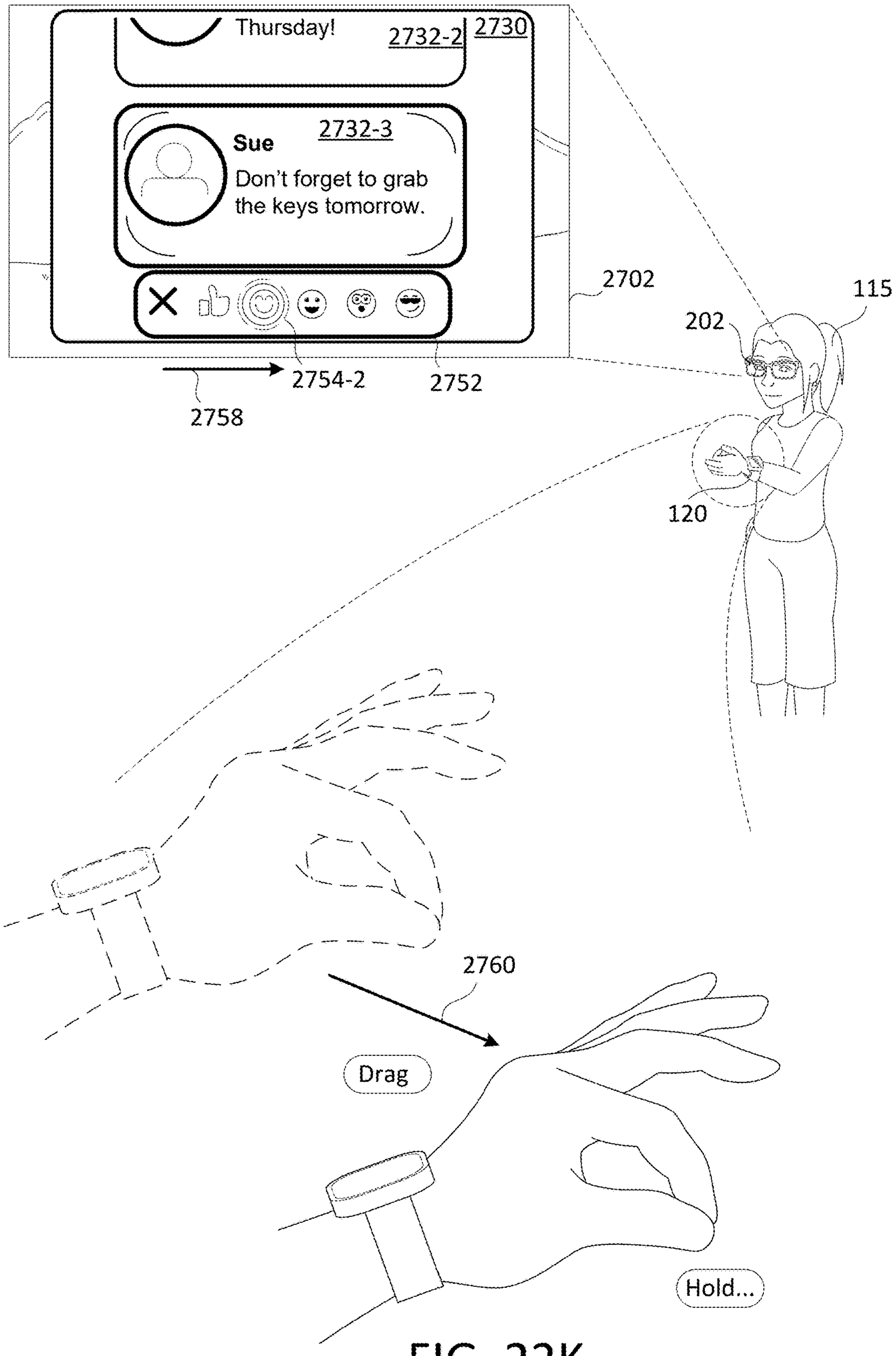

Thursday!
2732-2
2730
2732-3
Sue
Don't forget to grab the keys tomorrow.
2702
115
202
2754-2
2752
2758
120
2760
Drag
Hold...

FIG. 22K

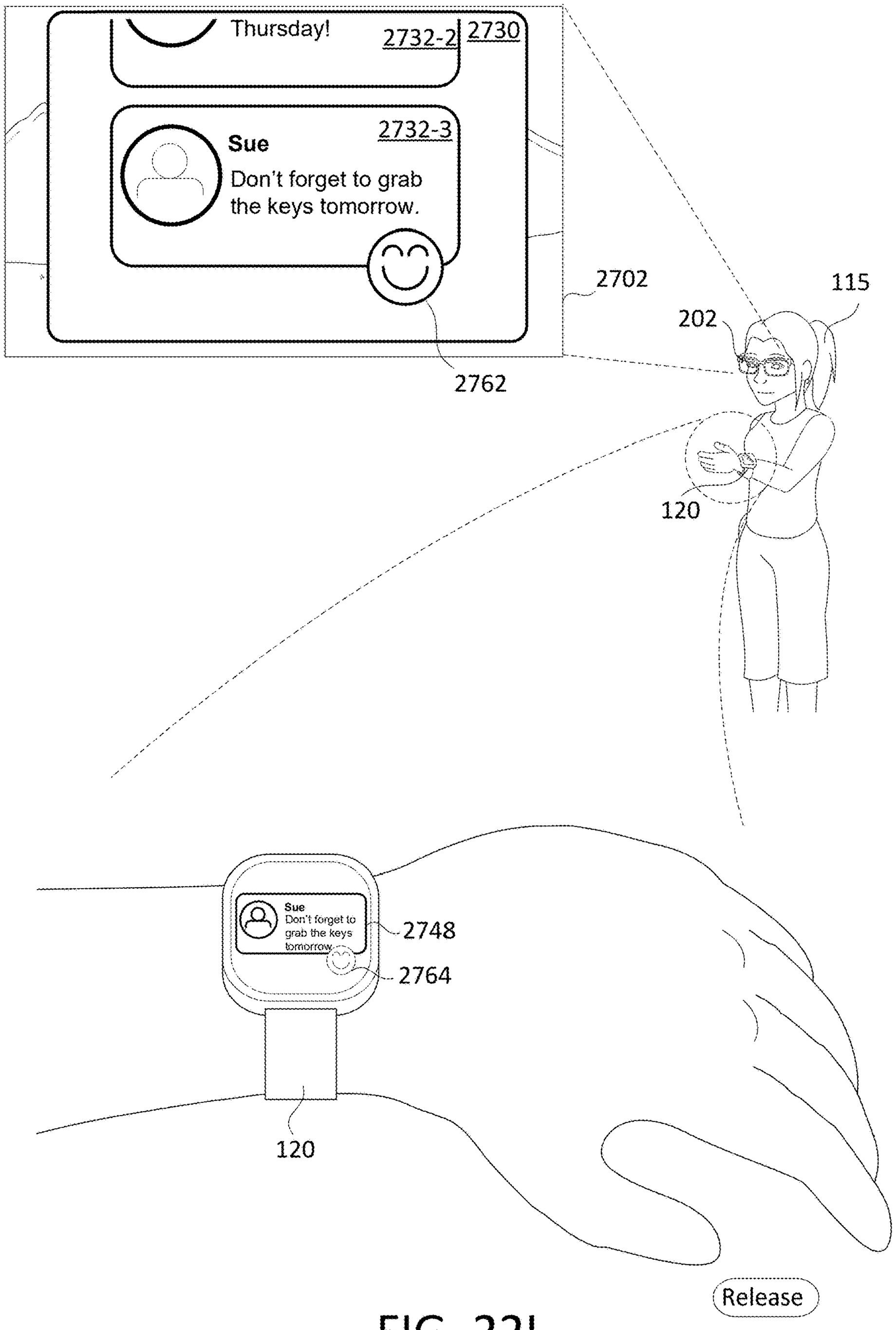

Thursday!
2732-2
2730
2732-3
Sue
Don't forget to grab the keys tomorrow.
2702
115
202
2762
120
Sue
Don't forget to grab the keys tomorrow.
2748
2764
120
Release

FIG. 22L

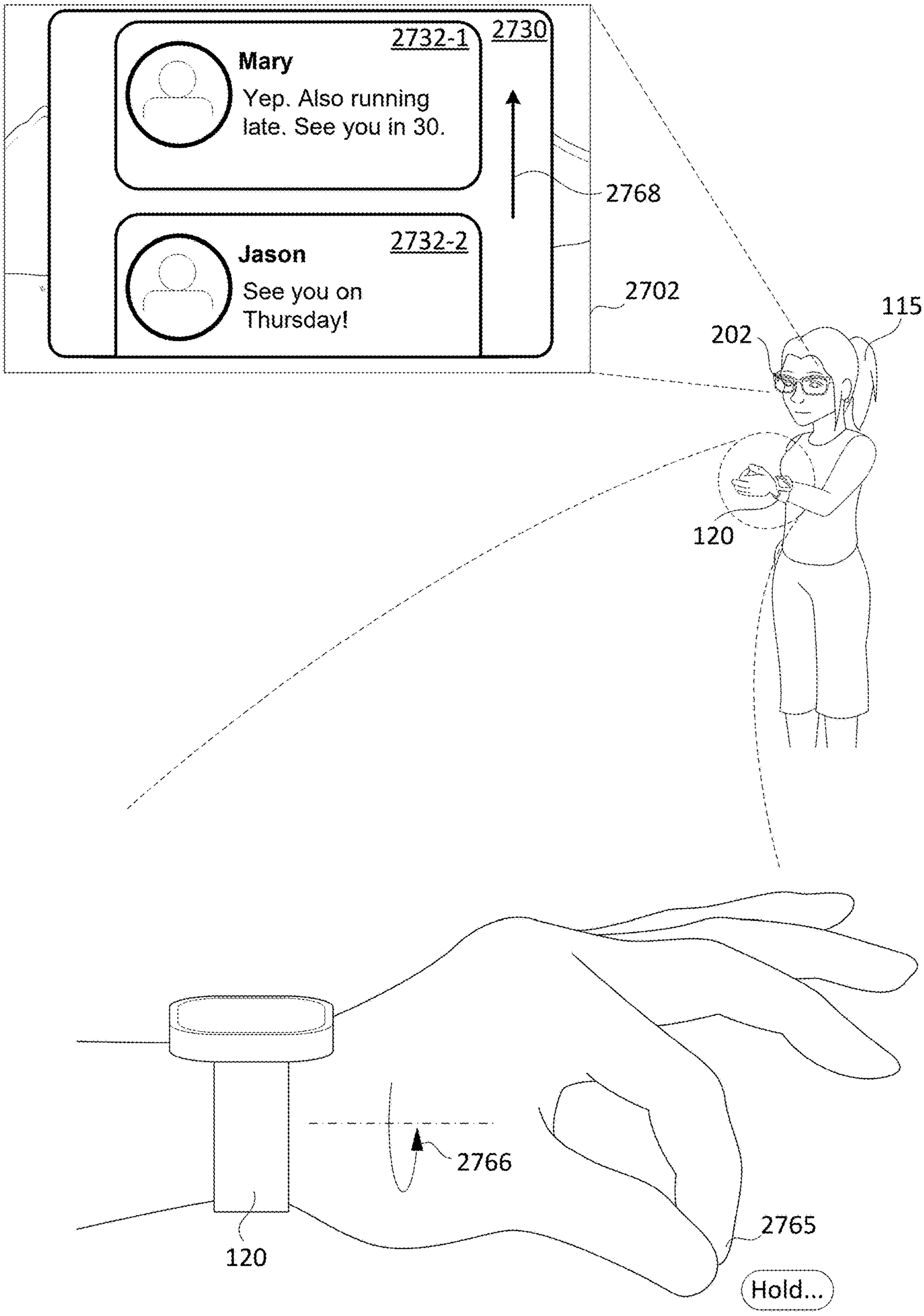

2732-1
2730
Mary
Yep. Also running late. See you in 30.
2732-2
Jason
See you on Thursday!
2768
2702
115
202
120
2766
2765
Hold...
120

FIG. 22M

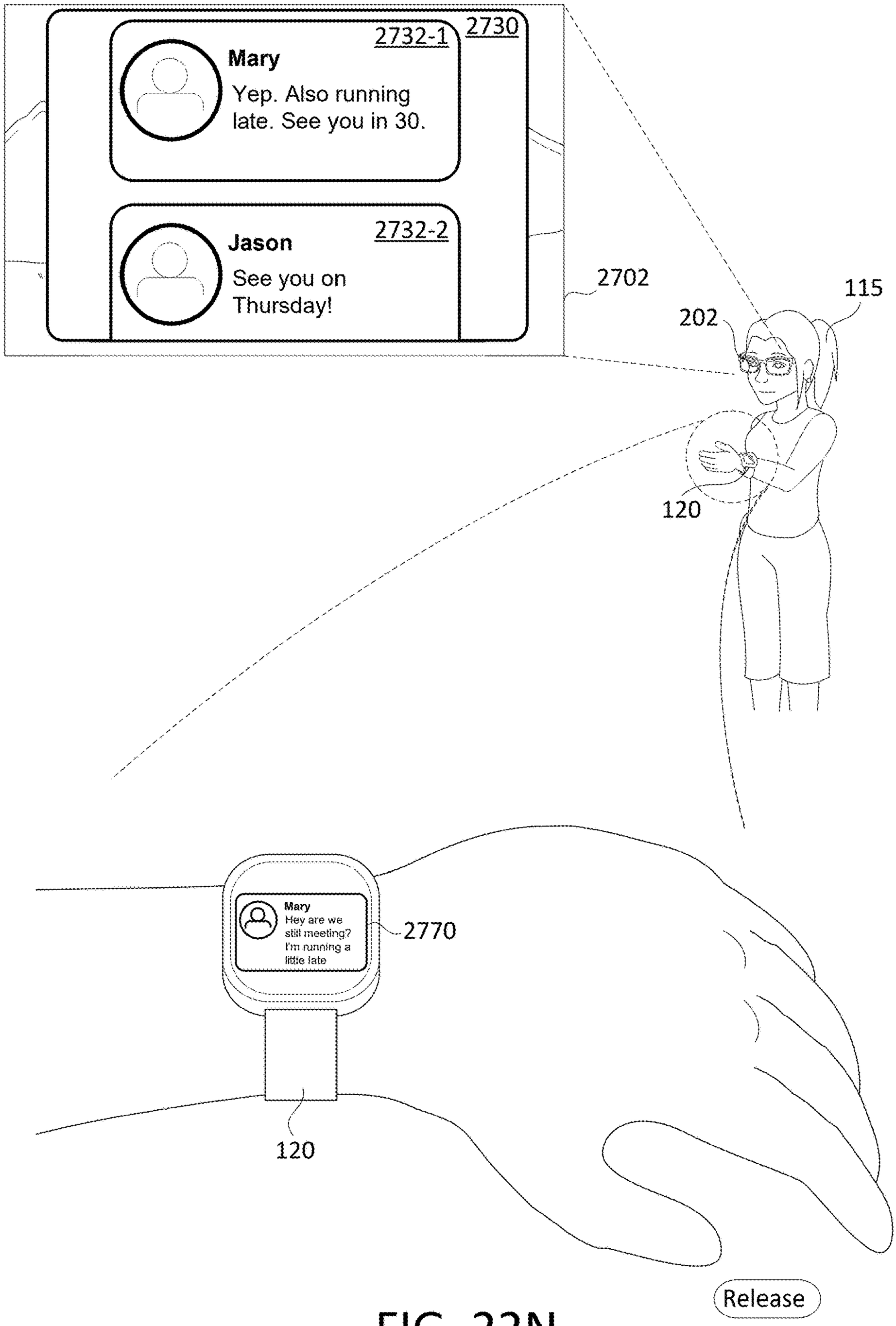

2730
2732-1
Mary
Yep. Also running late. See you in 30.
2732-2
Jason
See you on Thursday!
2702
115
202
120
Mary
Hey are we still meeting? I'm running a little late
2770
120
Release

FIG. 22N

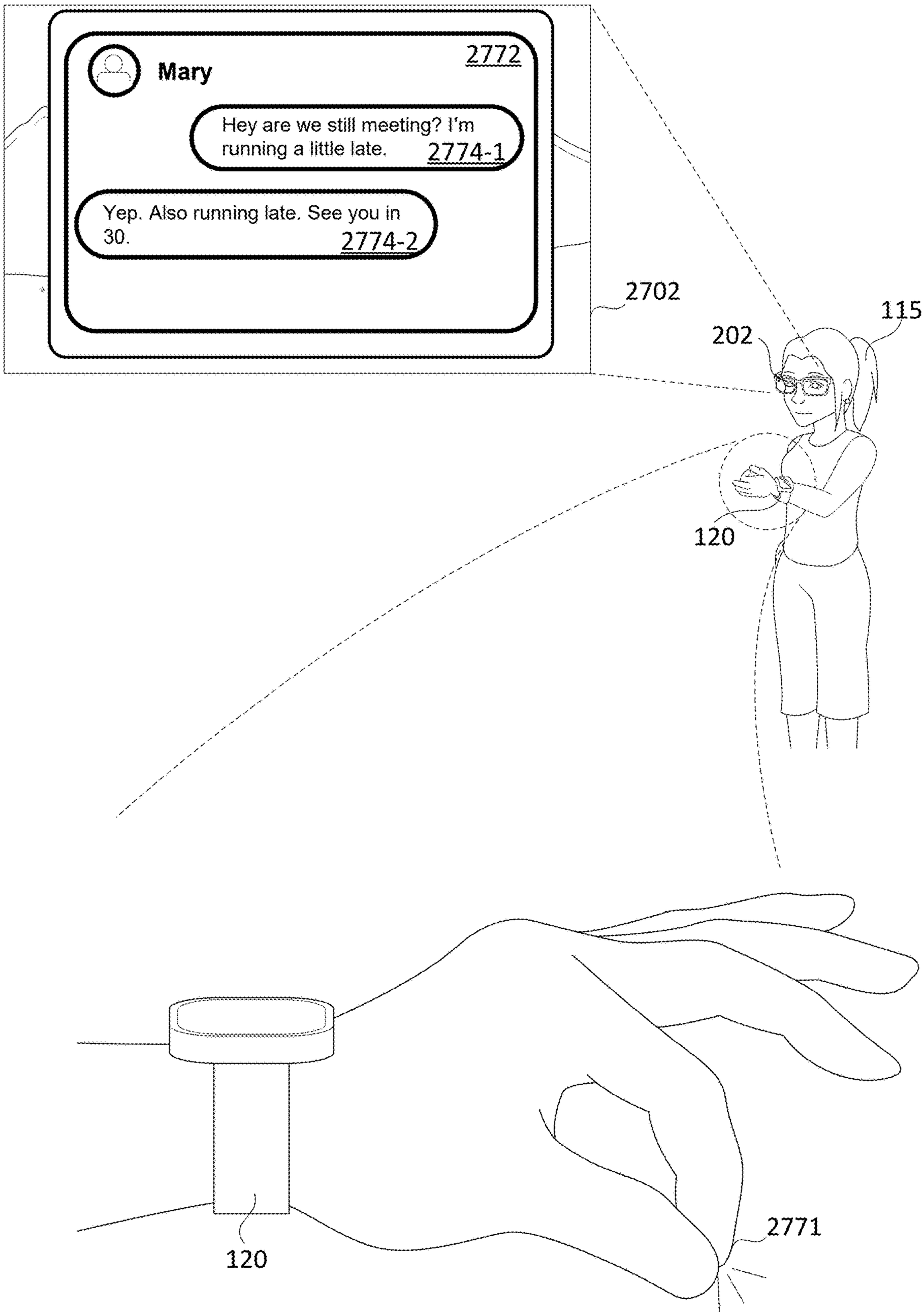

Mary
2772
Hey are we still meeting? I'm running a little late.
2774-1
Yep. Also running late. See you in 30.
2774-2
2702
115
202
120
120
2771

FIG. 22O

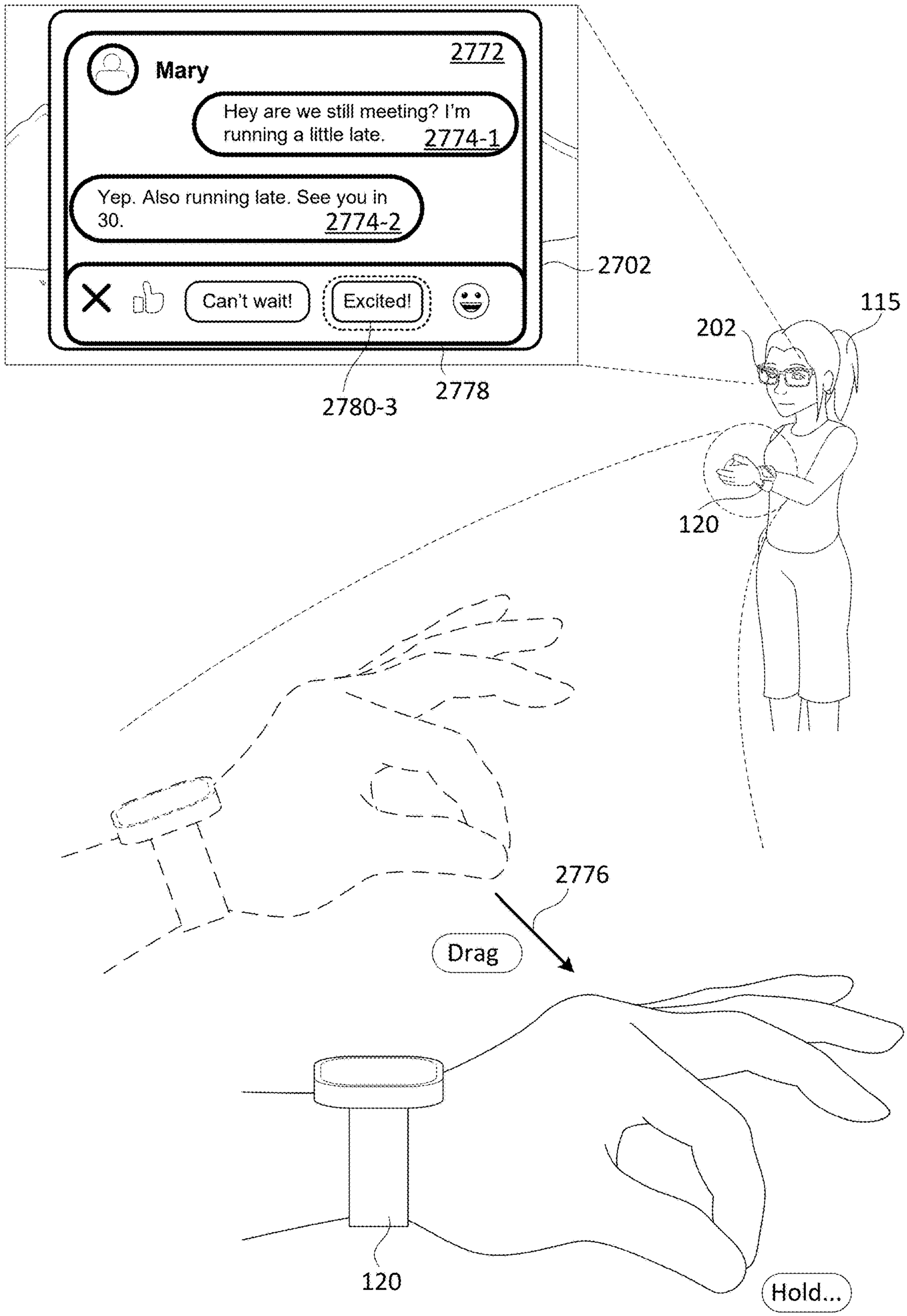

2772
Mary
Hey are we still meeting? I'm running a little late.
2774-1
Yep. Also running late. See you in 30.
2774-2
Can't wait!
Excited!
2702
115
202
120
2780-3
2778
2776
Drag
120
Hold...

FIG. 22P

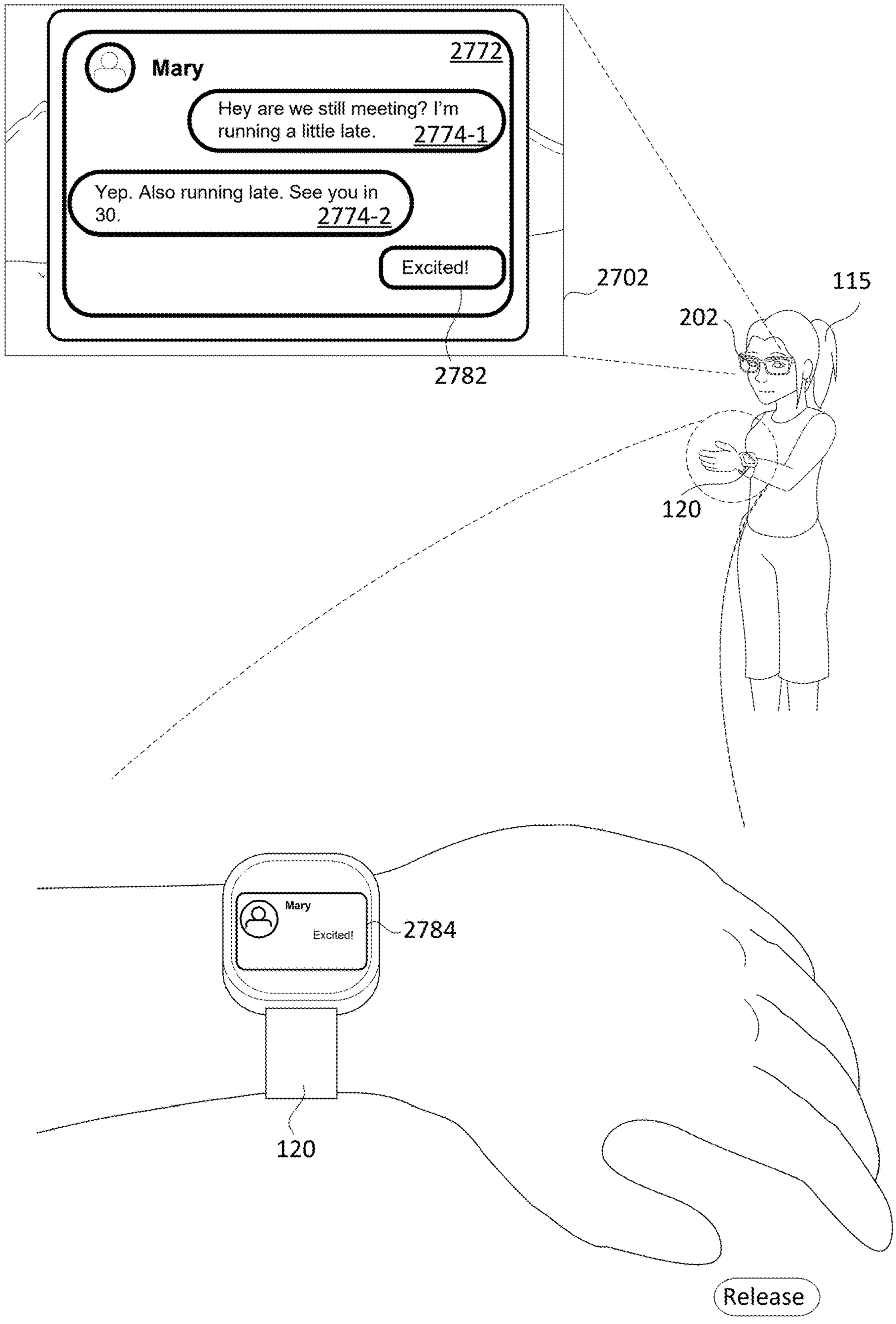

Mary
2772
Hey are we still meeting? I'm running a little late.
2774-1
Yep. Also running late. See you in 30.
2774-2
Excited!
2782
2702
115
202
120
Mary
Excited!
2784
120
Release

FIG. 22Q

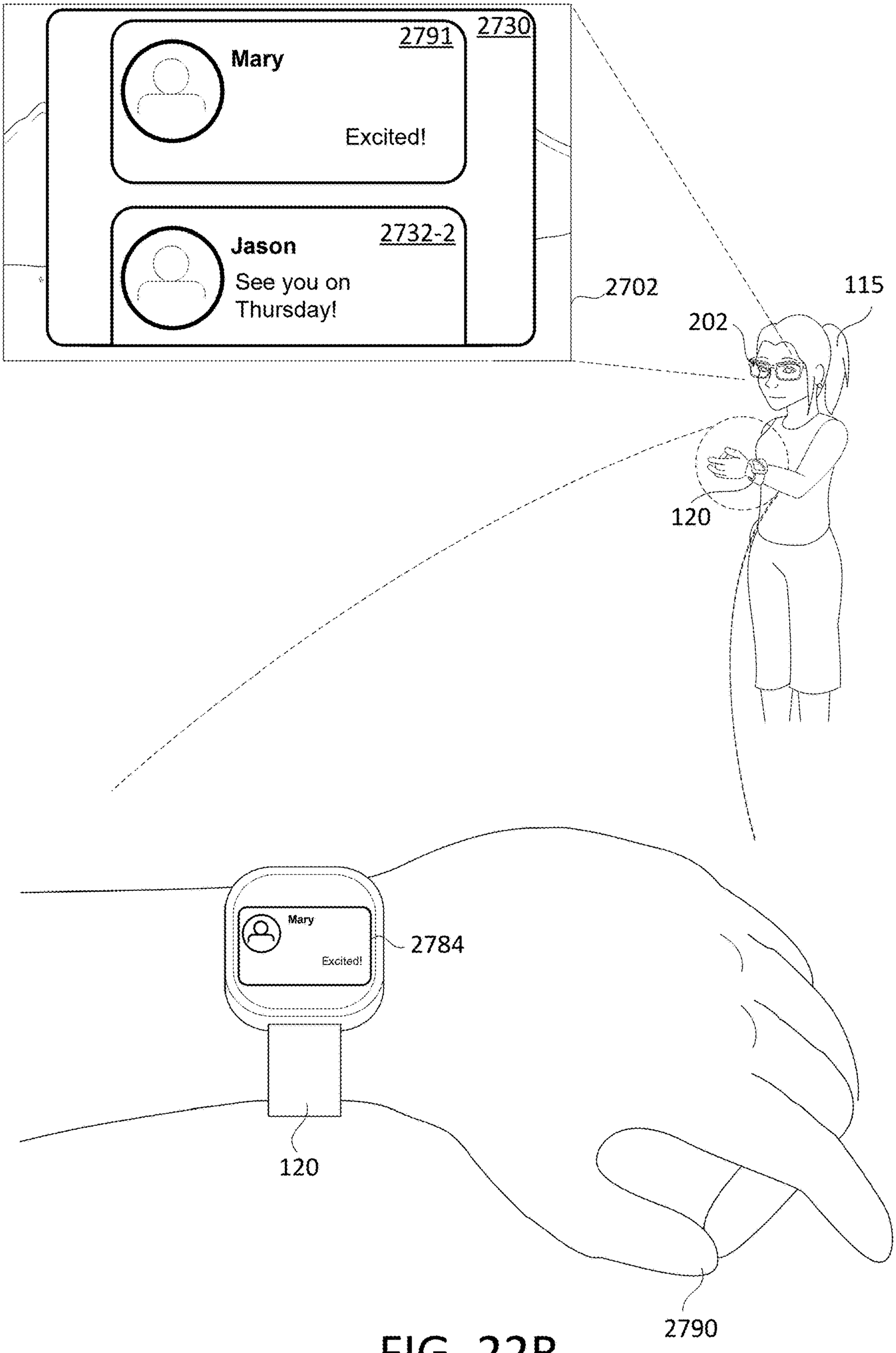

2730
2791
Mary
Excited!
2732-2
Jason
See you on Thursday!
2702
115
202
120
Mary
Excited!
2784
120
2790

FIG. 22R

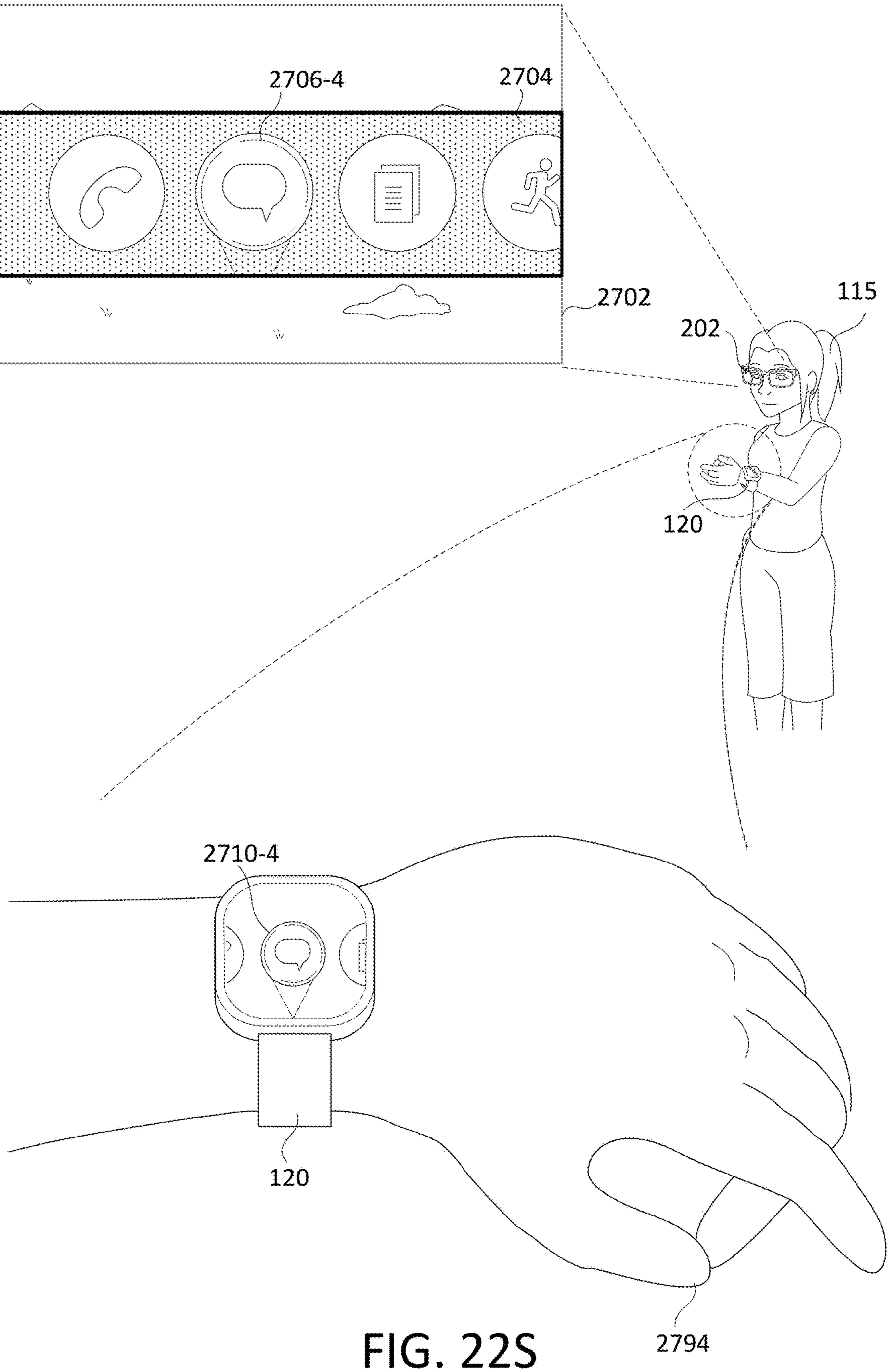


FIG. 22S

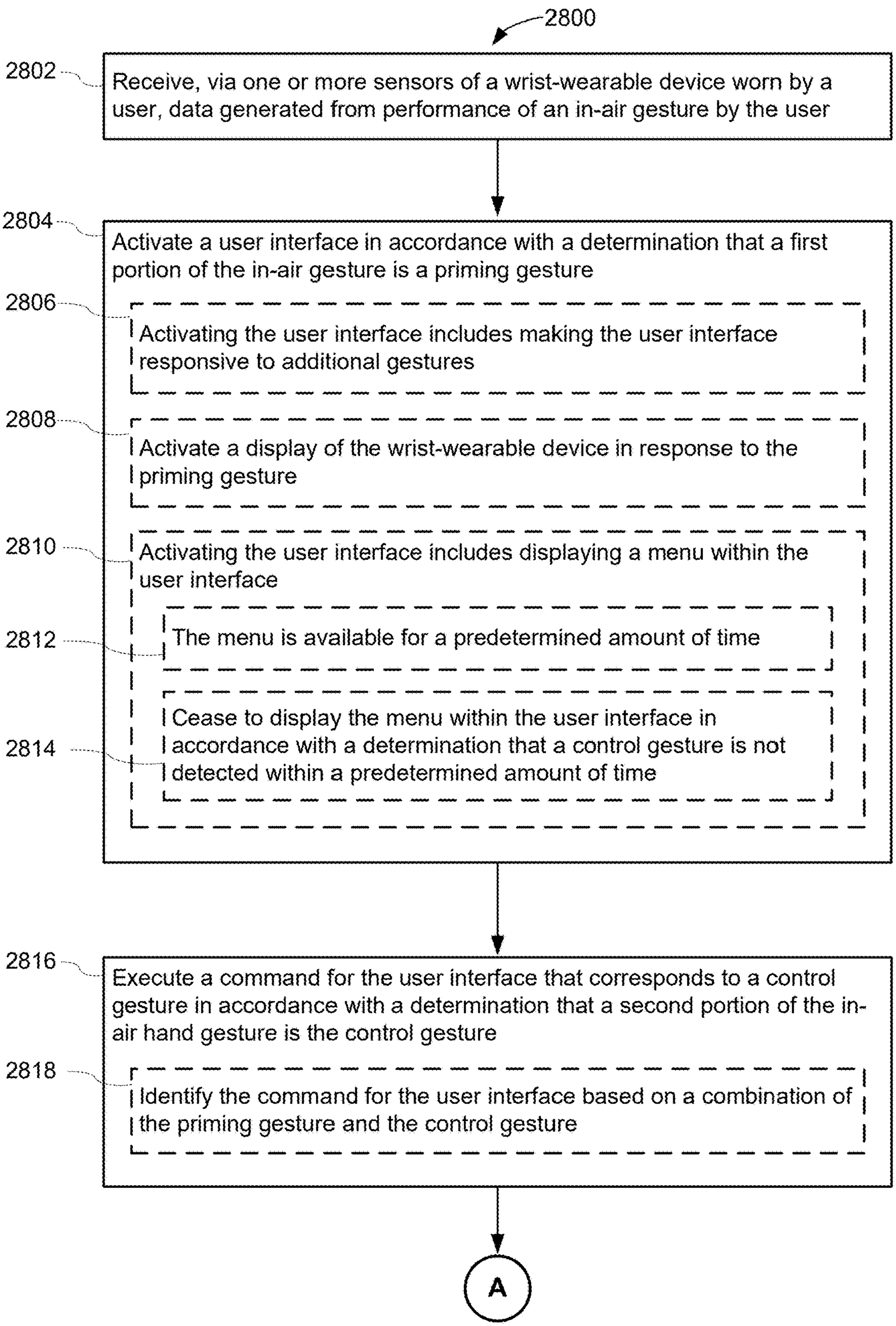

2800
2802
Receive, via one or more sensors of a wrist-wearable device worn by a user, data generated from performance of an in-air gesture by the user
2804
Activate a user interface in accordance with a determination that a first portion of the in-air gesture is a priming gesture
2806
Activating the user interface includes making the user interface responsive to additional gestures
2808
Activate a display of the wrist-wearable device in response to the priming gesture
2810
Activating the user interface includes displaying a menu within the user interface
2812
The menu is available for a predetermined amount of time
2814
Cease to display the menu within the user interface in accordance with a determination that a control gesture is not detected within a predetermined amount of time
2816
Execute a command for the user interface that corresponds to a control gesture in accordance with a determination that a second portion of the in-air hand gesture is the control gesture
2818
Identify the command for the user interface based on a combination of the priming gesture and the control gesture
A

FIG. 23A

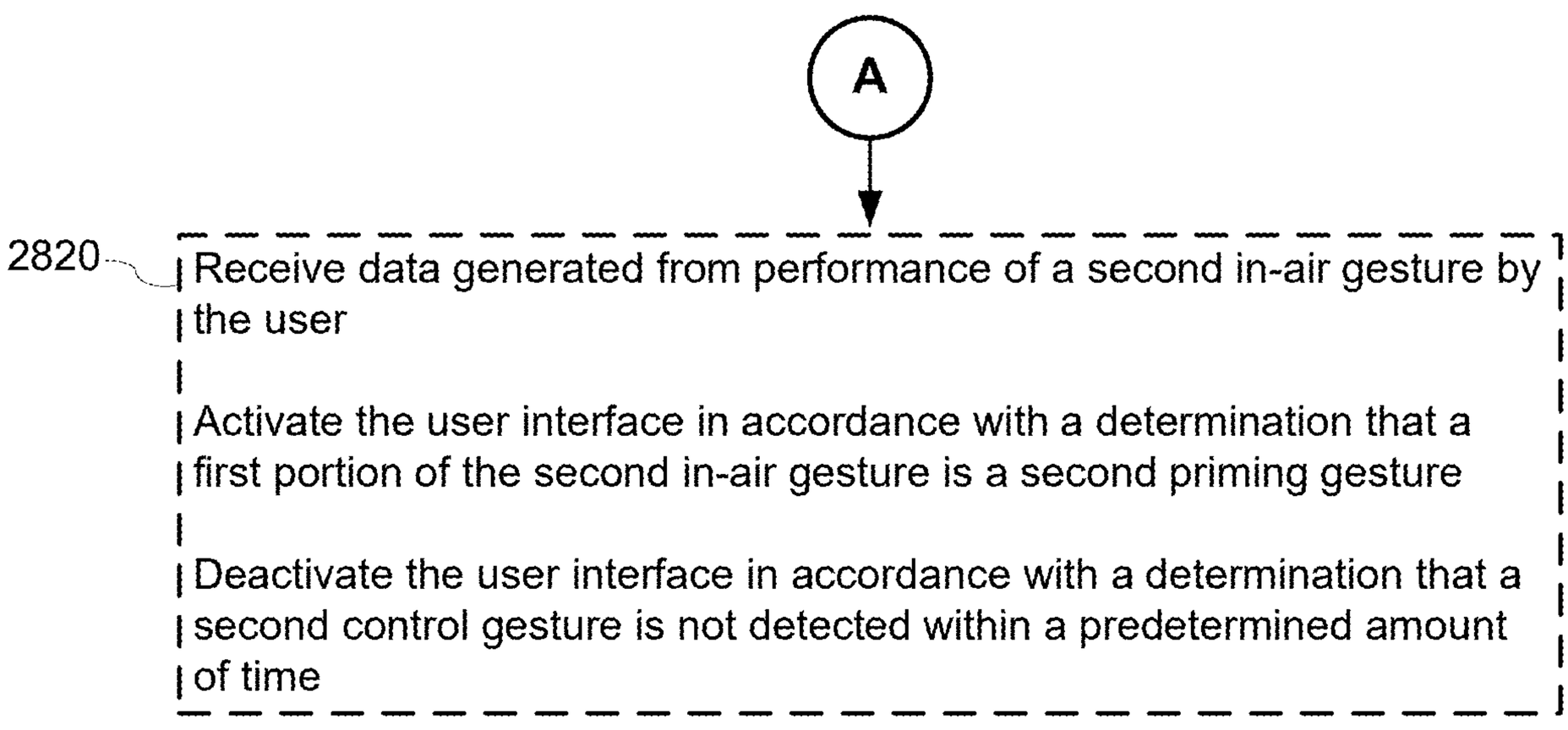

A
2820
Receive data generated from performance of a second in-air gesture by the user
Activate the user interface in accordance with a determination that a first portion of the second in-air gesture is a second priming gesture
Deactivate the user interface in accordance with a determination that a second control gesture is not detected within a predetermined amount of time

FIG. 23B

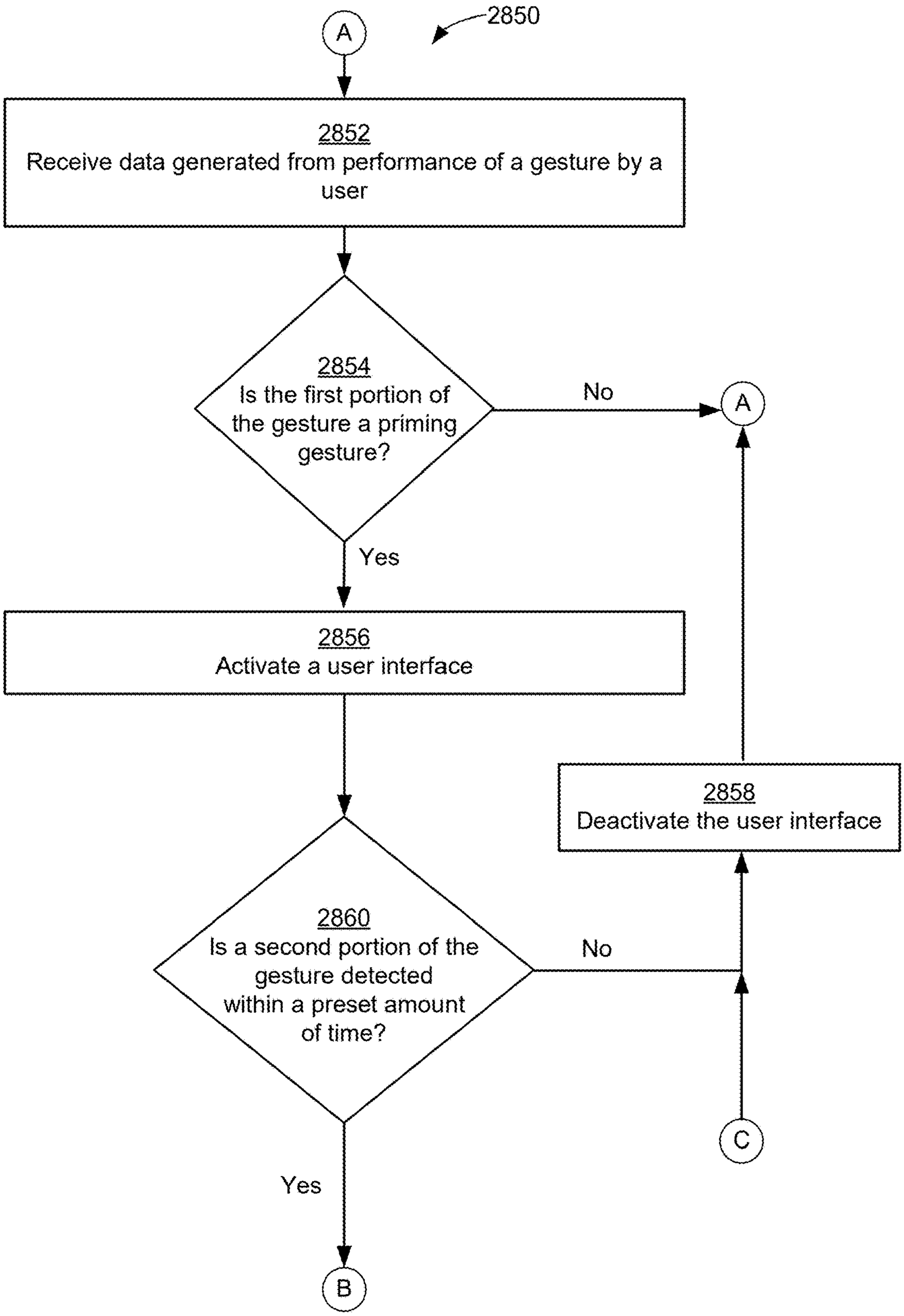

A
2850
2852
Receive data generated from performance of a gesture by a user
2854
Is the first portion of the gesture a priming gesture?
No
A
Yes
2856
Activate a user interface
2858
Deactivate the user interface
2860
Is a second portion of the gesture detected within a preset amount of time?
No
C
Yes
B

FIG. 23C

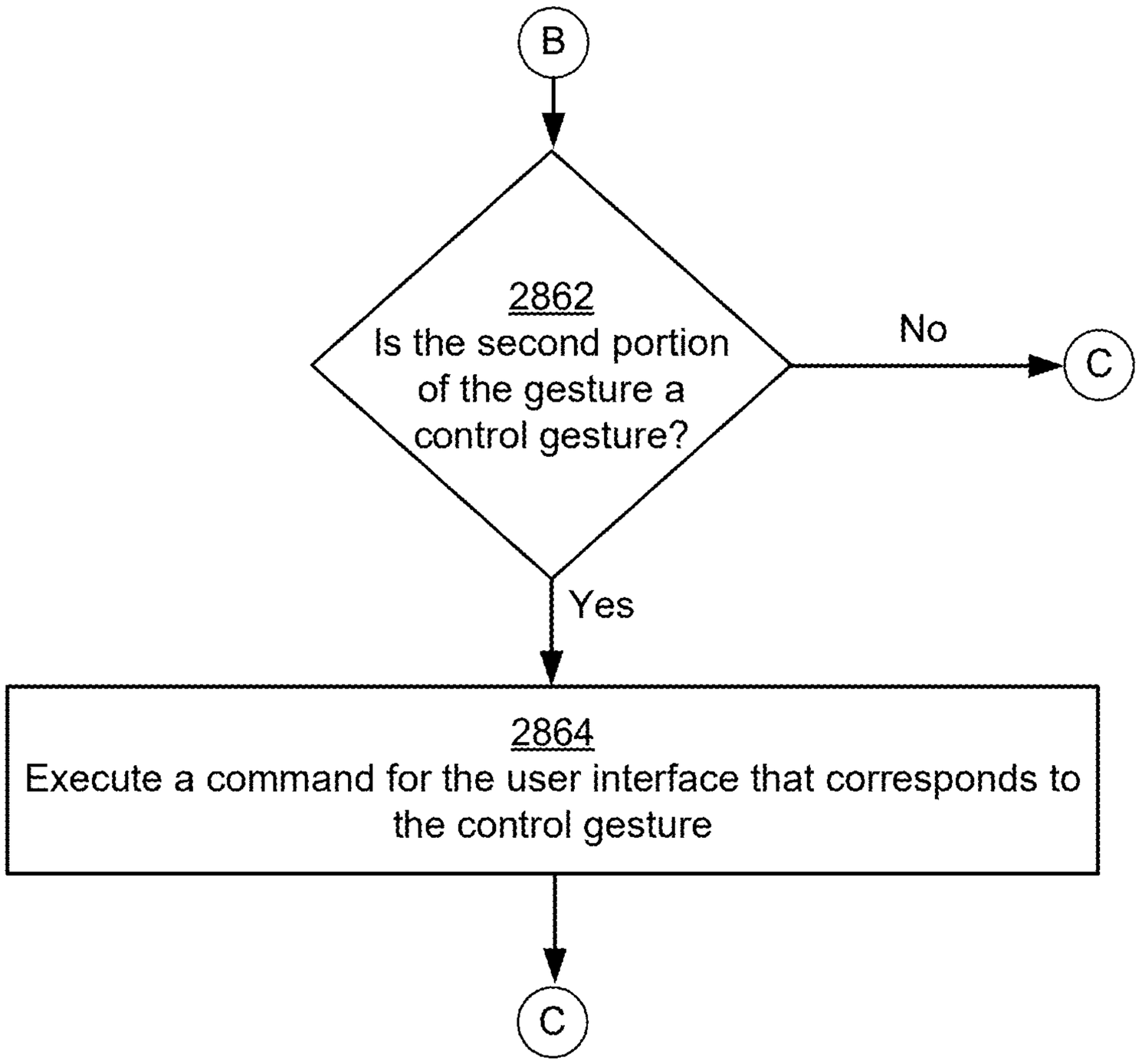

B
2862
Is the second portion of the gesture a control gesture?
No
C
Yes
2864
Execute a command for the user interface that corresponds to the control gesture
C

FIG. 23D

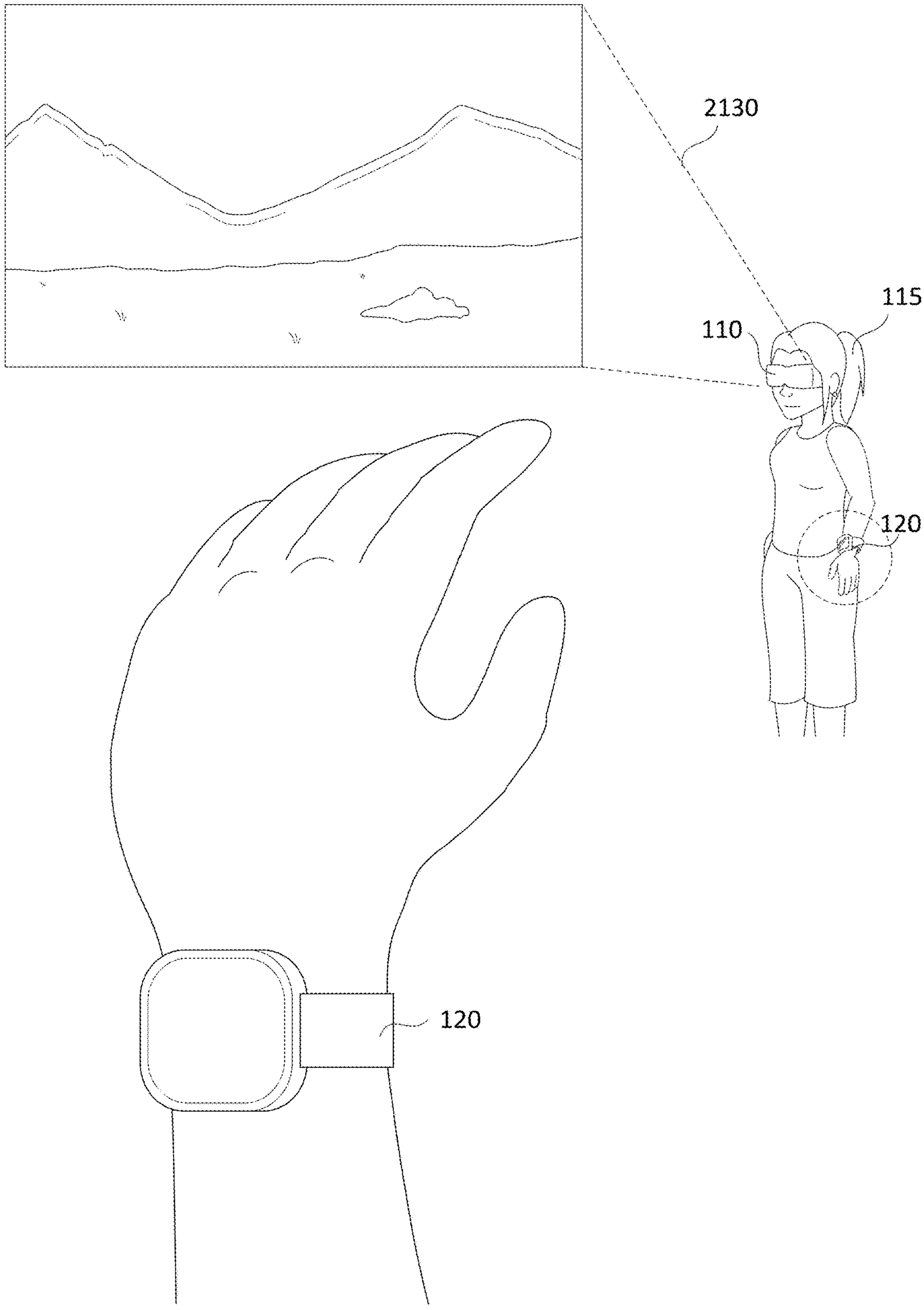


FIG. 24A

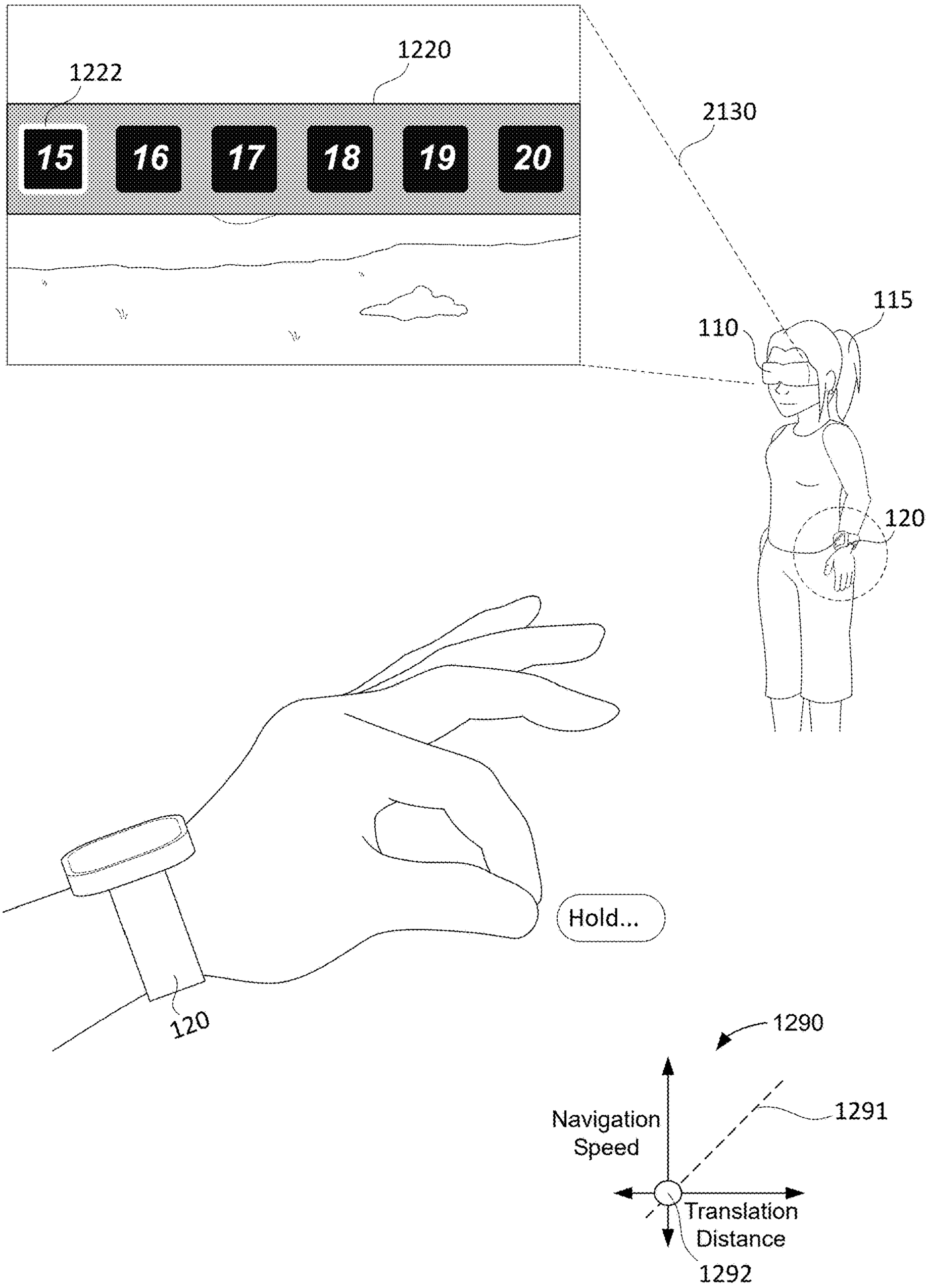

1222
1220
15
16
17
18
19
20
2130
115
110
120
Hold...
120
1290
Navigation Speed
1291
Translation Distance
1292

FIG. 24B

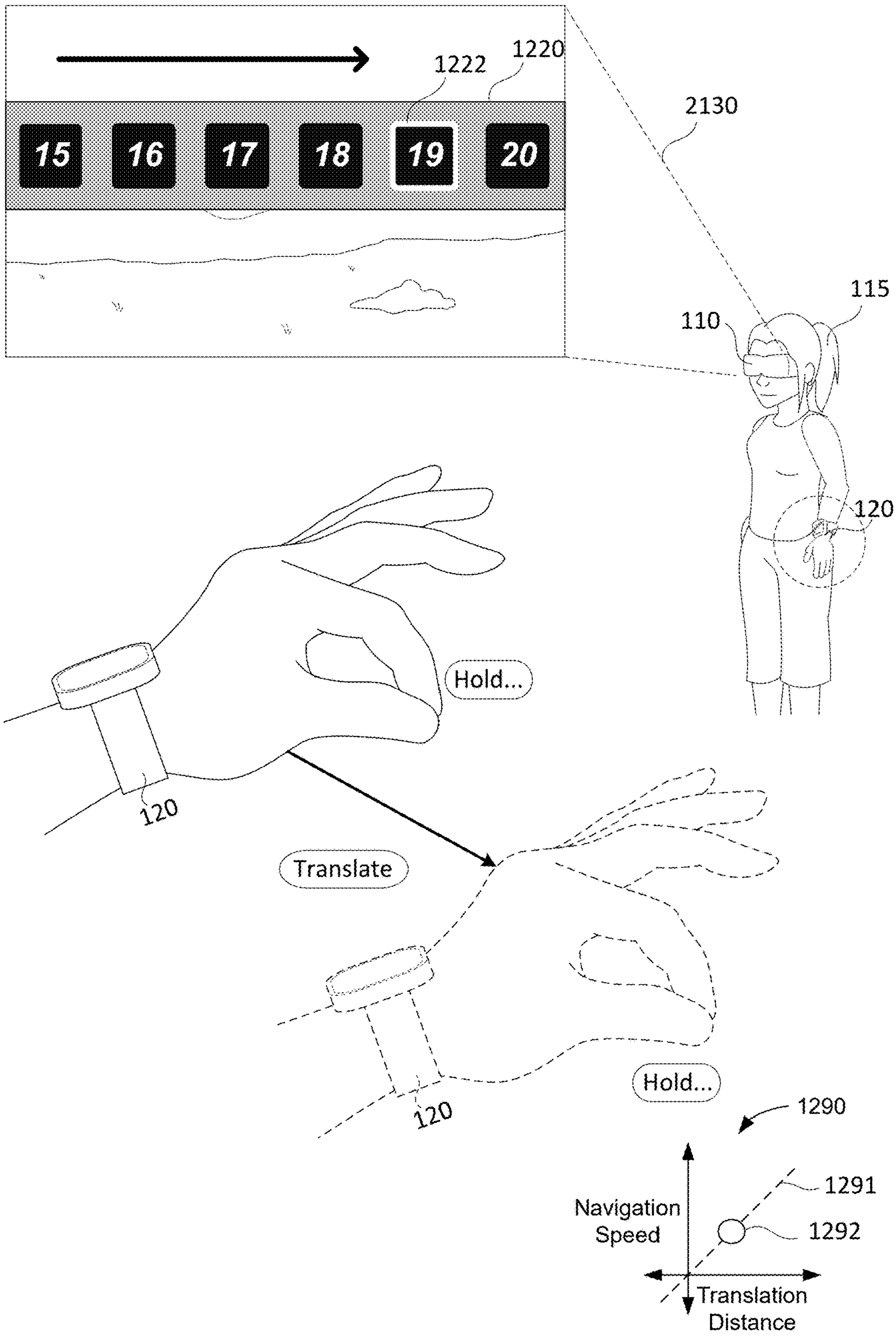

15
16
17
18
19
20
1222
1220
2130
115
110
120
Hold...
120
Translate
Hold...
120
1290
1291
1292
Navigation Speed
Translation Distance

FIG. 24C

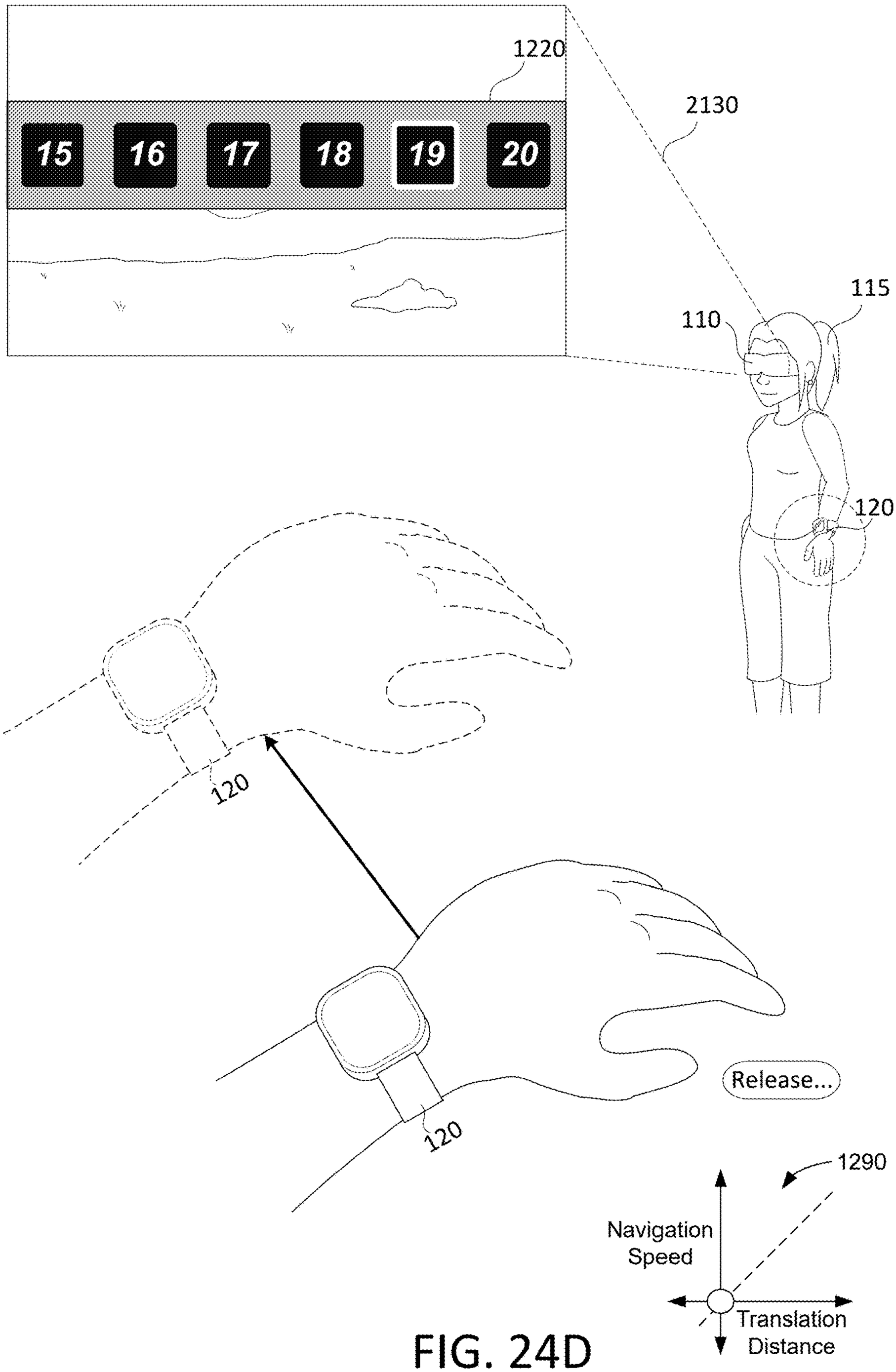

1220
15
16
17
18
19
20
2130
115
110
120
120
120
Release...
1290
Navigation Speed
Translation Distance

FIG. 24D

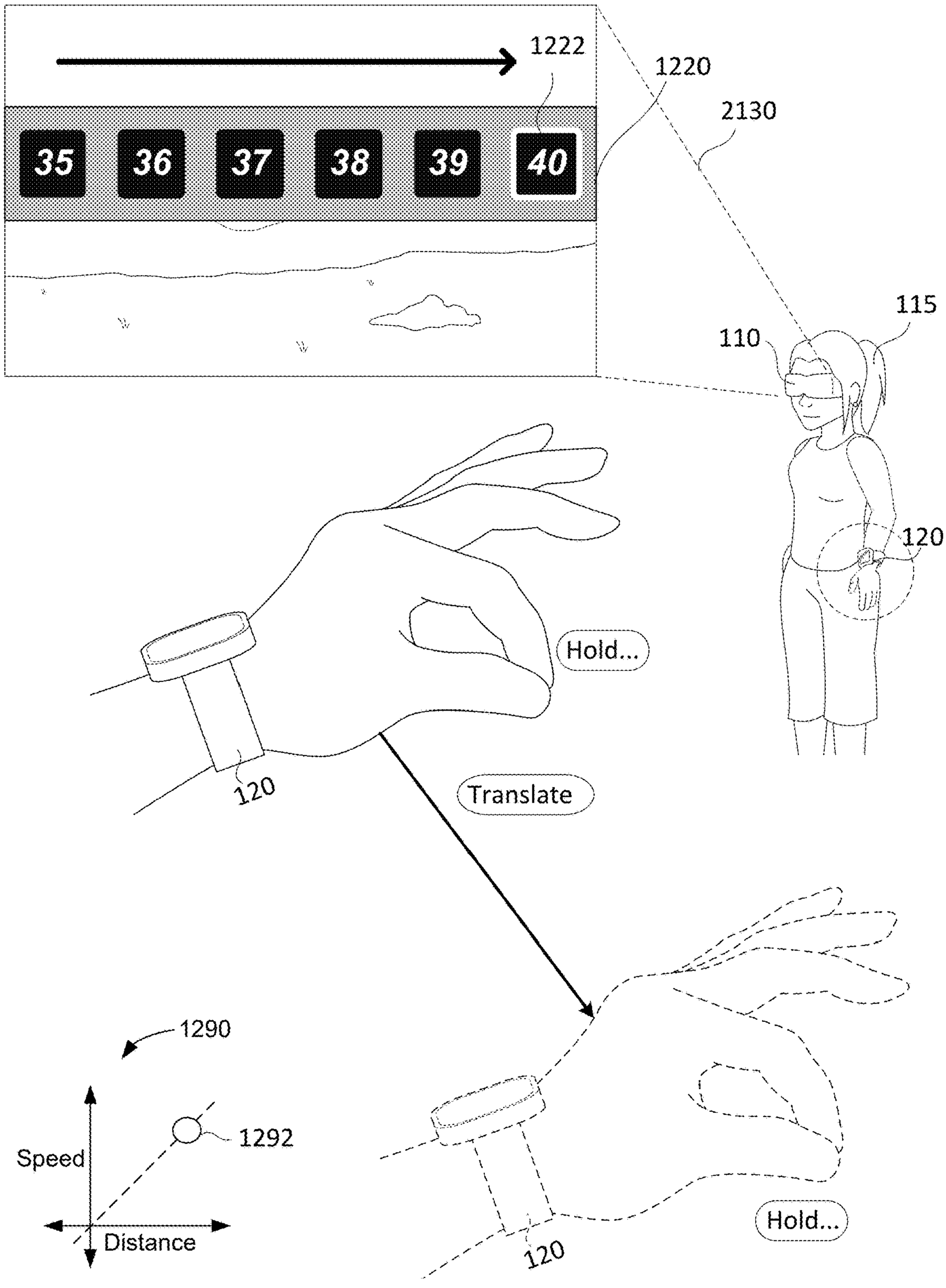

1222
1220
2130
35
36
37
38
39
40
115
110
120
Hold...
120
Translate
1290
Speed
1292
Distance
Hold...
120

FIG. 24E

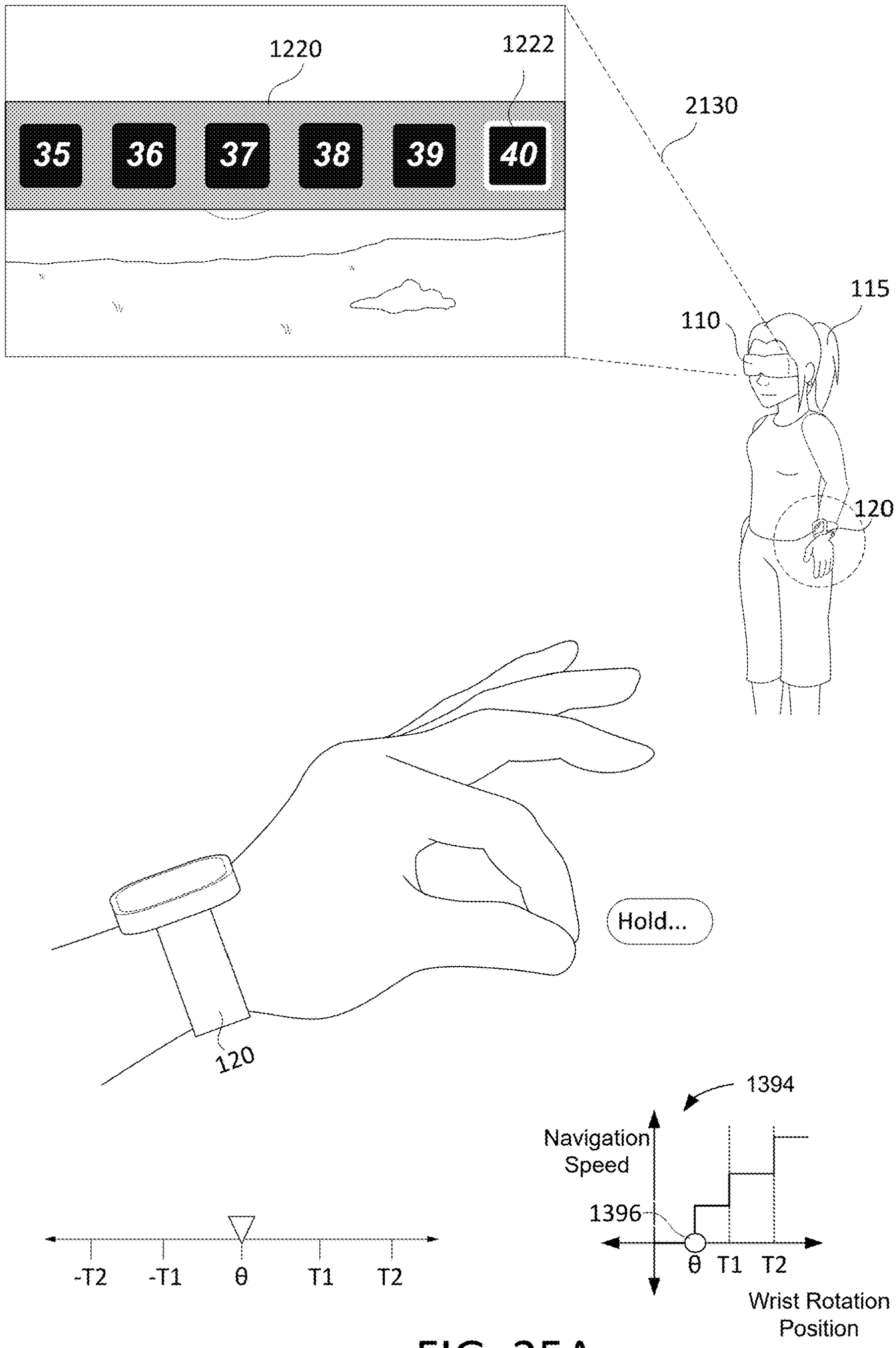

1220
1222
35
36
37
38
39
40
2130
115
110
120
Hold...
120
1394
Navigation Speed
1396
-T2
-T1
θ
T1
T2
θ
T1
T2
Wrist Rotation Position

FIG. 25A

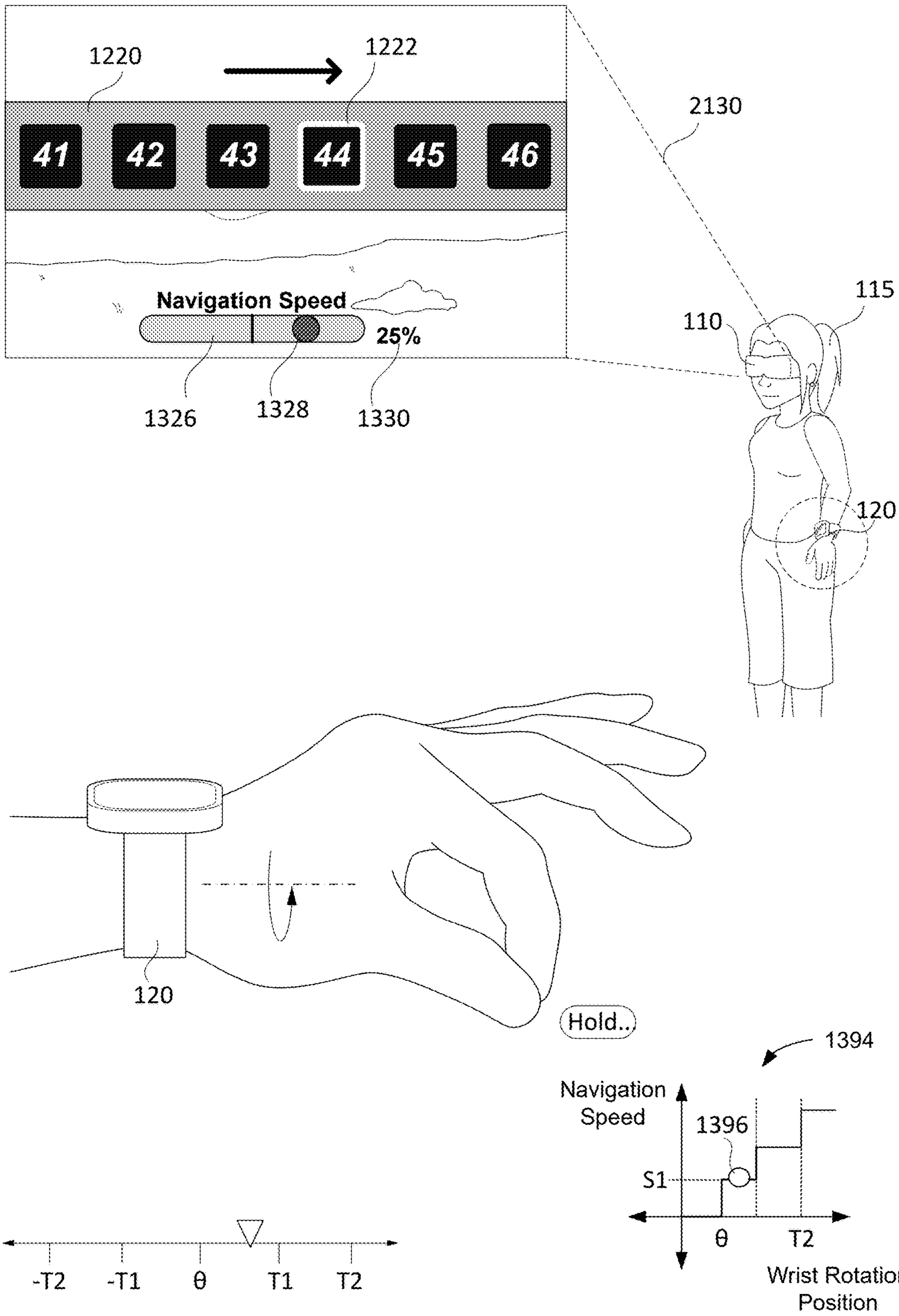

1220
1222
41
42
43
44
45
46
2130
Navigation Speed
25%
1326
1328
1330
115
110
120
120
Hold..
1394
Navigation Speed
1396
S1
θ
T2
Wrist Rotation Position
-T2
-T1
θ
T1
T2

FIG. 25B

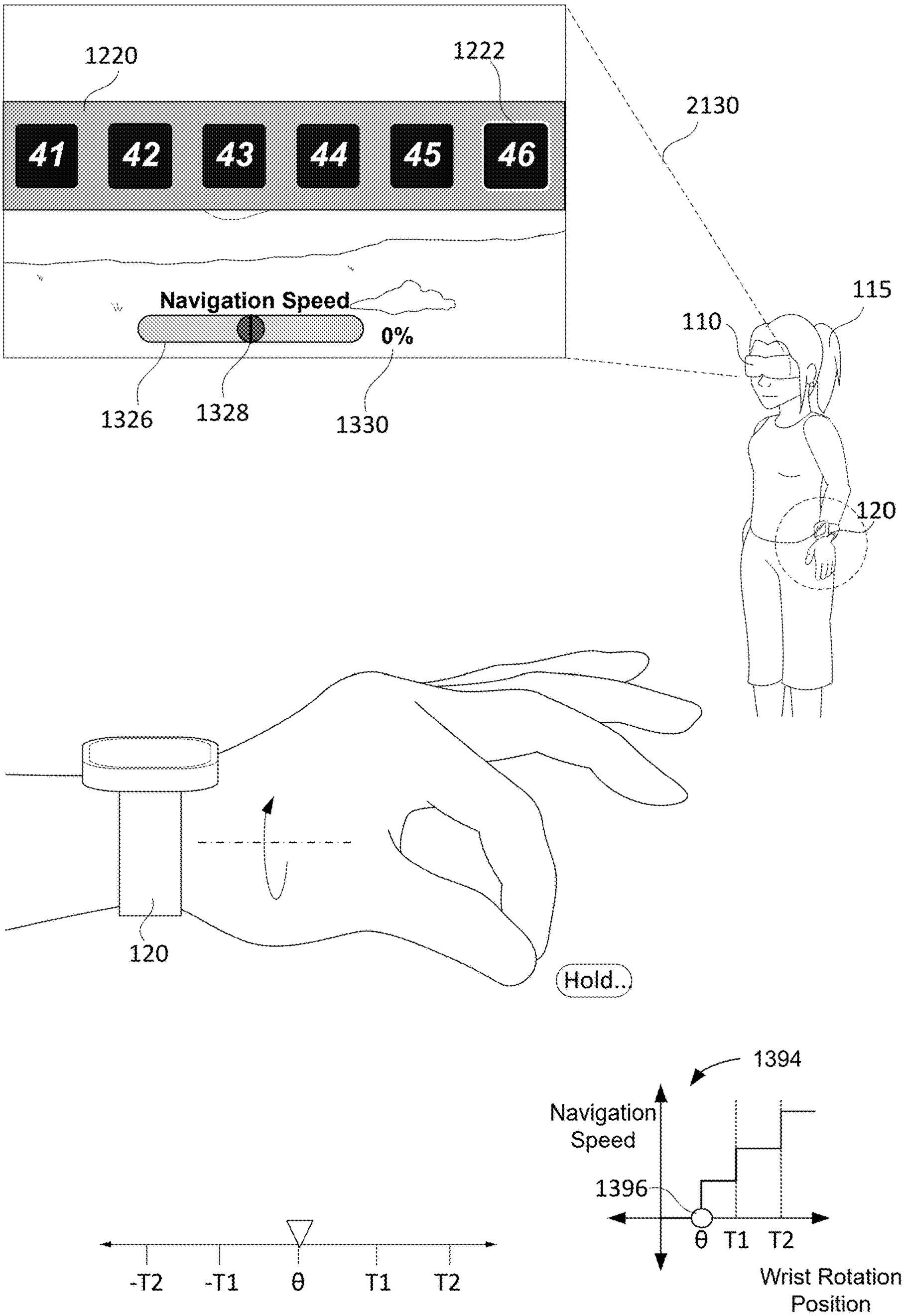

1220
1222
41
42
43
44
45
46
2130
Navigation Speed
0%
115
110
1326
1328
1330
120
120
Hold..
1394
Navigation Speed
1396
θ
T1
T2
Wrist Rotation Position
-T2
-T1
θ
T1
T2

FIG. 25C

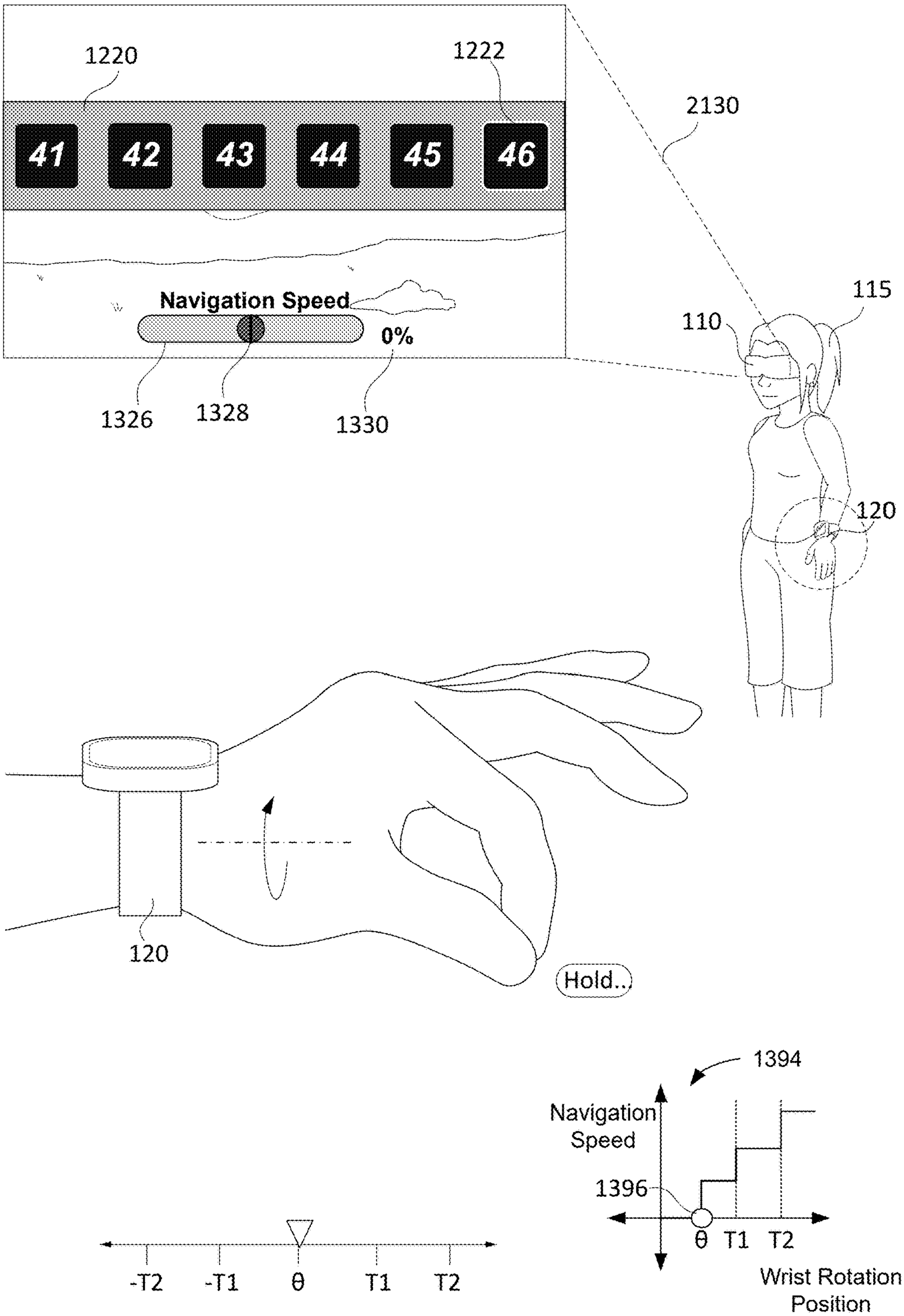
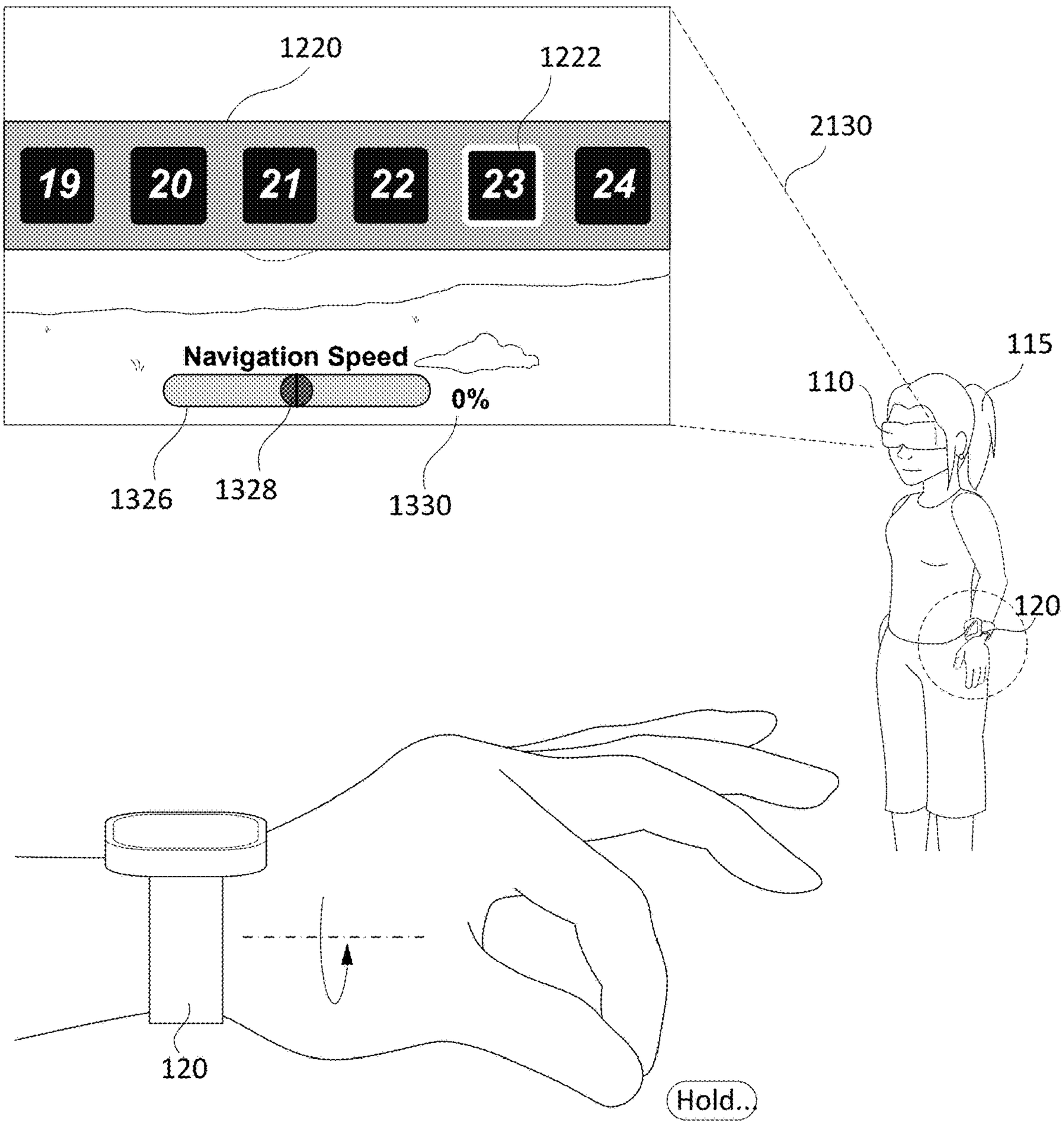

1220
1222
41
42
43
44
45
46
Navigation Speed
0%
1326
1328
1330
2130
115
110
120
120
Hold..
1394
Navigation Speed
1396
θ
T1
T2
-T2
-T1
θ
T1
T2
Wrist Rotation Position

FIG. 25D


1220
1222
19
20
21
22
23
24
2130
Navigation Speed
0%
115
110
1326
1328
1330
120
120
Hold..

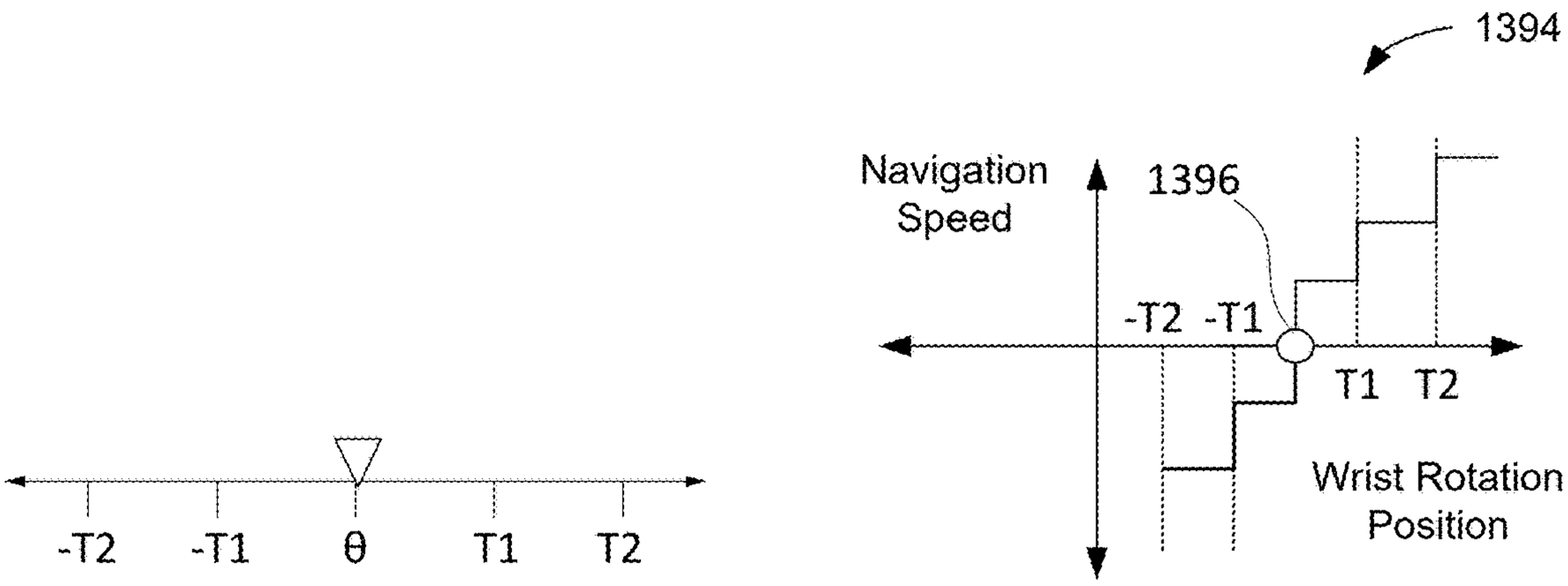
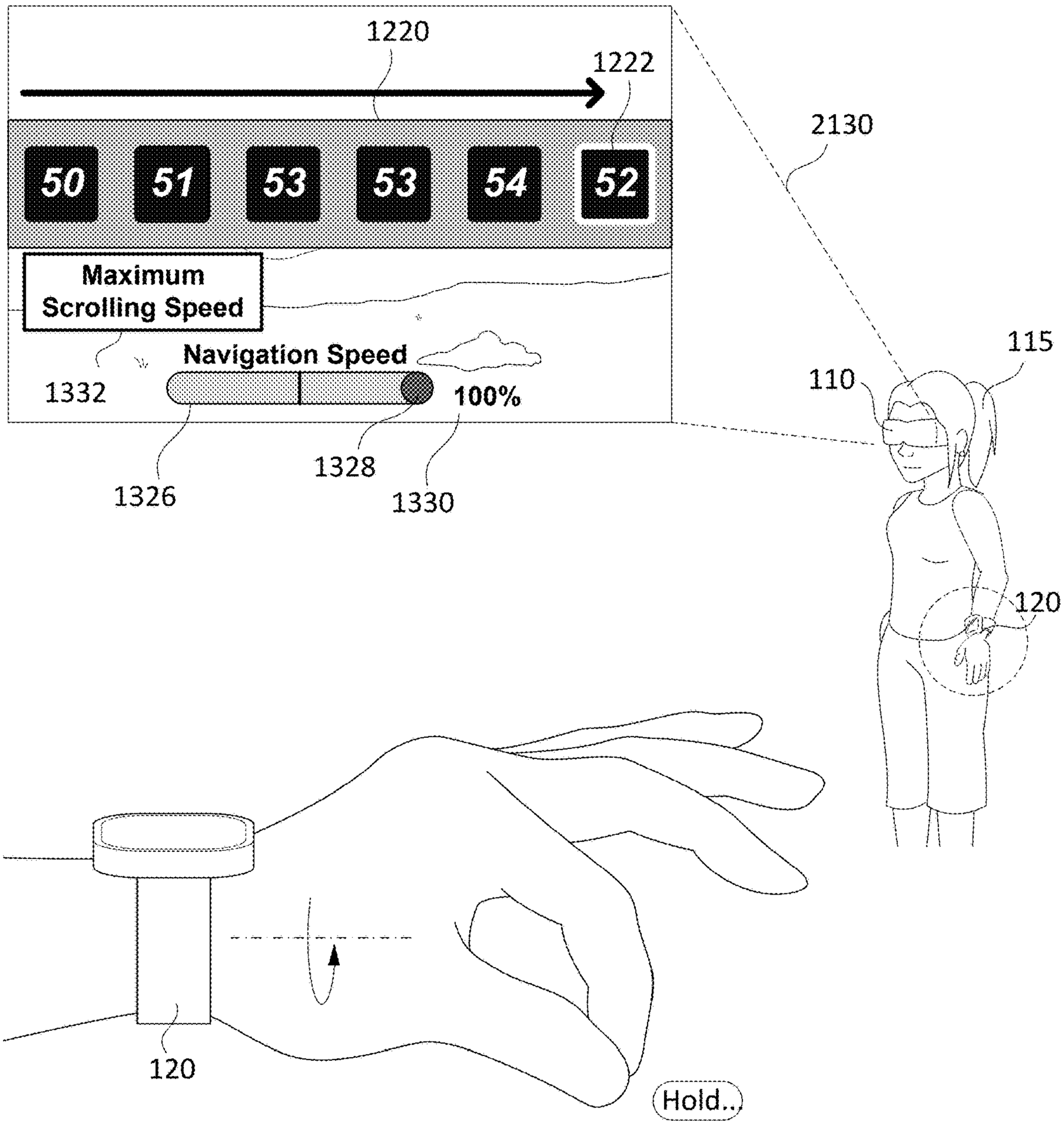

1394
Navigation Speed
1396
-T2 -T1
T1 T2
Wrist Rotation Position
-T2
-T1
θ
T1
T2

FIG. 25E


1220
1222
50
51
53
53
54
52
Maximum Scrolling Speed
Navigation Speed
1332
100%
1326
1328
1330
2130
115
110
120
120
Hold..

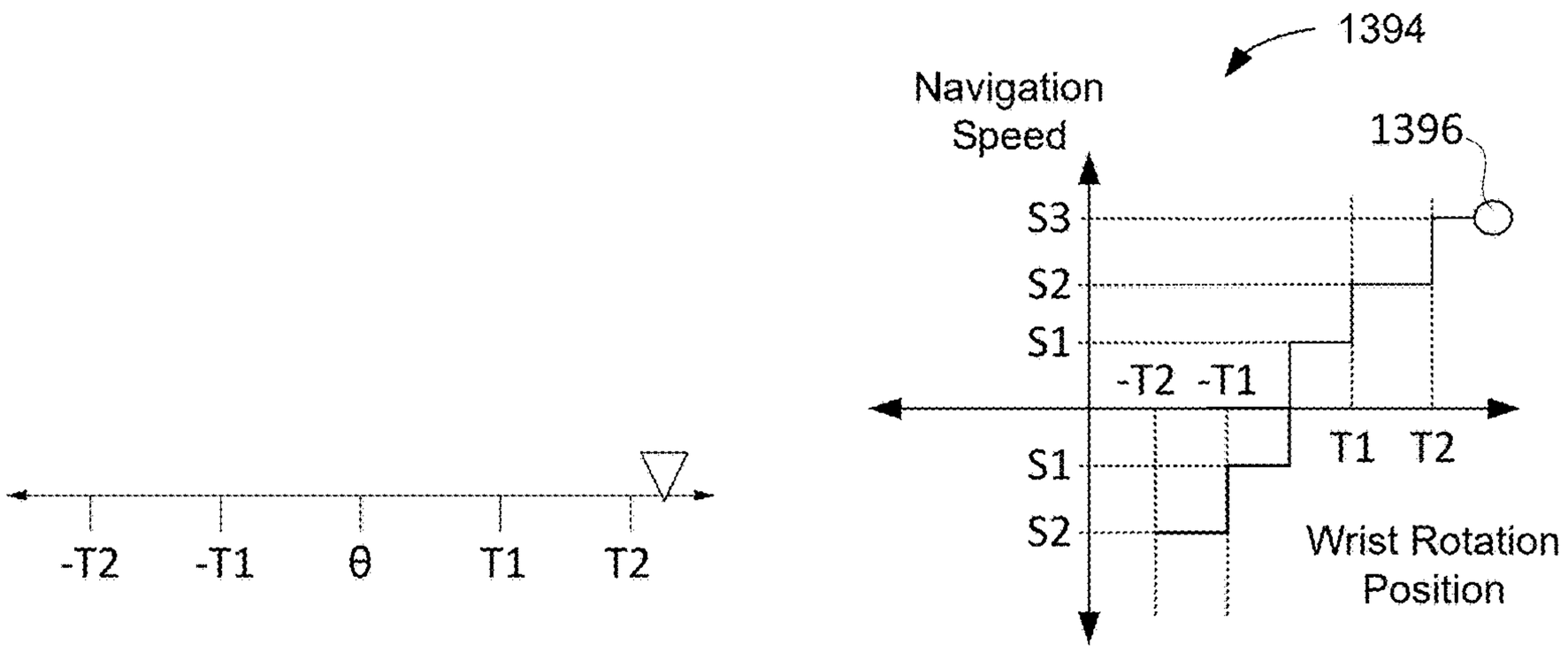

1394
Navigation Speed
1396
S3
S2
S1
-T2 -T1
T1 T2
S1
S2
Wrist Rotation Position
-T2
-T1
θ
T1
T2

FIG. 25F

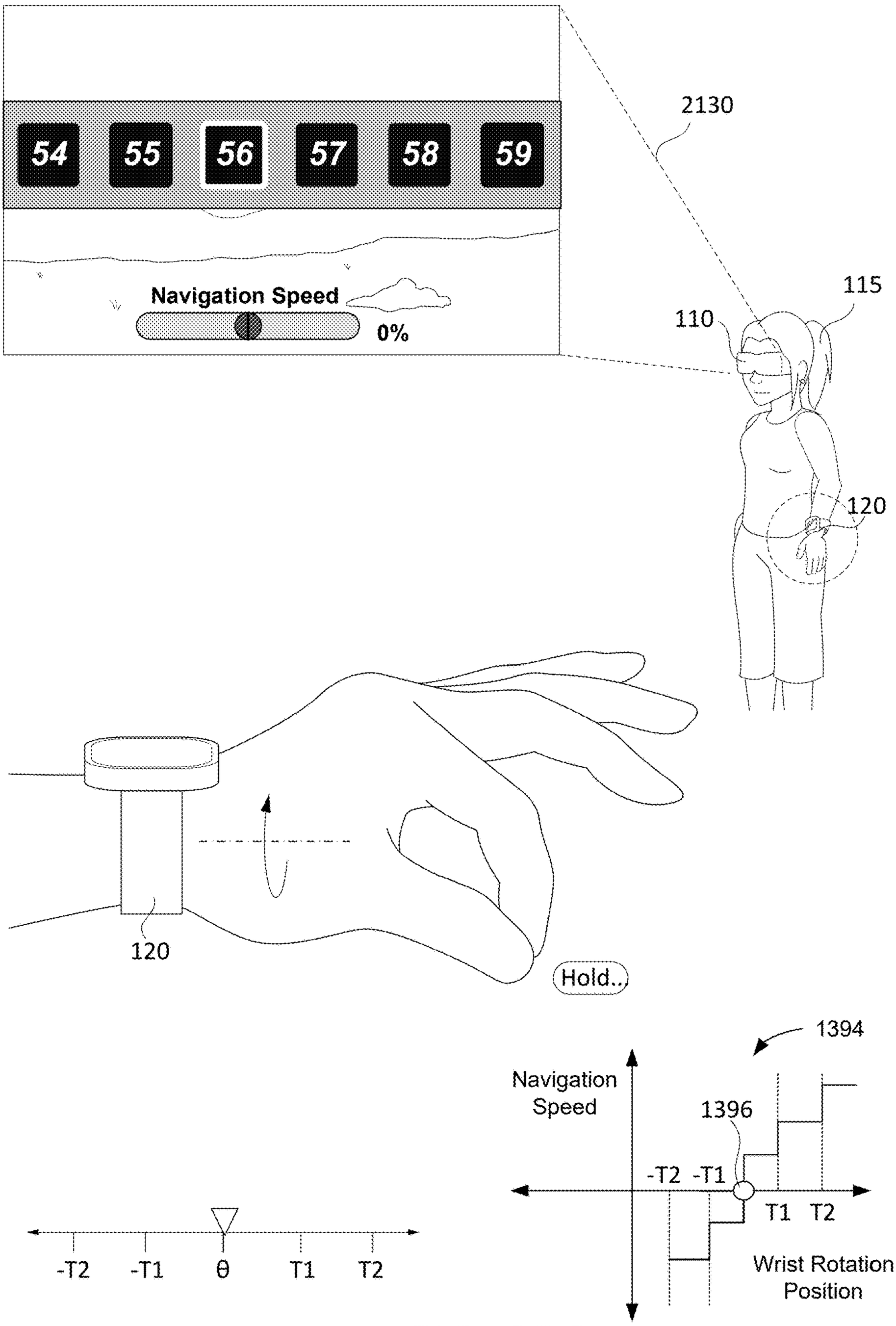

54
55
56
57
58
59
Navigation Speed
0%
2130
115
110
120
120
Hold..
1394
Navigation Speed
1396
-T2 -T1
T1 T2
Wrist Rotation Position
-T2
-T1
θ
T1
T2

FIG. 25G

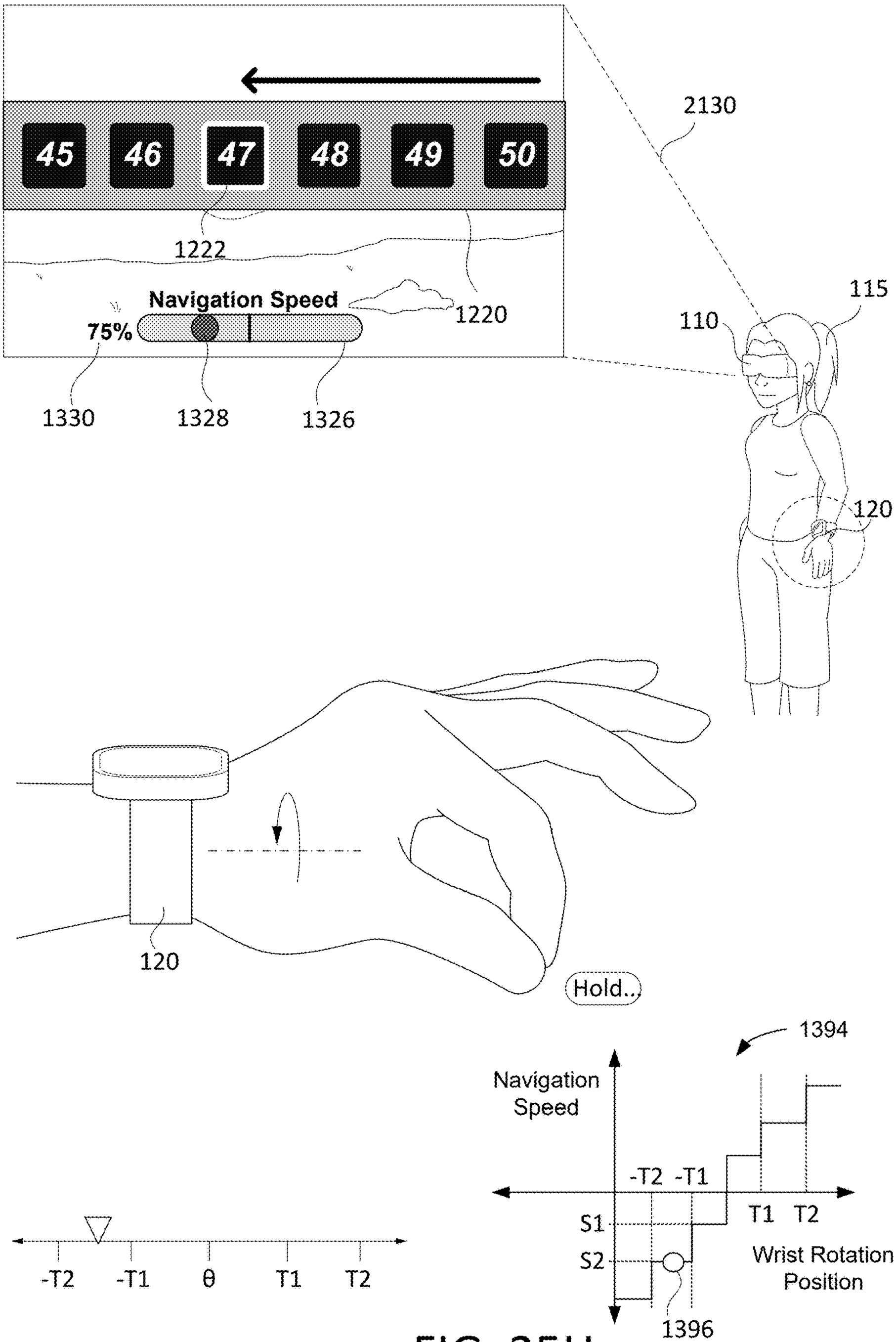

45
46
47
48
49
50
1222
Navigation Speed
75%
1220
1330
1328
1326
2130
115
110
120
120
Hold..
1394
Navigation Speed
-T2 -T1
T1 T2
S1
S2
Wrist Rotation Position
1396
-T2
-T1
θ
T1
T2

FIG. 25H

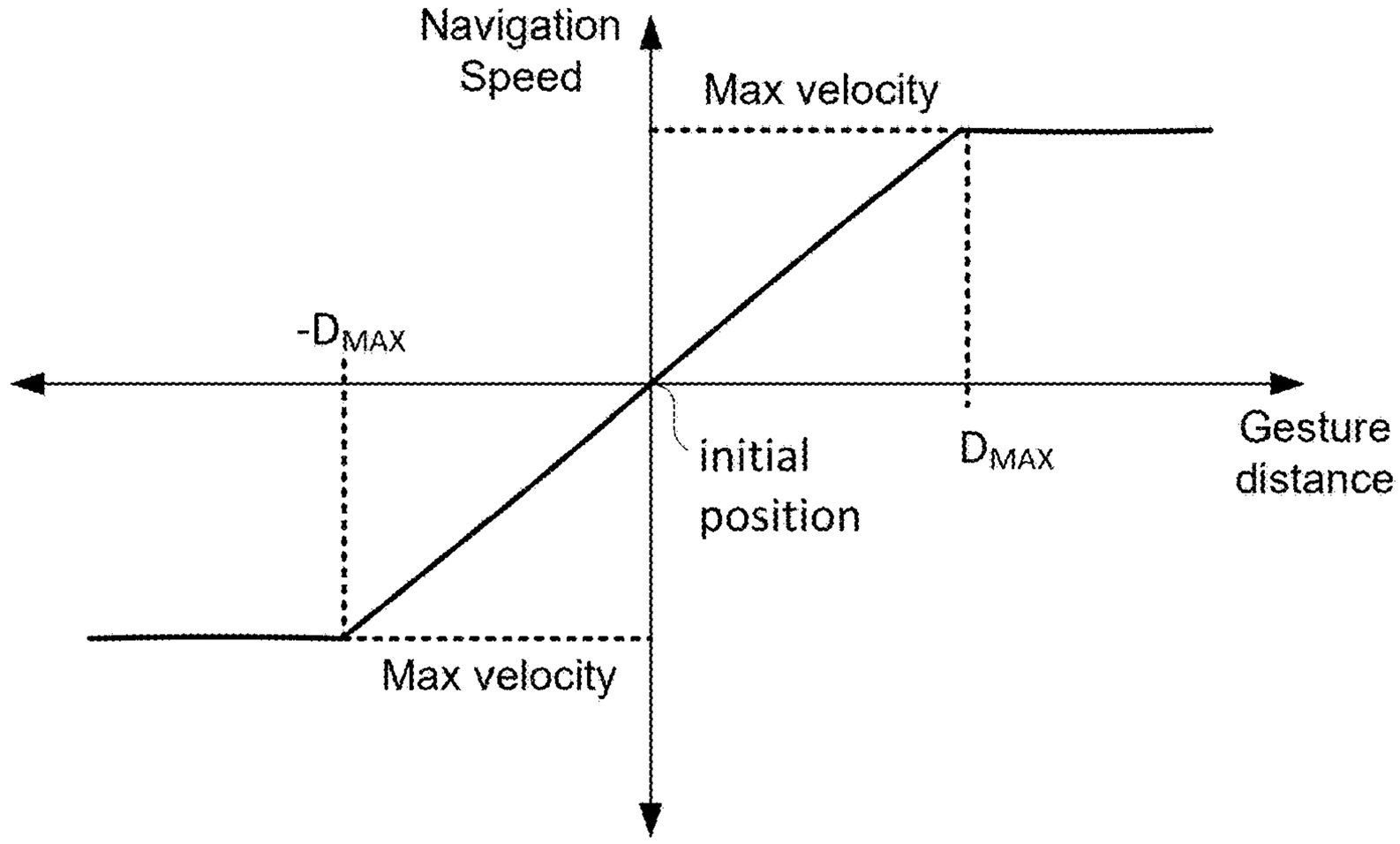


FIG. 26A

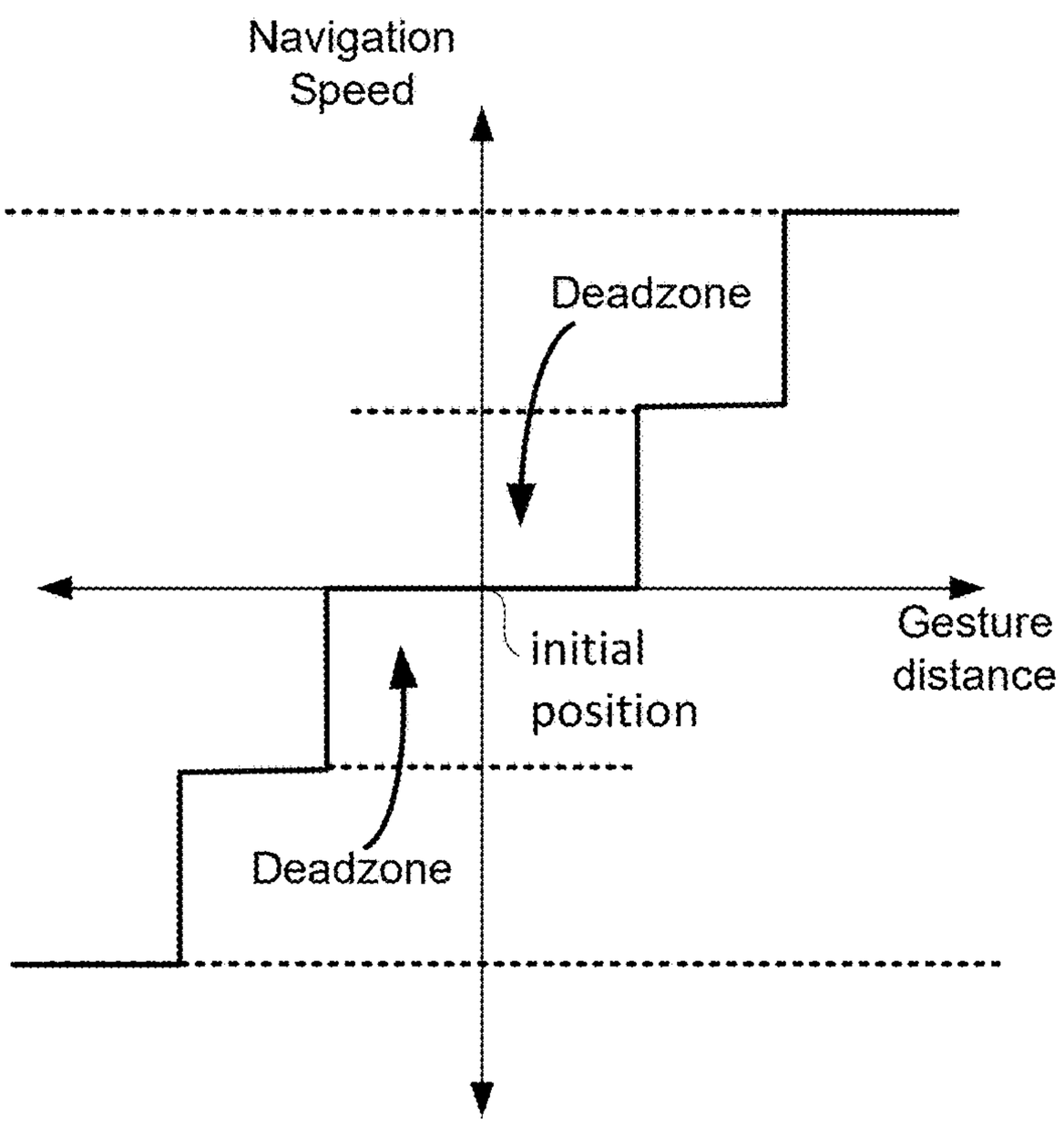


FIG. 26B

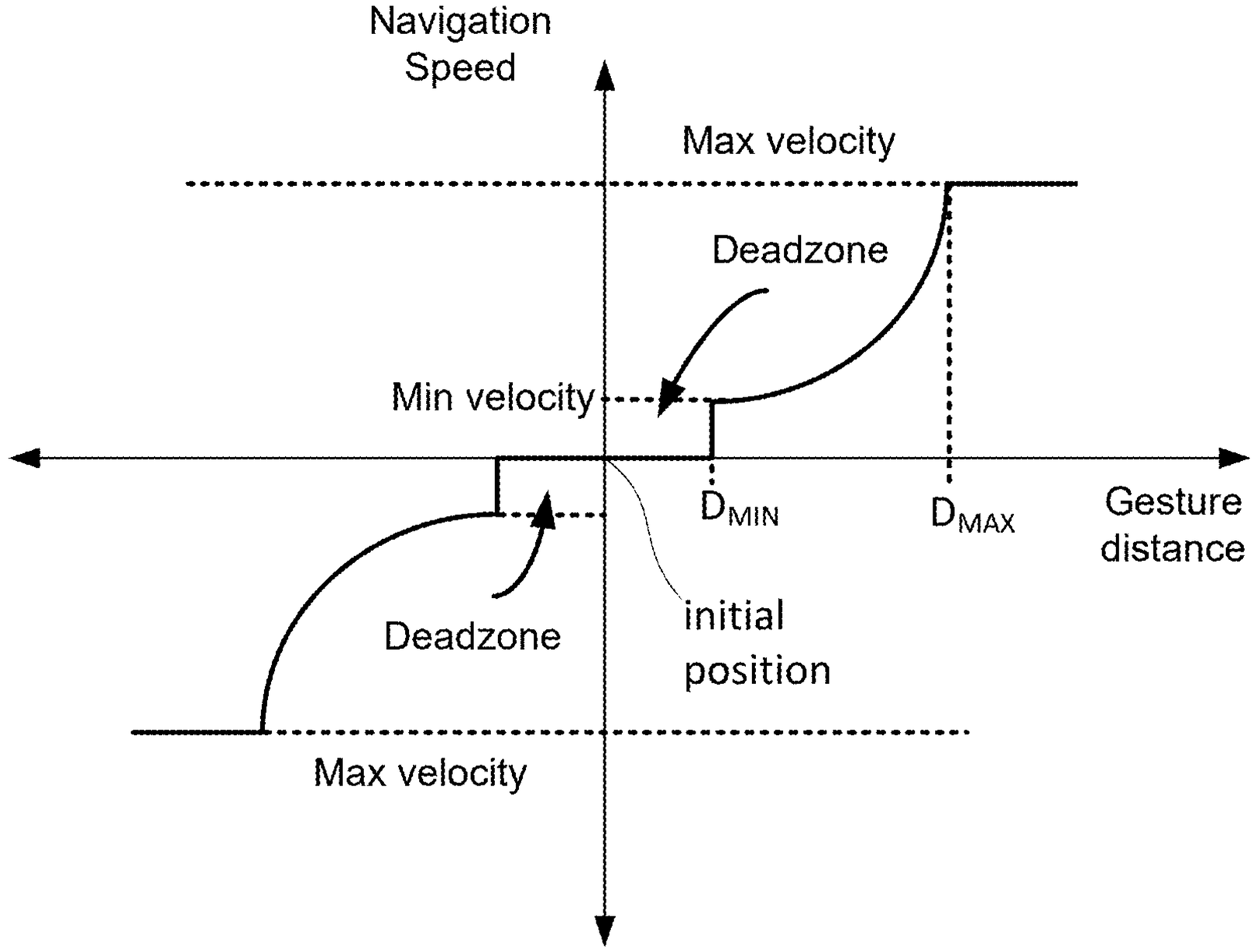

Navigation
Speed
Max velocity
Deadzone
Min velocity
D_{MIN}
D_{MAX}
Gesture distance
Deadzone
initial position
Max velocity

FIG. 26C

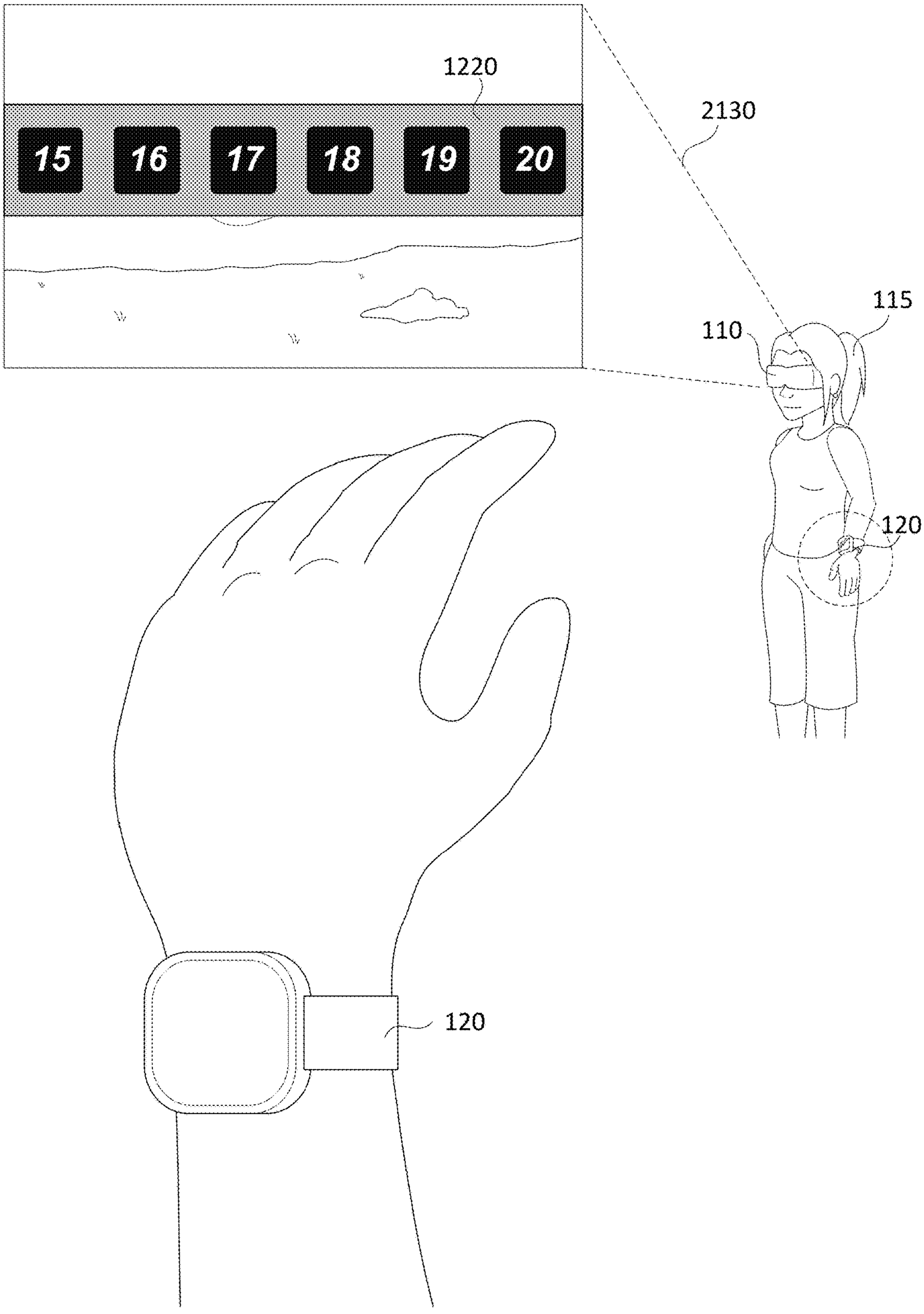
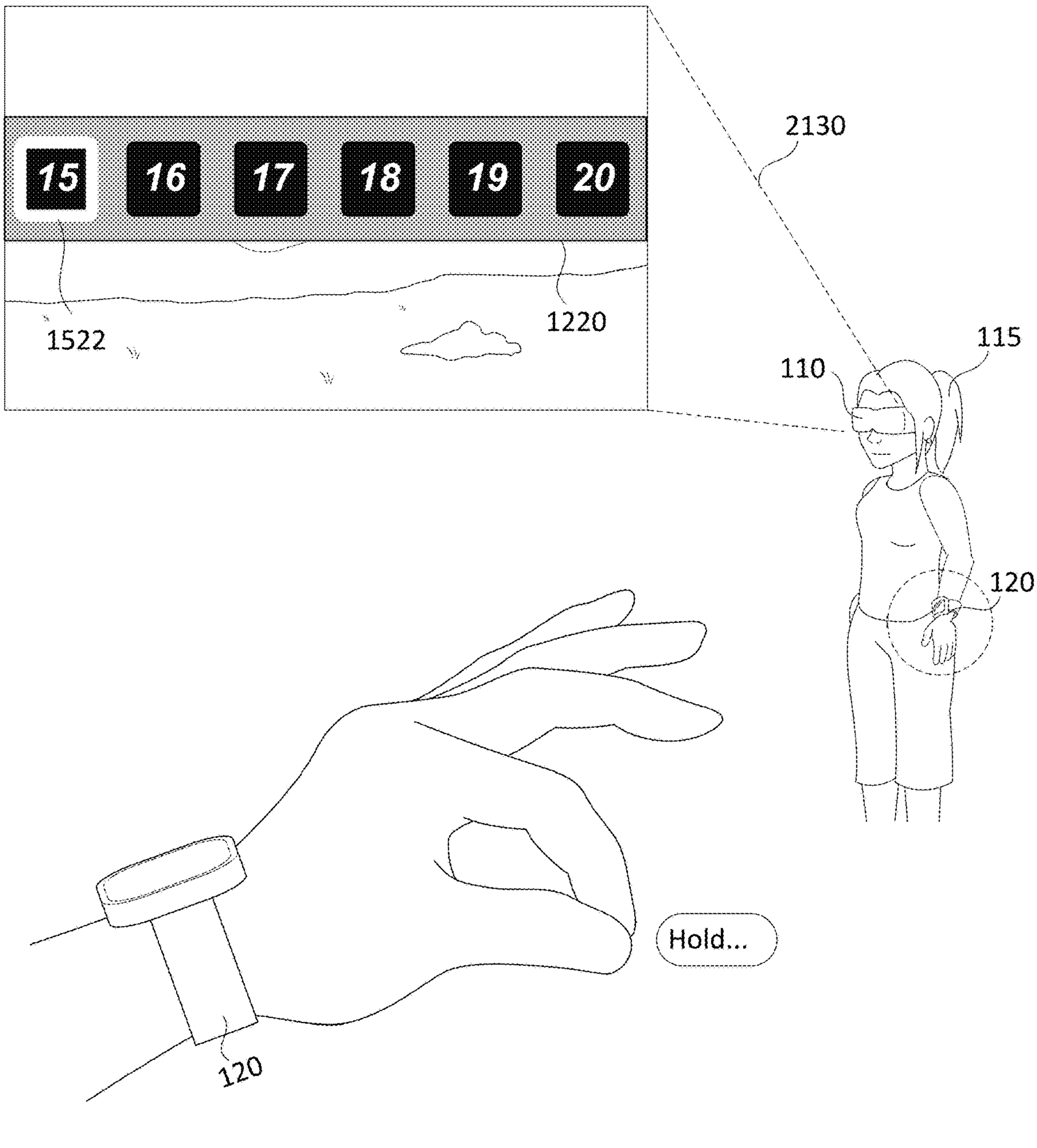
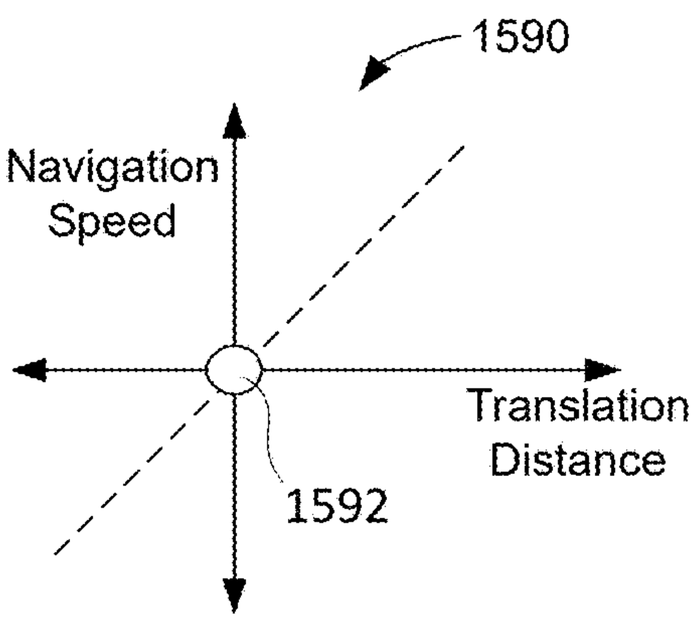


FIG. 27A


15
16
17
18
19
20
1522
1220
2130
115
110
120
Hold...
120


1590
Navigation Speed
Translation Distance
1592

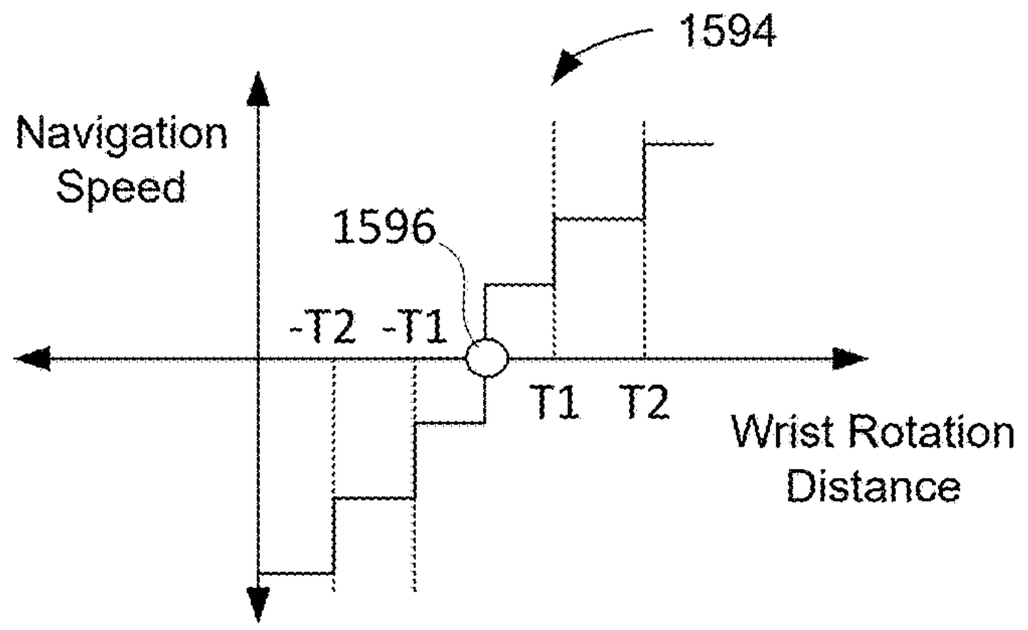
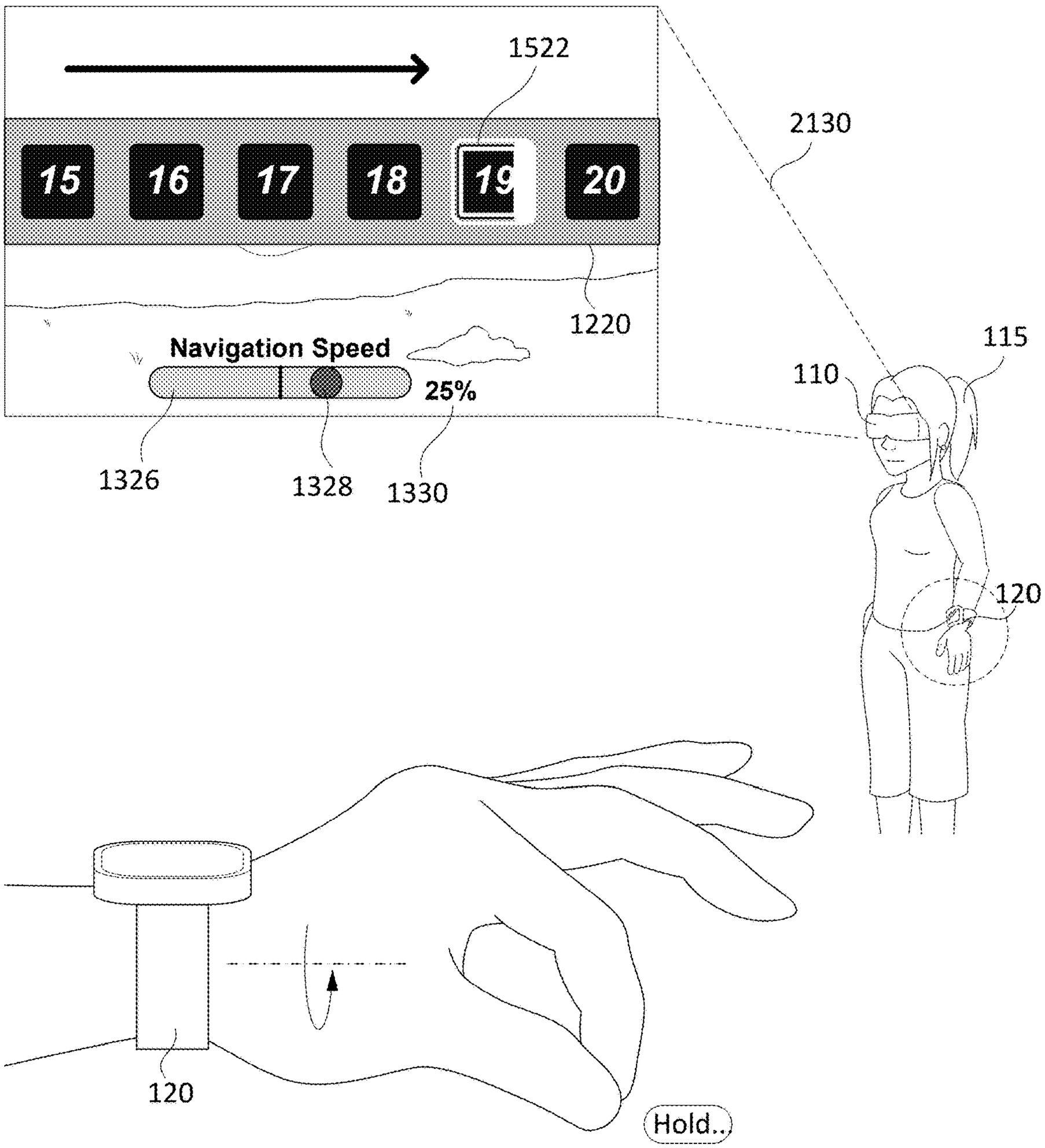

1594
Navigation Speed
1596
-T2
-T1
T1
T2
Wrist Rotation Distance

FIG. 27B


1522
15
16
17
18
19
20
2130
1220
Navigation Speed
25%
115
110
1326
1328
1330
120
120
Hold..

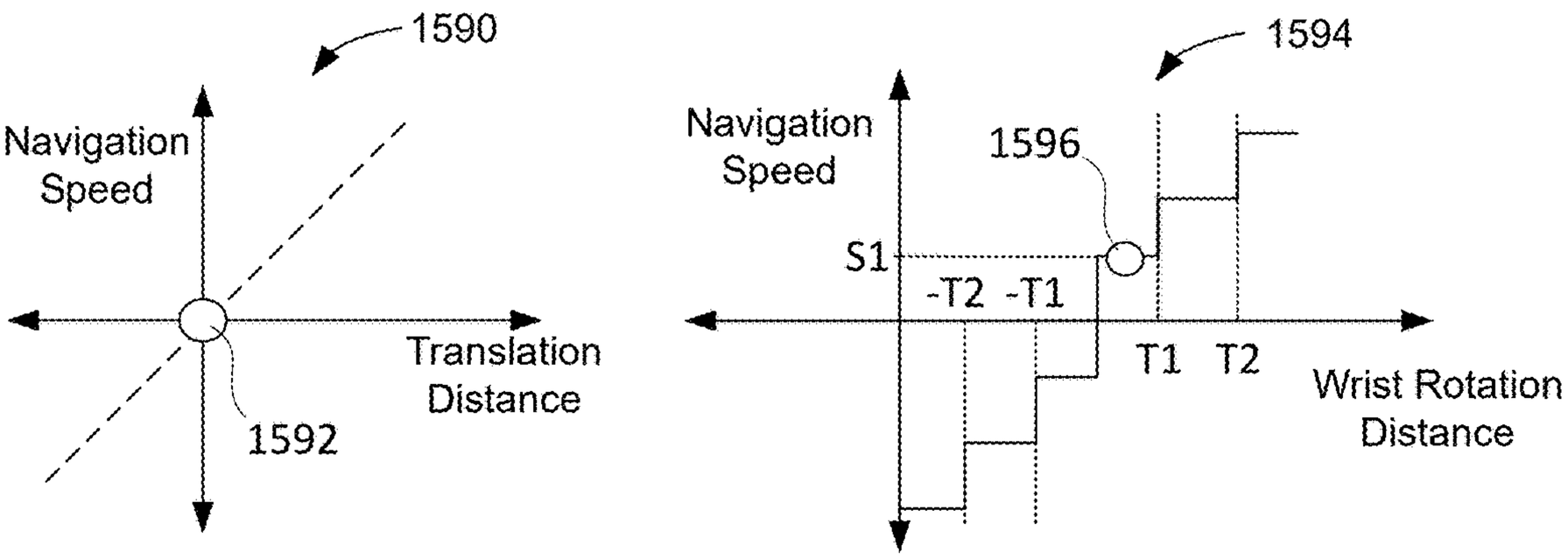
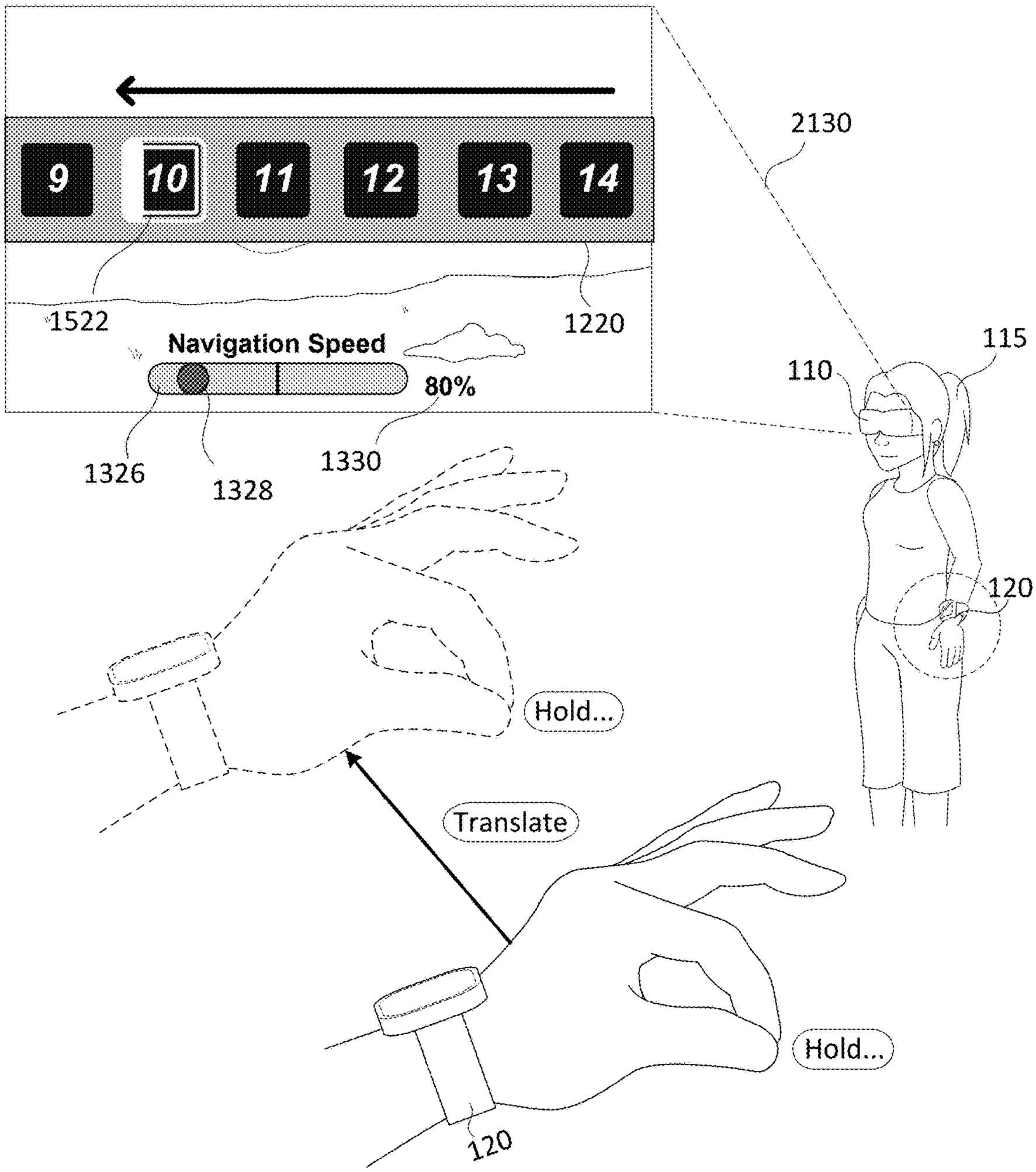
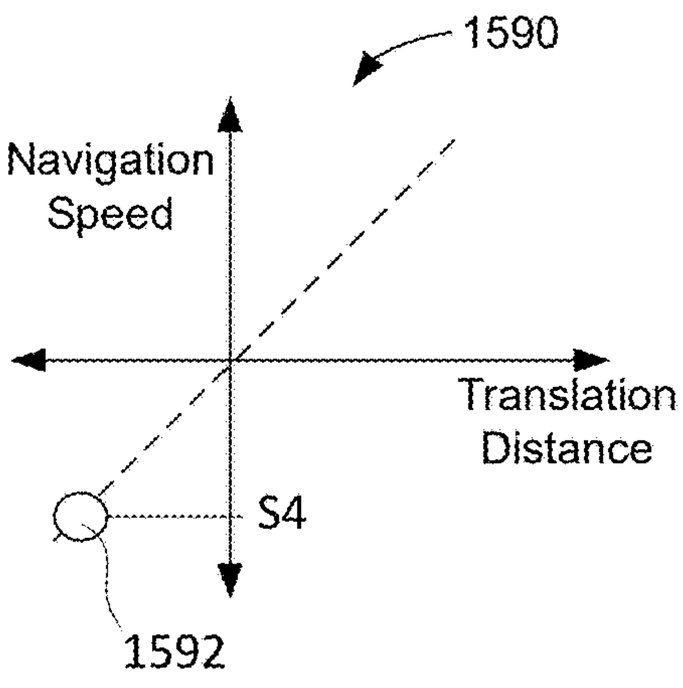

1590
Navigation Speed
Translation Distance
1592
1594
1596
Navigation Speed
S1
-T2 -T1
T1 T2
Wrist Rotation Distance

FIG. 27C


9
10
11
12
13
14
2130
1522
1220
Navigation Speed
80%
115
110
1326
1328
1330
120
Hold...
Translate
Hold...
120


1590
Navigation Speed
Translation Distance
S4
1592

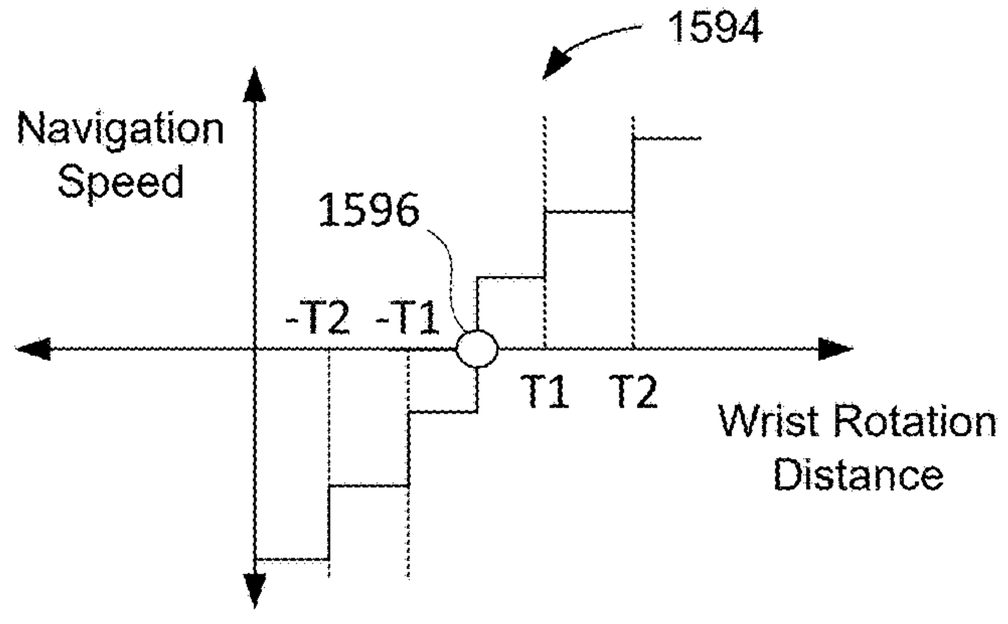

1594
Navigation Speed
1596
-T2
-T1
T1
T2
Wrist Rotation Distance

FIG. 27D

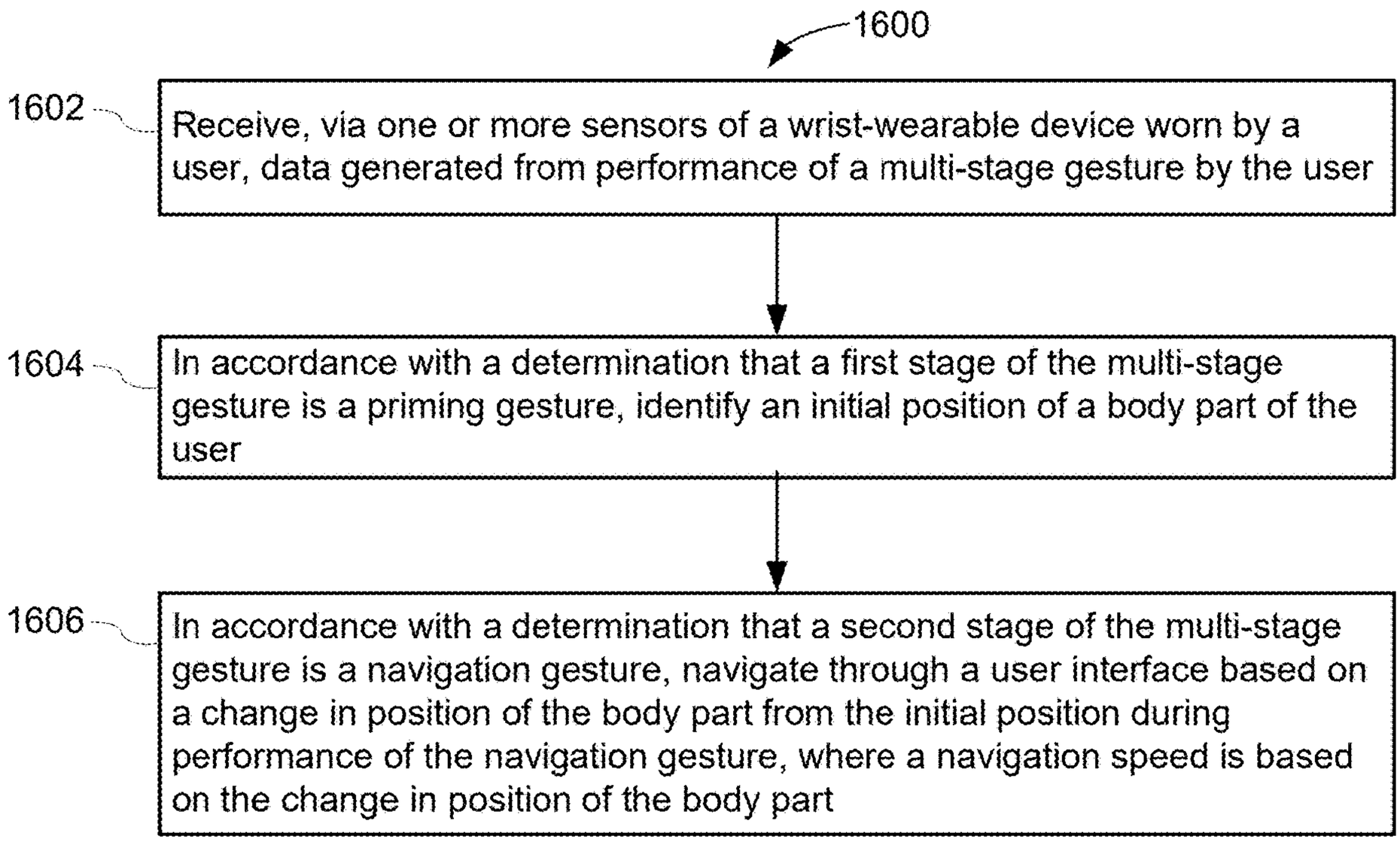

1600
1602
Receive, via one or more sensors of a wrist-wearable device worn by a user, data generated from performance of a multi-stage gesture by the user
1604
In accordance with a determination that a first stage of the multi-stage gesture is a priming gesture, identify an initial position of a body part of the user
1606
In accordance with a determination that a second stage of the multi-stage gesture is a navigation gesture, navigate through a user interface based on a change in position of the body part from the initial position during performance of the navigation gesture, where a navigation speed is based on the change in position of the body part

FIG. 28

ADJUSTING VOLUME AT A PAIR OF SMART GLASSES AND CONTROLLING A USER INTERFACE OF AN APPLICATION USING MULTI-STAGE IN-AIR HAND GESTURES DETECTED VIA A WRIST-WEARABLE DEVICE, AND SYSTEMS AND METHODS OF USE THEREOF

PRIORITY AND RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 19/239,748, filed Jun. 16, 2025, which is a continuation of U.S. patent application Ser. No. 18/364,396, now U.S. Pat. No. 12,360,608, filed Aug. 2, 2023, which is a continuation-in-part of U.S. patent application Ser. No. 18/359,855, now U.S. Pat. No. 12,436,620, filed Jul. 26, 2023, which claims priority to: (i) U.S. Provisional Patent Application No. 63/399,187, filed Aug. 18, 2022; (ii) U.S. Provisional Patent Application No. 63/399,188, filed Aug. 18, 2022; (iii) U.S. Provisional Patent Application No. 63/414,880, filed Oct. 10, 2022; and (iv) U.S. Provisional Patent Application No. 63/414,884, filed Oct. 10, 2022, each of which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates generally to wearable devices (e.g., wrist-wearable devices and head-wearable devices) and methods for detecting different types of gestures using wearable devices, including but not limited to, wearable devices configured to detect neuromuscular-based signals corresponding to multi-stage in-air gestures (e.g., gestures performed in distinct stages by a user's digits without contacting any electronic devices.

BACKGROUND

[0003] Users typically carry a number of electronic devices to assist them in their daily lives. For example, users carry smartphones, smartwatches, and other electronic devices that help make the users' days run more smoothly, e.g., by allowing them to send messages and emails, and to capture images and take notes. In order to perform certain operations on these devices (such as taking a photo or sending an email), a user may need to perform multiple operations on the display or keyboard of the device. Additionally, many devices require a user to open/setup their device and physically interact with it, which takes away from the user's experience and can lead to inefficient man-machine interfaces that waste limited computing and power resources, particularly for wearable devices. Further, devices that are responsive to user gestures suffer from false positives where the devices respond to inadvertent user gestures, which also takes away from the user's experience and can also lead to inefficient man-machine interfaces that waste limited computing and power resources, particularly for wearable devices. These potential issues can occur in the context of gestures detected based on neuromuscular signals as a user's movement of their hands during daily interactions can falsely trigger gesture sequences that were unintended.

[0004] As such, it would be desirable to address one or more of the above-identified issues, drawbacks, or areas for further exploration.

SUMMARY

[0005] As discussed above, there is a need for a wearable device that can detect (multi-stage) in-air gestures to control an electronic device (e.g., a cursor or point of focus) without needing to physically interact with the electronic device or require a large open space for user gestures. In particular, by splitting gesture sequences into priming and control stages, with the priming stage used to trigger a gesture sequence and the control stage used to confirm an intention to proceed with that gesture sequence, users are provided with an intuitive, easy-to-remember way to use in-air hand gestures to control wearable devices with a low rate of false positives (e.g., a false positive rate of less than 4%). In one example, a priming gesture can include a press-and-hold of the user's middle finger and thumb (which can then cause activation of a user interface, such as by causing display of a menu of options, followed by a navigation gesture that can include rotational movement of a user's wrist to move between the menu of options, followed by a control gesture (e.g., release of the press-and-hold gesture) to cause execution of a command associated with a currently in-focus option when the control gesture is received. As this one example shows, a user is provided with the ability to prime gesture interactions, such that if an unintended gesture interaction is primed, they are easily able to back out of that gesture sequence should that sequence have been unintentionally activated.

[0006] The systems (e.g., wearable devices) and methods described herein address at least some of the above-mentioned drawbacks by allowing a user to efficiently interact with a user interface using gestures detected by the one or more wearable devices (e.g., a wrist-wearable device) that include sensors for detecting gestures performed by the user. The sensors at the wearable devices can include electromyography (EMG) sensors (e.g., to detect muscular responses), inertial measurement unit (IMU) sensors, and time-of-flight sensors (e.g., to detect spatial distances).

[0007] As described herein, an (optionally multi-stage) in-air gesture performed by the user can correspond to an operation to control one or more wearable devices (e.g., a head-wearable device, wrist-wearable device, smartphone, and/or intermediary device). For example, for an in-air gesture, a wrist rotation gesture performed by the user at a wrist-wearable device can cause a point of focus to move within a user interface (and select user interface elements). Alternatively, a pinch gesture (e.g., where a user's pinkie finger contacts their thumb) or thumb movements could cause the point of focus to move and/or snap to a user interface element (e.g., give focus to, or select, the element). Furthermore, other types of gestures could activate various functions associated with a selected user interface element. For example, for a multi-stage in-air gesture, a pinch gesture (e.g., using the thumb and the pinky) performed by the user at a wrist-wearable device can cause the presentation of a menu on a head-wearable device. Furthermore, releasing that gesture could select a user interface element within the menu.

[0008] The wearable devices described herein, after receiving or detecting the user's in-air gestures, can provide data to a computing device which causes the computing device to perform operations at a head-wearable device or other electronic device. The computing device can be another wearable device or an intermediary device (e.g., a smartphone). In some instances, the wearable device (or an

intermediary device) is configured to cause operations to be performed at other electronic devices, such as a smartphone.

[0009] In this way, an (optionally multi-stage) in-air gesture performed by the user can directly cause operations to be performed to control one or more electronic devices. Other optionally multi-stage in-air gestures performed by the user can perform automatic operations, either at a head-wearable device, or at another electronic device. For example, a multi-stage in-air gesture (e.g., a pinch, tap, and snap gesture) performed by the user can initiate an automatic operation such as capturing a photo or video. In this example, the use of multiple stages for the gesture prevents the user from unintentionally capturing images when the user inadvertently performs a pinch, tap, or snap gesture, or performs the gesture as part of an activity unrelated to photo taking.

[0010] As an illustrative example of the applications of gesture detection, suppose a person, Robin, wants to navigate a user interface (e.g., to open a music application and select a playlist to listen to) while on a crowded bus or train. Conventionally, Robin would need to pull out her mobile phone or other device. Additionally, after Robin retrieves her mobile phone or device, she will need to perform a plurality of operations using a touch-sensitive surface or keyboard and mouse. This could be challenging and/or burdensome if Robin is already holding something, or does not have easy access to her devices. Moreover, using a mobile phone or device (or relying on large gestures or voice commands) can compromise Robin's privacy in such a situation with many people around.

[0011] A system described herein allows Robin to navigate a user interface quickly and efficiently without needing to retrieve any devices (or without requiring large gestures or voice commands that could be socially unacceptable or impractical). For example, Robin can navigate the user-interface and execute commands with small in-air gestures (e.g., wrist rotations and/or thumb and finger movements) that are detected by sensors at one or more wearable devices. This approach is quick and efficient for Robin, helps preserve her privacy, and can save energy at the wearable devices. The user interface can be displayed to Robin on a head-wearable device, the wrist-wearable device, and/or any other intermediary device. In this way, Robin is provided a hands-free method of executing commands and/or navigating the user interface quickly and efficiently.

[0012] As a second illustrative example of the applications of gesture detection, in this case multi-stage gesture detection, suppose Robin, is walking in a park and wants to quickly capture an image of a nearby bird before it flies away. Conventionally, Robin would need to pull out her mobile phone or other imaging device to take the photo. Additionally, after Robin retrieves her mobile phone or camera, she will need to perform a plurality of operations to take the photo. During this process, the bird may be startled and fly away before Robin can capture the image.

[0013] A system described herein allows Robin to quickly capture an image of a bird without needing to perform a plurality of operations at a user interface or make large gestures (that may startle the bird). In this example, Robin can take a photo and/or navigate a user-interface with small in-air gestures that are detected by sensors at one or more wearable devices. This approach to image capture is quick and efficient for Robin and can save energy at the wearable devices (e.g., a display is not required, nor is navigation of multiple graphical user interfaces). The photo can be displayed to Robin on a head-wearable device, the wrist-wearable device, a smartphone, and/or any other intermediary device. In this way, Robin is provided a hands-free method of capturing the image quickly and efficiently.

[0014] To continue this second example, suppose that after capturing an image, Robin wants to send the captured image of the bird to a friend. Conventionally, Robin would need use a smartphone or other intermediary device to send the captured image. Additionally, Robin would likely need to perform a plurality of operational steps on a graphical user interface to send the email. With the system described herein, Robin could use another in-air hand gesture to send the captured image without needing to utilize another electronic device such as a smartphone and/or laptop. In this example, Robin could perform the multi-stage in-air gesture to share the captured image with her friend without navigating multiple menus and/or graphical user interfaces on a smartphone or other intermediary device.

[0015] These improvements allow for the wearable devices to be designed such that they are comfortable, functional, practical, and socially acceptable for day-to-day use. Further, these improvements allow users to interact with wearable devices and/or user interface without requiring direct physical contact with any of the devices. Further, the user can also use certain optionally multi-stage, in-air gestures to modify which electronic device is being interacted with. All this furthers the goal of getting more users to adopt emerging technologies in the artificial-reality (AR and VR) spaces for more use cases, especially beyond just gaming uses in large, well-defined open spaces.

[0016] Further, the systems and methods described herein can allow for a more efficient and simplified man-machine interface, because they can provide a user with a means for interacting with electronic devices and digital mediums without inconveniencing the user or requiring the user to physically interact with any electronic devices. Therefore, the improvements simplify the user interface by providing fewer visual elements and simplify user input for interacting with such interfaces. For example, a single operation, as described herein, is capable of being executed by at least a multi-stage in-air gesture, and each variation of multi-stage in-air gesture can have its own independent operation, further defining the potential modes of interaction available to the user. Therefore, the user can execute more operations without dealing with the inconvenience of scrolling through menus or user interface elements Some of the gestures and operations described herein can be performed without any user interfaces being displayed, which allows users to interact with digital technology more seamlessly as they perform their daily tasks in the physical world and reduces energy consumption of the digital technology.

[0017] In accordance with some embodiments, a method is provided for using wrist movements to control a user-interface. The method includes: (i) receiving, via one or more neuromuscular-signal sensors of a wrist-wearable device worn by a user, data generated during performance of an in-air wrist movement by the user; (ii) moving a point of focus on the user interface in accordance with the in-air wrist movement; (iii) receiving, via the one or more neuromuscular-signal sensors, additional data generated during performance of an in-air gesture by the user; (iv) determining

that the in-air gesture is an execution gesture; and (v) executing a command corresponding to the execution gesture.

[0018] In accordance with some embodiments, a method is provided for using in-air gestures to control a point of focus in a user-interface. The method includes: (i) receiving, via one or more sensors of a wrist-wearable device worn by a user, data generated during performance of an in-air hand gesture by the user; (ii) determining, based on the sensor data, that the in-air hand gesture is a user-interface control gesture; (iii) moving a point of focus on the user interface in accordance with the user-interface control gesture; and (iv) in accordance with a determination that the point of focus is within a threshold distance of a selectable user interface element, selecting the user interface element by snapping the point of focus to the selectable user interface element.

[0019] In accordance with some embodiments, a method is provided for using a multi-stage in-air hand gesture detected at a wrist wearable device to activate user-interface interactions. The method includes receiving, via one or more sensors of a wrist-wearable device worn by a user, data generated from performance of a multi-stage in-air hand gesture by the user. The method also includes, in accordance with a determination that a first stage of the multi-stage in-air hand gesture is a priming gesture, activating a user interface, and in accordance with a determination that a second stage of the multi-stage in-air hand gesture is a control gesture received within a predefined threshold amount of time of the priming gesture, executing a command for the user interface that corresponds to the control gesture.

[0020] In accordance with some embodiments, a method is provided for using a gating in-air hand gesture for interacting with a user interface. The method includes while a gating in-air hand gesture is maintained, receiving a first indication of performance of an adjustment in-air hand gesture of a first magnitude, the adjustment in-air hand gesture of the first magnitude being directed to a user interface object presented via a head-wearable device, the user interface object associated with a plurality of values. The method also includes, in response to receiving the first indication of the performance of the adjustment in-air hand gesture of the first magnitude, adjusting the user interface object to have a first state after moving through some of the plurality of values based on the first magnitude. The method further includes, after receiving an indication of a release of the gating in-air hand gesture, in response to receiving a second indication of performance of the adjustment in-air hand gesture, forgoing adjusting the user interface object such that the user interface object continues to have the first state. The method also includes, while the gating in-air hand gesture is again maintained, receiving a third indication of performance of the adjustment in-air hand gesture of a second magnitude, distinct from the first magnitude, the adjustment in-air hand gesture of the second magnitude being directed to the user interface object while it has the first state. The method additionally includes, in response to receiving the third indication of the performance of the adjustment in-air hand gesture of the second magnitude, adjusting the user interface object to move through more of the plurality of values based on the second magnitude such that the user interface object has a second state, distinct from the first state.

[0021] In accordance with some embodiments, a method is provided for using a multi-stage in-air hand gesture for user-interface interactions. The method includes receiving, via one or more sensors of a wrist-wearable device worn by a user, data generated from performance of a multi-stage in-air hand gesture by the user. The method also includes, in accordance with a determination that a first stage of the multi-stage in-air hand gesture is a priming gesture, identifying an initial position of a body part of the user. The method further includes, in accordance with a determination that a second stage of the multi-stage in-air hand gesture is a navigation gesture, navigating through a user interface based on a change in position of the body part from the initial position during performance of the navigation gesture, wherein a navigation speed is based on the change in position of the body part.

[0022] In some embodiments, a computing device (e.g., a wrist-wearable device or a head-wearable device, or an intermediary device, such as a smartphone or desktop or laptop computer that can be configured to coordinate operations at the wrist-wearable device and the head-wearable device) includes one or more processors, memory, a display (in some embodiments, the display can be optional, such as for certain example intermediary devices that can coordinate operations at the wrist-wearable device and the head-wearable device, and thus have ample processing and power resources, but need not have its own display), and one or more programs stored in the memory. The programs are configured for execution by the one or more processors. The one or more programs include instructions for performing (or causing performance of) any of the methods described herein (e.g., including methods **800**, **900**, **1000**, **1600**, **2800**, and **2850** that are described in detail below).

[0023] In some embodiments, a non-transitory computer-readable storage medium stores one or more programs configured for execution by a computing device (e.g., a wrist-wearable device or a head-wearable device, or an intermediary device, such as a smartphone or desktop or laptop computer that can be configured to coordinate operations at the wrist-wearable device and the head-wearable device) having one or more processors, memory, and a display (in some embodiments, the display can be optional, such as for certain example intermediary devices that can coordinate operations at the wrist-wearable device and the head-wearable device, and thus have ample processing and power resources, but need not have its own display). The one or more programs include instructions for performing (or causing performance of) any of the methods described herein (e.g., including methods **800**, **900**, **1000**, **1600**, **2800**, and **2850** that are described in detail below).

[0024] Thus, methods, systems, and computer-readable storage media are disclosed for neuromuscular-signal-based detection of in-air hand gestures. Such methods and systems may complement or replace conventional methods for gesture detection.

[0025] The features and advantages described in the specification are not necessarily all inclusive and, in particular, some additional features and advantages will be apparent to one of ordinary skill in the art in view of the drawings, specification, and claims provided in this disclosure. Moreover, it should be noted that the language used in the specification has been principally selected for readability

and instructional purposes and has not necessarily been selected to delineate or circumscribe the subject matter described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] So that the present disclosure can be understood in greater detail, a more particular description can be had by reference to the features of various embodiments, some of which are illustrated in the appended drawings. The appended drawings, however, merely illustrate pertinent features of the present disclosure and are therefore not to necessarily be considered limiting, for the description can admit to other effective features as the person of skill in this art will appreciate upon reading this disclosure.

[0027] FIGS. **1**A-**1**H illustrate an example user scenario of interacting with an artificial-reality system (e.g., including at least a virtual reality headset and a wrist-wearable device) in accordance with some embodiments.

[0028] FIGS. **2**A-**2**F illustrate an example user scenario of interacting with a wearable device in accordance with some embodiments.

[0029] FIGS. **3**A-**3**C illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments.

[0030] FIGS. **4**A-**4**F illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments.

[0031] FIGS. **5**A-**5**E illustrate an example user scenario of interacting with an artificial-reality system (e.g., including at least augmented-reality glasses and a wrist-wearable device) in accordance with some embodiments.

[0032] FIGS. **6**A-**6**G illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments.

[0033] FIGS. **6**H-**60** illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments.

[0034] FIGS. **7**A-**7**R illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments.

[0035] FIGS. **7**S-**7**U illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments.

[0036] FIGS. **8**A-**8**B are flow diagrams illustrating an example method for using in-air gestures to control a point of focus in a user-interface in accordance with some embodiments.

[0037] FIGS. **9**A-**9**B are flow diagrams illustrating another example method for using in-air gestures to control a point of focus in a user-interface in accordance with some embodiments.

[0038] FIGS. **10**A-**10**B are flow diagrams illustrating an example method for using wrist movements to control a user-interface in accordance with some embodiments.

[0039] FIGS. **11**A, **11**B, **11**C-**1**, **11**C-**2**, **11**D-**1**, and **11**D-**2** illustrate example AR systems in accordance with some embodiments.

[0040] FIGS. **12**A-**12**B illustrate an example wrist-wearable device in accordance with some embodiments.

[0041] FIGS. **13**A, **13**B-**1**, **13**B-**2**, and **13**C illustrate example artificial-reality systems in accordance with some embodiments.

[0042] FIGS. **14**A-**14**B illustrate an example handheld device in accordance with some embodiments.

[0043] FIGS. **15**A-**15**C illustrate example wearable gloves in accordance with some embodiments.

[0044] FIGS. **16**A-**16**F illustrate an example user scenario of interacting with an artificial-reality system (e.g., including at least a virtual reality headset and a wrist-wearable device) in accordance with some embodiments.

[0045] FIGS. **17**A-**17**C illustrate another example user scenario of interacting with an artificial-reality system (e.g., including at least augmented-reality glasses and a wrist-wearable device) in accordance with some embodiments.

[0046] FIGS. **18**A-**18**D illustrate another example user scenario of interacting with an artificial-reality system (e.g., including at least augmented-reality glasses and a wrist-wearable device) in accordance with some embodiments.

[0047] FIGS. **19**A-**19**D illustrate another example user scenario of interacting with an artificial-reality system (e.g., including at least augmented-reality glasses and a wrist-wearable device) in accordance with some embodiments.

[0048] FIGS. **20**A-**20**D illustrate an example user scenario of interacting with a wearable device in accordance with some embodiments.

[0049] FIGS. **21**A-**21**D illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments.

[0050] FIGS. **22**A-**22**S illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments.

[0051] FIGS. **23**A-**23**B are flow diagrams illustrating an example method for activating user-interface interactions in accordance with some embodiments.

[0052] FIGS. **23**C-**23**D are flow diagrams illustrating an example method for activating user-interface interactions in accordance with some embodiments.

[0053] FIGS. **24**A-**24**E illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments.

[0054] FIGS. **25**A-**25**H illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments.

[0055] FIGS. **26**A-**26**C illustrate graphs representing example relationships between navigation speed and gesture distance in accordance with some embodiments.

[0056] FIGS. **27**A-**27**D illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments.

[0057] FIG. **28** is a flow diagram illustrating an example method for using a multi-stage in-air hand gesture for user-interface interactions in accordance with some embodiments.

[0058] In accordance with common practice, the various features illustrated in the drawings are not necessarily drawn to scale, and like reference numerals can be used to denote like features throughout the specification and Figures.

DETAILED DESCRIPTION

[0059] Embodiments of this disclosure may include or be implemented in conjunction with various types or embodiments of artificial-reality systems. Artificial reality constitutes a form of reality that has been altered by virtual objects for presentation to a user. Such artificial reality may include and/or represent virtual reality (VR), augmented reality (AR), mixed reality (MR), hybrid reality, or some combination and/or variation of one or more of the these. Artificial-reality content may include completely generated con-

tent or generated content combined with captured (e.g., real-world) content. The artificial-reality content may include video, audio, haptic feedback, or some combination thereof, any of which may be presented in a single channel or in multiple channels (such as stereo video that produces a three-dimensional effect to a viewer). Additionally, in some embodiments, artificial reality may also be associated with applications, products, accessories, services, or some combination thereof, which are used, for example, to create content in an artificial reality and/or are otherwise used in (e.g., to perform activities in) an artificial reality.

[0060] Artificial-reality systems may be implemented in a variety of different form factors and configurations. Some artificial-reality systems include a near-eye display (NED), which provides visibility into the real world (e.g., the AR system **7000** in FIG. **13**A) or that visually immerses a user in an artificial reality (e.g., the virtual-reality system **7010** in FIG. **13**B). While some artificial-reality devices are self-contained systems, other artificial-reality devices communicate and/or coordinate with external devices to provide an artificial-reality experience to a user. Examples of such external devices include handheld controllers, mobile devices, desktop computers, devices worn by a user (e.g., the HIPD **8000** in FIG. **14**A), devices worn by one or more other users, and/or any other suitable external system.

Example User Gesture Scenarios

[0061] As an example, suppose Robin is jogging while wearing augmented-reality glasses and she receives a message from a friend. In this example, Robin would like to respond to her friend without interrupting her jogging. Conventionally, Robin would need to manipulate buttons on her glasses, or pull out a connected electronic device and navigate on a touch display or keyboard in order to compose and send a reply to the message. With the systems described herein, Robin can use in-air hand gestures to compose and send a response without interrupting her jog. For example, Robin could use wrist rotations to move a point of focus to elements in the messenger interface and use tap (e.g., the thumb contacting the side of the index finger) or pinch (e.g., the thumb contacting the middle finger) gestures to activate functions associated with the elements. The gestures in this example are small and unobtrusive, not requiring a large, open space for Robin to maneuver or the manipulation of handheld devices.

[0062] FIGS. **1**A-**1**H illustrate an example user scenario of interacting with an artificial-reality system in accordance with some embodiments. The user **115** in FIG. **1**A is wearing a head-wearable device **110** (e.g., a virtual reality headset) and a wrist-wearable device **120** (e.g., a smartwatch). In some embodiments, the wrist-wearable device **120** is an instance of the wrist-wearable device **6000** (FIG. **12**). In some embodiments, the head-wearable device **110** is an instance of the augmented-reality system **7000**. The user **115** in FIG. **1**A is viewing a scene **130** that includes a messenger interface **108** (e.g., corresponding to a messenger application). In the example of FIG. **1**A, the user **115** is not performing a gesture.

[0063] FIG. **1**B shows the user **115** performing a first gesture (e.g., a priming gesture) that involves the user curling their fingers to their palm. FIG. **1**B further shows the scene **130** updating (responsive to the first gesture) to include a point of focus **105** selecting an icon **106** (e.g., corresponding a photo gallery command) on the interface **108**. In accordance with some embodiments, the priming gesture in FIG. **1**B causes the interface **108** to be responsive to navigation gestures (e.g., causes the point of focus **105** appear and be manipulable by the user **115**). Although FIG. **1**B shows the first gesture involving the user maintaining their thumb above their index finger, in some embodiments, the first gesture may be performed with the thumb resting on the index finger. FIG. **1**B illustrates the first gesture as a priming gesture, however in other embodiments the priming gesture includes other in-air gestures performed by the user **115** (e.g., a maintained pinch gesture using the user's thumb and another phalange, a quick pinch gesture using two of the user's phalanges, and/or a double pinch gesture). For example, a priming gesture for navigation gestures can be a thumb tap-and-hold gesture. In some embodiments, the icon **106** is selected by default (e.g., based on a setting in the messenger application, or a user preference). In some embodiments, the icon **106** is selected based on a gaze of the user (e.g., determined via eye tracking). In some embodiments, the icon **106** had the focus the previous time the user interacted with the interface **108** and the messenger application defaults to that previous point of focus.

[0064] FIG. **1**C shows the user **115** rotating their wrist (e.g., a navigation gesture) while maintaining the first gesture from FIG. **1**B. The rotation in FIG. **1**C is inward (e.g., toward the user's body) and corresponds to a leftward direction from the perspective the user **115**. FIG. **1**C further shows the point of focus **105** moving to the left in the interface **108** and selecting the icon **107** (e.g., corresponding to a photo capture command). In some embodiments, the point of focus **105** continues to move to the left while the user maintains the wrist rotation gesture. In some embodiments, the point of focus **105** moves to the left a preset amount per gesture (e.g., regardless of how long the user maintains the gesture). For example, the point of focus **105** moves to an adjacent selectable user interface element each time a navigation gesture is performed. In some embodiments, the point of focus **105** moves with a speed that corresponds to a speed of the wrist rotation. For example, the point of focus **105** moves at one of two different speeds based on whether the wrist rotation gesture has a speed above or below a speed threshold. In some embodiments, the point of focus **105** moves with a speed that corresponds to an angle of the wrist rotation. For example, the point of focus **105** moves at one of two different speeds based on whether the wrist rotation gesture has an angle above or below an angular threshold.

[0065] FIG. **1**D shows the user **115** rotating their wrist (e.g., a navigation gesture) while maintaining the first gesture from FIG. **1**C. The rotation in FIG. **1**D is outward (e.g., away from the user's body) and corresponds to a rightward direction from the perspective of the user **115**. FIG. **1**D further shows the point of focus **105** moving to the right in the interface **108** and selecting the icon **109** (e.g., corresponding to an emoji menu).

[0066] FIG. **1**E shows the user **115** performing a tap gesture (e.g., a control gesture) that involves the user's thumb contacting a surface of the user's index finger. In the example of FIG. **1**E, the user is maintaining the first gesture from FIG. **1**D. In some embodiments, a control gesture (e.g., the tap gesture) can be performed and recognized without maintaining the priming gesture (e.g., the first gesture). In some embodiments, (e.g., where the user is resting the thumb against the surface of the index finger while perform-

ing the first gesture), the tap gesture is detected in accordance with the thumb pressing against the surface of the index finger with a force that meets one or more criteria (e.g., with a force that is greater than a preset threshold). For example, the tap gesture could be a 'deep' or 'forceful' tap gesture that requires a sufficient amount of force to be recognized by the sensors (e.g., the sensors in the wrist-wearable device **120**). In accordance with some embodiments, the tap gesture corresponds to a command to activate the selected icon (e.g., the icon **109**). FIG. **1**E further shows the emoji menu **111** being displayed (e.g., in response to activation of icon **109**). The point of focus **105** is selecting a winking emoji **113** in the example of FIG. **1**E. In some embodiments, the emoji **113** is selected by default (e.g., based on a setting in the messenger application, or a user preference). In some embodiments, the emoji **113** is selected based on a gaze of the user (e.g., determined via eye tracking). In some embodiments, the emoji **113** is the last emoji selected by the user within the messenger application and the messenger application defaults to that previous selection.

[0067] FIG. **1**F shows the user **115** rotating their wrist (e.g., a navigation gesture) while maintaining the first gesture from FIG. **1**E. The rotation in FIG. **1**F is upward (e.g., the user's thumb moves towards the user's arm as a result of the rotation). FIG. **1**F further shows the point of focus **105** moving up in the interface **108** and selecting the emoji **116**.

[0068] FIG. **1**G shows the user **115** rotating their wrist (e.g., a navigation gesture) while maintaining the first gesture from FIG. **1**F. The rotation in FIG. **1**G is downward (e.g., the user's pinkie finger moves toward the user's arm as a result of the rotation). FIG. **1**G further shows the point of focus **105** moving down in the interface **108** and selecting the emoji **117**.

[0069] FIG. **1**H shows the user **115** performing a tap gesture (e.g., a control gesture) that involves the user's thumb contacting a surface of the user's index finger. In the example of FIG. **1**E, the user is maintaining the first gesture from FIG. **1**G. In some embodiments, a control gesture (e.g., the tap gesture) can be performed and recognized without maintaining the priming gesture (e.g., the first gesture). In accordance with some embodiments, the tap gesture corresponds to a command to insert the selected emoji **117** into the response box **121**. FIG. **1**H further shows the emoji menu **111** ceasing to be displayed (e.g., in response to the tap gesture). In some embodiments, the emoji menu **111** continues to be displayed until a close (or 'go back') command is received from the user **115**. In the example of FIG. **1**H, the point of focus is no longer displayed (e.g., nothing is selected) in accordance with the tap gesture being performed. In some embodiments, the point of focus continues to be displayed (e.g., until the user releases the first gesture or performs a dismissal gesture).

[0070] In some embodiments, the wrist-wearable device **120** and/or the head-wearable device **110** provides visual, audio, and/or haptic feedback to the user to indicate that a performed gesture has been detected (e.g., distinct feedback provided in response to each type of gesture).

[0071] FIGS. **2**A-**2**F illustrate an example user scenario of interacting with a wearable device in accordance with some embodiments. The user **115** in FIG. **2**A is wearing a wrist-wearable device **120** (e.g., a smartwatch) that includes a display **204** showing a photo gallery user interface **206** (e.g., a photo application). The user interface **206** in FIG. **2**A includes a plurality of images displayed in a single column with an image **208** presented near a center of the display. The user **115** in FIG. **2**A is not performing a gesture.

[0072] FIG. **2**B shows the user **115** performing a first pinch gesture (e.g., a navigation gesture) that involves the user's index finger contacting the thumb (one time). FIG. **2**B further shows the interface **206** updating (responsive to the first pinch gesture) to present an image **210** near the center of the display. In the example of FIG. **2**B, the first pinch gesture causes the plurality of images to scroll downward once time resulting in the image **208** moving to a top of the display **204** and the image **210** moving near the center of the display **204**. For example, the index finger pinch gesture shown in FIG. **2**B corresponds to a downward (forward) navigation command.

[0073] FIG. **2**C shows the user **115** performing a second pinch gesture (e.g., a navigation gesture) that involves the user's middle finger contacting the thumb (one time). FIG. **2**C further shows the interface **206** updating (responsive to the second pinch gesture) to present the image **208** near the center of the display. In the example of FIG. **2**C, the second pinch gesture causes the plurality of images to scroll upward one time resulting in the image **210** moving to a bottom of the display **204** and the image **208** moving near the center of the display **204**. For example, the middle finger pinch gesture shown in FIG. **2**C corresponds to an upward (reverse) navigation command.

[0074] FIG. **2**D shows the user **115** performing a pinch-and-hold gesture (e.g., a navigation gesture) that involves the user's index finger maintained in contact with the thumb. FIG. **2**D further shows the interface **206** updating (responsive to the pinch-and-hold gesture) to present an image **212** near the center of the display. In the example of FIG. **2**D, the pinch-and-hold gesture causes the plurality of images to scroll downward (continuously while the gesture is maintained) resulting in an image **212** moving near the center of the display **204**. For example, the index finger pinch-and-hold gesture shown in FIG. **2**D corresponds to a continuous downward (forward) navigation command. The relative location of the image **212** within the photo gallery column is indicated by the indicator **214** having a position **214**-*a* in FIG. **2**D (e.g., indicating that the image **212** is near the top of the photo gallery column). In some embodiments, a force of the pinch-and-hold gesture corresponds to scroll speed for the corresponding navigation command. For example, a force between the index finger and thumb below a force threshold results in a scroll at a first speed and a force between the index finger and thumb above the force threshold results in a scroll at a second speed (greater than the first speed).

[0075] FIG. **2**E shows the user **115** maintaining the pinch-and-hold gesture. FIG. **2**E further shows the interface **206** updating (responsive to the pinch-and-hold gesture being maintained) to present an image **216** near the center of the display. The relative location of the image **216** within the photo gallery column is indicated by the indicator **214** having a position **214**-*b* in FIG. **2**E (e.g., indicating that the image **216** is near the bottom of the photo gallery column).

[0076] FIG. **2**F shows the user **115** releasing the pinch-and-hold gesture and the image **216** being selected. In the example of FIG. **2**F, the image **216** is selected in accordance with it being nearest to the middle of the display **204** at the time when the pinch-and-hold gesture is released. FIG. **2**E further shows a menu **218** being presented (e.g., a menu of

options for manipulating the image **216**) in accordance with the selection of the image **216**. In some embodiments, the menu **218** is presented in response to a separate gesture (e.g., an activation/control gesture) performed while the image **216** is selected.

[0077] FIGS. **3**A-**3**C illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments. The user **115** in FIG. **3**A is wearing a wrist-wearable device **120** (e.g., a smartwatch) that includes a display **204** showing a user interface **304** (e.g., a settings interface). The user interface **304** in FIG. **3**A includes a plurality of privacy settings **308** (e.g., selectable user interface elements) for an application (e.g., an application executing on the wrist-wearable device **120**). In the example of FIG. **3**A, a privacy setting **308-1** is selected by a point of focus **306**. The user **115** in FIG. **3**A is not performing a gesture. In some embodiments, the privacy setting **308-1** is selected by default (e.g., based on a setting or user preference). In some embodiments, the privacy setting **308-1** is selected based on a gaze of the user (e.g., determined via eye tracking). In some embodiments, the privacy setting **308-1** is selected in response to a previous gesture (not shown) from the user **115**.

[0078] FIG. **3**B shows the user **115** performing a first pinch gesture (e.g., a navigation gesture) that involves the user's index finger contacting the thumb (one time). FIG. **3**B further shows the interface **304** updating (responsive to the first pinch gesture) to move the point of focus **306** to a privacy setting **308-2**. In the example of FIG. **3**B, the first pinch gesture causes the point of focus **306** to move downward once time. For example, the index finger pinch gesture shown in FIG. **3**B corresponds to a downward (forward) navigation command.

[0079] FIG. **3**C shows the user **115** performing a second pinch gesture (e.g., a navigation gesture) that involves the user's pinkie finger contacting the thumb (one time). FIG. **3**C further shows the interface **304** updating (responsive to the second pinch gesture) to show general settings (e.g., close the privacy settings and return to general settings). For example, the pinkie finger pinch gesture shown in FIG. **3**C corresponds to a 'close' or 'go back' navigation command. FIG. **3**C further shows the privacy option **310** selected by the point of focus **306**. In some embodiments, the privacy option **310** is selected by default (e.g., based on a setting or user preference). In some embodiments, the privacy option **310** is selected in response to the user **115** closing the privacy settings shown in FIG. **3**B. Thus, in the example of FIGS. **3**A-**3**C a first type of gesture (e.g., the index finger pinch gesture) corresponds to navigation through a set of options and a second type of gesture (e.g., the pinkie finger pinch gesture) corresponds to navigation through a set of menus (e.g., a hierarchy of menus).

[0080] In some embodiments, the wrist-wearable device **120** provides visual, audio, and/or haptic feedback to the user to indicate that a performed gesture has been detected (e.g., distinct feedback provided in response to each type of gesture).

[0081] FIGS. **4**A-**4**F illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments. The user **115** in FIG. **4**A is wearing a head-wearable device **402** (e.g., augmented-reality glasses) and a wrist-wearable device **120** (e.g., a smartwatch). In some embodiments, the wrist-wearable device **120** is an instance of the wrist-wearable device **6000** (FIG. **12**). In some embodiments, the head-wearable device **402** is an instance of the augmented-reality system **7000**. The user **115** in FIG. **4**A is viewing a scene **404** that includes an appearance settings interface **406** (e.g., corresponding to an application or operating system). In some embodiments, the scene **404** corresponds to a display of the wrist-wearable device **120** or a display of the head-wearable device **402**. For example, the scene **404** is displayed by the head-wearable device **402** in response to the user **115** gazing toward the wrist-wearable device **120**. In the example of FIG. **4**A, the user **115** is not performing a gesture.

[0082] FIG. **4**B shows the user **115** performing a first gesture (e.g., a priming gesture) that involves the user curling their fingers to their palm. FIG. **4**B further shows the scene **404** updating (responsive to the first gesture) to include a point of focus (e.g., cursor) **408** at a location **408**-*a* on the interface **406**. In accordance with some embodiments, the priming gesture in FIG. **4**B causes the interface **406** to be responsive to navigation gestures (e.g., causes the point of focus **408** appear and be manipulable by the user **115**). In some embodiments, the location **408**-*a* of the point of focus (e.g., an initial location for the point of focus) is selected by default (e.g., based on a setting or user preference). In some embodiments, the location **408**-*a* of the point of focus is a center of the user interface **406** or the scene **404**.

[0083] FIG. **4**B further shows an indicator **410** (e.g., a virtual directional-pad) indicating that the user **115** is able to move their thumb as if the thumb is in contact with a directional-pad. In some embodiments, the indicator **410** is presented (e.g., via the head-wearable device **402**) to the user **115** in response to the first gesture. In some embodiments, the indicator **410** is not presented to the user **115** (e.g., in accordance with a preference setting). In some embodiments, the position of the user's thumb when the first gesture is performed becomes an origin point (e.g., coordinates 0,0) for the virtual directional-pad.

[0084] FIG. **4**C shows the user **115** moving their thumb in a direction extending away from the user's wrist (e.g., a navigation gesture). FIG. **4**C further shows the point of focus **408** moving to the right on the interface **406** (responsive to the thumb movement) to a location **408**-*b* on the interface **406**. FIG. **4**C further shows the indicator **410** updating to indicate that the user **115** is activating a rightward direction on the virtual directional-pad. FIG. **4**C also shows a snap boundary (threshold) **412** for a user interface element **414**. In the example of FIG. **4**C, the location **408**-*b* of the point of focus **408** is beyond the snapping boundary **412** and the user interface element **414** is not selected.

[0085] FIG. **4**D shows the user **115** continuing to have their thumb in the direction away from their wrist (e.g., maintaining the navigation gesture). FIG. **4**D further shows the point of focus **408** moving to the right on the interface **406** (responsive to maintained thumb gesture) to a location **408**-*c* on the interface **406**. In the example of FIG. **4**D, the point of focus **408** has moved within the snap boundary for the user interface element **414** and has snapped to the user interface element **414** (e.g., as indicated by the point of focus **408**-*c* location being in the center of the user interface element **414**). FIG. **4**D also shows that the user interface element **414** is selected in accordance with the point of focus **408** snapping to the user interface element **414**. In some embodiments, the point of focus **408** is not displayed to the user while the point of focus **408** is snapped to a user

interface element (e.g., the point of focus **408** is replaced with an indication that the user interface element is selected).

[0086] FIG. **4**E shows the user **115** moving their thumb in a direction contracting toward from the user's wrist (e.g., a navigation gesture). FIG. **4**E further shows the point of focus **408** moving to the left on the interface **406** (responsive to the thumb movement) to a location **408**-*d* on the interface **406**. In the example of FIG. **4**E, the location **408**-*d* of the point of focus **408** is overlaid with the user interface element **414** (e.g., is within an un-snap boundary) and the user interface element **414** continues to be selected. FIG. **4**E further shows the indicator **410** updating to indicate that the user **115** is activating a leftward direction on the virtual directional-pad.

[0087] FIG. **4**F shows the user **115** continuing to have their thumb in the direction toward their wrist (e.g., maintaining the navigation gesture). FIG. **4**F further shows the point of focus **408** moving to the left on the interface **406** (responsive to maintained thumb gesture) to a location **408**-*e* on the interface **406**. In the example of FIG. **4**F, the point of focus **408** has moved has snapped to the user interface element **416** (e.g., as indicated by the point of focus **408**-*e* location being in the center of the user interface element **416**). In some embodiments, the point of focus **408** snaps to the user interface element **416** in accordance with movement of the point of focus **408** within a snap boundary of the user interface element **416**. In some embodiments, the point of focus **408** snaps to the user interface element **416** in accordance with the point of focus **408** unsnapping from the user interface element **414**. For example, the point of focus **408** moves beyond an un-snap boundary for the user interface element **414** and automatically snaps to the user interface element **416**. In some embodiments, the point of focus **408** snaps to the user interface element **416** in accordance with the point of focus **408** moving to a location where the user interface element **416** is the closest user interface element to the point of focus **408**. FIG. **4**F also shows that the user interface element **416** is selected in accordance with the point of focus **408** snapping to the user interface element **416**.

[0088] In some embodiments, the wrist-wearable device **120** and/or the head-wearable device **402** provides visual, audio, and/or haptic feedback to the user to indicate that a performed gesture has been detected (e.g., distinct feedback provided in response to each type of gesture).

[0089] FIGS. **5**A-**5**E illustrate an example user scenario of interacting with an artificial-reality system in accordance with some embodiments. The user **115** in FIG. **5**A is wearing a head-wearable device **402** (e.g., augmented-reality glasses) and a wrist-wearable device **120** (e.g., a smart-watch). In some embodiments, the wrist-wearable device **120** is an instance of the wrist-wearable device **6000** (FIG. **12**). In some embodiments, the head-wearable device **402** is an instance of the augmented-reality system **7000**. The user **115** in FIG. **5**A is viewing a scene **504** that includes a calendar interface **506** (e.g., corresponding to a calendar application). The calendar interface **506** in FIG. **5**A shows the month of January with no event selected. In some embodiments, the calendar interface **506** is presented in response to a user performing a control gesture while an icon for the calendar application is selected. In the example of FIG. **5**A, the user **115** is not performing a gesture. FIG. **5**A further shows a scale **510** indicating an amount of rotation of the user's wrist and including multiple rotation thresholds, labeled T**1** and T**2**.

[0090] In some embodiments, a wrist rotation gesture with rotation less than the T**1** threshold corresponds to a first type of navigation gesture (e.g., navigate to adjacent day), a wrist rotation gesture with a rotation between the T**1** and T**2** thresholds corresponds to a second type of navigation gesture (e.g., navigate to next event), and a wrist rotation gesture with a rotation greater than the T**2** threshold corresponds to a third type of navigation gesture (e.g., navigate to adjacent month).

[0091] FIG. **5**B shows the user **115** performing a first gesture (e.g., a priming gesture) that involves the user curling their fingers to their palm. FIG. **5**B further shows the scene **504** updating (responsive to the first gesture) to select an event on January 1st on the interface **506**. In accordance with some embodiments, the priming gesture in FIG. **5**B causes the interface **506** to be responsive to navigation gestures. Although FIG. **5**B shows the first gesture involving the user maintaining their thumb above their index finger, in some embodiments, the first gesture may be performed with the thumb resting on the index finger. In some embodiments, the January 1st event is selected by default (e.g., based on a setting in the calendar application, or a user preference). In some embodiments, the January 1st event is selected based on a gaze of the user (e.g., determined via eye tracking). In some embodiments, the January 1st event is selected in accordance with it being the first event or next event in the month (e.g., in the current month). The scale **510** in FIG. **5**B indicates that the user **115** has not rotated their wrist. In some embodiments, the positioning (orientation) of the user's wrist when the first gesture is performed is assigned as an origin point (zero point of rotation) on the scale **510**.

[0092] FIG. **5**C shows the user **115** performing a wrist rotation gesture (e.g., a navigation gesture) that involves the user rotating their wrist outward (e.g., away from their body). FIG. **5**C further shows the scene **504** updating (responsive to the wrist rotation gesture) to select an event on January 8th on the interface **506** (e.g., corresponding to activation of the next event affordance **507**). The scale **510** in FIG. **5**C indicates that the user **115** has rotated their wrist beyond the T**1** threshold but not to the T**2** threshold (e.g., has performed the second type of navigation gesture corresponding to selection of a next event) as shown by the rotation indicator **514**. In some embodiments, the January 8th event is selected in accordance with the direction of the wrist rotation and amount of rotation (e.g., the type of navigation gesture).

[0093] FIG. **5**D shows the user **115** performing another wrist rotation gesture (e.g., a navigation gesture) that involves the user rotating their wrist inward (e.g., toward their body). FIG. **5**D further shows the scene **504** updating (responsive to the wrist rotation gesture) to select an event on December 10th on the interface **506** (e.g., corresponding to activation of the previous month affordance **509**). The scale **510** in FIG. **5**D indicates that the user **115** has rotated their wrist beyond the (negative) T**2** threshold (e.g., has performed the third type of navigation gesture corresponding to navigation to an adjacent month) as shown by the rotation indicator **516**. In some embodiments, the December 10th event is selected in accordance with the direction of the wrist rotation and amount of rotation (e.g., the type of navigation gesture). In some embodiments, the wrist rotation

gesture corresponds to a command to navigate to the previous month (December) and the December 10th event is selected by default (e.g., due to it being the first event in December).

[0094] FIG. **5**E shows the user **115** performing another wrist rotation gesture (e.g., a navigation gesture) that involves the user rotating their wrist outward (e.g., away from their body). FIG. **5**E further shows the scene **504** updating (responsive to the wrist rotation gesture) to display events (none) for December 11th on the interface **506**. The scale **510** in FIG. **5**E indicates that the user **115** has rotated their wrist less than the T**1** threshold (e.g., has performed the first type of navigation gesture corresponding to navigation to an adjacent day) as shown by the rotation indicator **518**. In some embodiments, December 11th is selected in accordance with the direction of the wrist rotation and amount of rotation (e.g., the type of navigation gesture).

[0095] FIGS. **6**A-**6**G illustrate another example user scenario of interacting with the wrist-wearable device **120** in accordance with some embodiments. The user **115** in FIG. **6**A is wearing the head-wearable device **402** (e.g., augmented-reality glasses) and the wrist-wearable device **120** (e.g., a smartwatch). The user **115** in FIG. **6**A is viewing a navigable user interface **601** (e.g., a user interface corresponding to a home screen and/or landing page) on the display of the head-wearable device **402**. In some embodiments, the navigable user interface **601** is displayed in response to a wake gesture performed by the user. For example, the user **115** is able to wake the head-wearable device **402** and/or the wrist-wearable device **120** by performing a wake gesture (e.g., a middle finger and thumb double tap gesture). In some embodiments, waking the head-wearable device **402** and/or the wrist-wearable device **120** causes the navigable user interface **601** to be displayed. In some embodiments, waking the head-wearable device **402** and/or the wrist-wearable device **120** causes the system (e.g., the head-wearable device **402** and/or the wrist-wearable device **120**) to be responsive to additional gestures (such as navigational gestures and/or gestures linked to particular applications).

[0096] In some embodiments, the same or similar navigable user interface also appears on the display **204** of the wrist-wearable device as shown in FIG. **6**A. The navigable user interface **601** includes content (e.g., time and data information and an unread message) and quick-action user interface elements **602** which the user **115** can navigate to through gestures (e.g., to open selected applications in particular states). In some embodiments, the quick-action user interface elements **602** are customizable by the user **115** to fit their needs for applications they wish to access quickly. In accordance with some embodiments, the quick-action user interface elements **602** are application icons located in the user interface **601** that allow the user **115** to immediately access and open the corresponding application (e.g., in response to performing a single navigation gesture).

[0097] FIG. **6**A shows one configuration of quick-action user interface elements **602**, but this application is not limited to that configuration. In various embodiments, there are less than four or more than four quick-action user interface elements **602** (e.g., each located along a periphery of the user interface **601**). In some embodiments, each quick-action user interface element **602** navigates to a different application or page on the wrist-wearable device **120**. For example, in FIG. **6**A four different applications are represented by the quick-action user interface elements: a messaging application corresponding to quick-action user interface element **602***a*, music application corresponding to quick-action user interface element **602***b*, notifications application corresponding to quick-action user interface element **602***c*, and camera application corresponding to quick-action user interface element **602***d*. In some embodiments, other applications such as phone, email, and/or exercise applications can each be assigned a corresponding quick-action user interface element **602**.

[0098] In some embodiments, navigation to a quick-action user interface element causes activation of a function associated with the user interface element (e.g., without requiring an additional user input, such as a control gesture). In some embodiments, the function involves opening an application in a particular state. For example, navigation to a quick-action user interface element corresponding to a messaging application may cause presentation of a particular interface of the messaging application (e.g., a user interface for recent messages or a user interface for user contacts). In this way, the user is able to activate commonly used and/or important functions without requiring additional inputs or navigating additional menus or interfaces. The user **115** in FIG. **6**A is making a first gesture at a first time. In some embodiments, the first gesture is a priming gesture for navigation via a virtual directional-pad (as represented by the indicator **410**). FIGS. **6**A-**6**G, shows navigation of applications using the quick-action user interface elements.

[0099] FIG. **6**B shows the user **115** moving their thumb in a direction toward the back of their hand (e.g., an upward navigation gesture while maintaining the first gesture) at a second time, subsequent to the first time. The upward navigation gesture in FIG. **6**B corresponds to the quick-action user interface element **602***d* for a camera application (as shown in FIG. **6**A). As the user moves their thumb, the indicator **410** updates to indicate that the user **115** is activating an upward direction on the virtual directional-pad. FIG. **6**B further shows activation of the camera application in response to the user gesture, e.g., including activating an imaging device on the head-wearable device **402**. In some embodiments, an icon (e.g., camera icon **604**) is displayed for the user **115** on the display of the head-wearable device to indicate that the camera application is active. In some embodiments, the display **204** of the wrist-wearable device does not display an active camera live feed as shown in FIG. **6**B. In some embodiments, the display **204** shows an indication that the camera application is active (e.g., an icon similar to camera icon **604**). In some embodiments, the display **204** on the wrist-wearable device shows an active camera feed of what the imaging device is capturing.

[0100] FIG. **6**C shows the user **115** moving their thumb in a direction extending towards the user's wrist (e.g., a leftward navigation gesture) at a third time, subsequent to the second time. FIG. **6**C further shows the result of this gesture is the user **115** scrolling through the one or more camera options (e.g. from a photo option in FIG. **6**B and to a video option in FIG. **6**C). As the user **115** moves their thumb, the indicator **410** updates to indicate that the user **115** is activating a leftward direction on the virtual directional-pad. In some embodiments, as shown in FIG. **6**C, the display of the head-wearable device includes a video icon **606** to indicate to the user **115** that the imaging device is active and is in a video mode.

[0101] FIG. **6**D shows the user **115** moving their thumb in a direction extending away from the user's wrist (e.g., a rightward navigation gesture) at a fourth time, subsequent to the third time. As the user moves their thumb away from the user's wrist, the indicator **410** updates to indicate that the user **115** is activating a rightward direction on the virtual directional-pad. The rightward thumb movement in FIG. **6**D results in the user **115** scrolling through the one or more camera options (e.g. from the video option in FIG. **6**C and to the photo option in FIG. **6**D). In some embodiments, the one or more camera options include other options such as a gallery of photos and/or videos that the user can scroll to/from with the navigation gestures.

[0102] FIG. **6**E shows the user **115** performing a tap gesture (e.g., a control gesture while maintaining the first gesture) at a fifth time, subsequent to the fourth time. The tap gesture in FIG. **6**E involves the user's thumb contacting a surface of the user's index finger. FIG. **6**E further shows the result of the tap gesture is a captured image as indicated by the notification **608**. In some embodiments, the user can capture multiple images by performing one or more taps in to capture additional images.

[0103] FIG. **6**F shows the user **115** holding a gesture (e.g., a middle finger pinch gesture) to navigate to another screen at a sixth time, subsequent to the fifth time. In some embodiments, the user **115** navigates to a home screen by holding a pinch gesture with two phalanges (e.g. a thumb and middle finger pinch) for a predetermined amount of time (e.g. about 1-3 seconds). FIG. **6**G shows the user **115** continuing to maintain the gesture from FIG. **6**F at a seventh time, subsequent to the sixth time. In the example of FIG. **6**G, maintaining the gesture causes the user interface to be disabled (e.g., ceased to be displayed). In some embodiments, if the user **115** maintains the pinch-and-hold gesture described in FIG. **6**F for at least a preset amount of time, the user interface ceases to be presented and the display **204** of the wrist-wearable device will appear blank (e.g., powers down, goes to sleep, and/or dims). In some embodiments, maintaining the pinch-and-hold gesture does not shut off the display for the head-wearable device **402**. In some embodiments, in response to the pinch-and-hold gesture, the head-wearable device **402** ceases to display any user interface or overlay.

[0104] FIGS. **6**H-**60** illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments. For example, FIGS. **6**H-**60** illustrate different types of navigational gestures and corresponding navigation operations and functions.

[0105] The user **115** in FIG. **6**H is wearing the head-wearable device **402** (e.g., augmented-reality glasses) and the wrist-wearable device **120** (e.g., a smartwatch). The user **115** in FIG. **6**H is viewing a navigable user interface **650** (e.g., a user interface corresponding to a home screen and/or landing page) on the display of the head-wearable device **402** and/or the wrist-wearable device **120**. In some embodiments, the navigable user interface **650** is displayed in response to a wake gesture performed by the user. The navigable user interface **650** includes an icon **652** corresponding to a first application and associated action icons **654** (e.g. action icons **654-1**-**654-3**) corresponding to particular functions for the first application. The navigable user interface **650** also includes an icon **656** corresponding to a second application and associated action icons **658** (e.g. action icons **654-1**-**654-3**) corresponding to particular functions for the second application. The navigable user interface **650** further includes other application icons **660**, **662**, and **664**. In some embodiments, each application is stored/executed at the head-wearable device **402** and/or the wrist-wearable device **120**. In some embodiments, an application is stored/executed at an intermediary device coupled to the wearable devices shown. In FIG. **6**H the user **115** is not performing a gesture.

[0106] FIG. **6**I shows the user **115** performing a first gesture (e.g., a first type of priming gesture) that involves the user curling their fingers to their palm. FIG. **6**I further shows the user interface **650** updating (responsive to the first gesture) to include a point of focus **667** selecting the icon **652** (e.g., corresponding a first application). In accordance with some embodiments, the priming gesture in FIG. **6**I causes the interface **650** to be responsive to navigation gestures (e.g., causes the point of focus **667** be presented and be manipulable by the user **115**). In some embodiments, the icon **652** is selected based on a gaze of the user (e.g., determined via eye tracking). In some embodiments, the icon **652** is given focus in accordance with it being the top-leftmost icon (e.g., is a default icon for giving focus in accordance with the priming gesture).

[0107] FIG. **6**J shows the user **115** moving their thumb in a direction extending away from the user's wrist (e.g., a first type of navigation gesture). FIG. **6**J further shows the point of focus **667** moving to the right on the interface **650** (responsive to the thumb movement) to select the icon **654-1**. FIG. **6**J further shows the indicator **410** updating to indicate that the user **115** is activating a rightward direction on the virtual directional-pad.

[0108] FIG. **6**K shows the user **115** moving their thumb in a direction away from the back of the user's hand (e.g., a first type of navigation gesture). FIG. **6**K further shows the point of focus **667** moving down on the interface **650** (responsive to the thumb movement) to select the icon **658-1**. FIG. **6**K further shows the indicator **410** updating to indicate that the user **115** is activating a downward direction on the virtual directional-pad. In some embodiments, each d-pad thumb gesture results in the point of focus **667** moving to the adjacent icon in the direction of the gesture (e.g., a rightward gesture causes the point of focus **667** to move to the next icon on the right from its previous location).

[0109] FIG. **6**L shows the user **115** performing a pinch gesture (e.g., a pinch-and-hold gesture) that involves the user's index finger contacting the thumb (e.g., a second type of priming gesture). FIG. **6**L further shows the user interface **650** including the point of focus **667** selecting the icon **658-1**. For example, the point of focus **667** is presented in accordance with the user maintaining the pinch gesture for at least a threshold amount of time (e.g., 1-3 seconds).

[0110] FIG. **6**M shows the user **115** performing a pinch-and-drag gesture (e.g., a second type of navigation gesture) that involves the user horizontally translating their arm in a first direction (e.g., to the right) while maintaining the pinch gesture from FIG. **6**L. In particular, the user's arm moves in a horizontal translation in FIG. **6**M in accordance with the drag arrow. FIG. **6**M further shows the user interface **650** updating (responsive to the pinch-and-drag gesture) to move focus from the icon **658-1** (in FIG. **6**L) to the point of focus location **670**-*a*. In some embodiments, the point of focus is displayed to the user as a cursor when not selecting a user interface element (e.g., an icon). In some embodiments, rather than performing a translation, the user may pinch and

rotate their wrist (e.g., rotate their wrist is shown and described with reference to FIGS. **5**A-**5**E) to move the point of focus. In some embodiments, a pinch-and-hold gesture is a priming gesture for either a translation-based navigation gesture or a wrist-rotation based navigation gesture and the user is able to perform either to move the point of focus.

[0111] FIG. **6**N shows the user **115** performing a pinch-and-drag gesture (e.g., the second type of navigation gesture) that involves the user horizontally translating their arm in a second direction (away from the user's body) while maintaining the pinch gesture from FIG. **6**L. In particular, the user's arm moves in a horizontal translation in FIG. **6**N in accordance with the drag arrow. FIG. **6**N further shows the user interface **650** updating (responsive to the pinch-and-drag gesture) to move focus from the point of focus location **670**-*a* (in FIG. **6**M) to the point of focus location **670**-*b* (e.g., moves the point of focus upward in the user interface).

[0112] FIG. **6**O shows the user **115** performing a pinch-and-drag gesture (e.g., the second type of navigation gesture) that involves the user horizontally translating their arm in the second direction (away from the user's body) while maintaining the pinch gesture from FIG. **6**N. In particular, the user's arm moves in a horizontal translation in FIG. **6**O in accordance with the drag arrow. FIG. **6**O further shows the user interface **650** updating (responsive to the pinch-and-drag gesture) to move focus from the point of focus location **670**-*b* (in FIG. **6**N) to select the icon **654-2**. Although FIGS. **6**M-**60** show the cursor moving in cardinal directions, in some embodiments, the user may move the cursor in any direction in accordance with a drag gesture in a particular direction. In some embodiments, the amount of movement of the point of focus corresponds to an amount of movement of the pinch-and-drag gesture (e.g., amount of translation).

[0113] Thus, FIGS. **6**H-**60** illustrate a scenario where the user interface is responsive to multiple types of navigational gesture. In some embodiments, the first type of navigational gesture causes a point of focus to move (e.g., snap) from one icon to another. In some embodiments, the second type of navigational gesture allows the user to move the point of focus freely (e.g., without requiring jumping to adjacent icons). In some embodiments, the first type of navigational gesture (e.g., the virtual d-pad navigation) is detected/identified using a first type of sensor (e.g., an EMG sensor). In some embodiments, the first type of navigational gesture (e.g., the pinch-and-drag gesture) is detected/identified using a second type of sensor (e.g., an IMU sensor) in addition to, or alternatively to, the first type of sensor.

[0114] FIGS. **7**A-**7**R illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments. The user **115** in FIG. **7**A is wearing the head-wearable device **402** (e.g., augmented-reality glasses) and the wrist-wearable device **120** (e.g., a smartwatch). The user **115** in FIG. **7**A is viewing the scene **504** on the display of the head-wearable device **402**. The user **115** in FIG. **7**A is making a first at a first time. In some embodiments, the first is not a gesture that corresponds to an action at the head-wearable device **402** or the wrist-wearable device **120**. In some embodiments, the first gesture is a priming gesture for navigation via a virtual directional-pad (as represented by the indicator **410**). In some embodiments, the wrist-wearable device **120** is prepared to receive user input through one or more gestures (e.g., in accordance with the first gesture being maintained).

[0115] FIG. **7**B illustrates the user's **115** performing a double tap gesture to activate a user-interface. In some embodiments, as shown in FIG. **7**B, the user **115** is able to wake the head-wearable device **402** and/or the wrist-wearable device **120** by performing the double tap gesture (e.g., two tap gestures in succession). In some embodiments, when the user **115** performs a tap gesture (e.g., a control gesture that involves the user's thumb contacting a surface of the user's index finger) it activates the display **204** of the wrist-wearable device **120** and/or a display of the head-wearable device **402**.

[0116] In some embodiments, only one of the displays (e.g., either the wrist-wearable device display **204** or the head-wearable device display) is activated. In some embodiments, the middle finger pinch gesture as shown in FIG. **2**C is a wake gesture (e.g., that activates the user-interface on either the head-wearable device or the display **204** of the wrist-wearable device **120**). For example, when the display **204** of the wrist-wearable device is inactive (e.g., the display of the head-wearable device is also in active in some embodiments), and the user **115** maintains the middle finger pinch gesture, the display of the wrist-wearable device is activated and the user interface in FIG. **7**B is displayed. In some embodiments, the user interface is shown on both the display **204** of the wrist-wearable device and in the scene **504** of the head-wearable device **402**.

[0117] In some embodiments, while the display **204** of the wrist-wearable device **120** is inactive, only a subset of the sensor channels **1385***a*-**1385***h* are active (e.g., a second subset of the sensor channels **1385***a*-**1385***h* are inactive). In some embodiments, while the display **204** of the wrist-wearable device **120** is inactive, the user **115** performs a control gesture to activate the display **204** of the wrist-wearable device **120** and the control gesture is captured by the active subset of sensor channels **1385***a*-**1385***h*.

[0118] FIG. **7**C illustrates the user **115** performing a gesture to navigate the user-interface **601**. In FIG. **7**C, the user **115** is moving their thumb in a direction extending away from the user's wrist (e.g., a rightward navigation gesture). As the user moves their thumb rightward, the indicator **410** updates to indicate that the user **115** is activating a rightward direction on the virtual directional-pad. As a result of the navigation gesture, the user **115** has accessed the quick-action user interface element **602***a* on the right-hand side of the user interface (shown in FIG. **7**B) which displays (e.g., activates) the messaging application. The messaging application, as shown in FIG. **7**C, includes two quick-action user interface elements reply icon **702** and home icon **704** (e.g., displayed to aid the user **115** in further navigation). The home icon **704** returns the user to the home user interface **601** displayed in FIG. **7**B. The reply icon **702** allows the user to respond to one of the message shown (e.g., respond to the message that has focus within the user interface when the reply icon **702** is activated). The messaging application interface also shows a list of messages including showing a most recent message in the conversation between the user **115** and another user (e.g., a user Mary and a user Jason). In some embodiments, a user interface for the messaging application is shown on the display **204** (e.g., in addition to, or alternatively to, presenting it in the scene **504**).

[0119] FIG. **7**D illustrates the user **115** performing a control gesture (e.g., a pinch or tap gesture) to select a

reaction to a message. In some embodiments, while the messaging application is active and the user performs a pinch-and-hold gesture (e.g., as shown in FIG. **7**D), the user activates a panel **708** (e.g., a menu) that includes one or more emoji responses. In some embodiments, the panel **708** allows the user **115** to quickly react to a message sent by another user. In some embodiments, when the panel **708** is displayed, one of the emojis is given focus (e.g., is highlighted) as shown by selection indicator **706** (e.g., a halo element). The close icon **707** causes the panel **708** to cease to be displayed. In some embodiments, another emoji or the close icon **707** is highlighted. In some embodiments, the panel **708** ceases to be displayed in accordance with the user **115** releasing the pinch-and-hold gesture.

[0120] FIG. **7**E illustrates the user **115** performing a navigation gesture to scroll through the emojis in the panel **708**. The navigation gesture in FIG. **7**E includes user **115** rotating their wrist while maintaining the pinch gesture from FIG. **7**D. The rotation in FIG. **7**E is counterclockwise and corresponds to a rightward direction from the perspective of the user **115**. FIG. **7**E further illustrates the selection indicator **706** moving to the right to the happy face emoji **710**. In some embodiments, the selection indicator **706** continues to move to the right in accordance with movement of the wrist rotation gesture. In some embodiments, the selection indicator **706** moves to the right a preset amount per gesture (e.g., regardless of velocity, duration, and/or distance of the gesture). In some embodiments, the selection indicator **706** includes dots or some other selection indication. Another example of a selection indicator is the selection indicator **717** shown in FIG. **7**H.

[0121] FIG. **7**F illustrates the user **115** releasing the pinch-and-hold gesture to select an emoji, thereby reacting to the message sent by another user. For example, the happy face emoji **710** is sent to the remote person (e.g., Mary). FIG. **7**F further illustrates the happy face emoji **710** positioned next to the message the user **115** reacted to (the message from Mary). In some embodiments, the location of the happy face emoji **710** after selection is customizable by the user **115**, thus the emoji can appear in a different corner or a different portion of the message entirely. In some embodiments, the user **115** can customize the setting so that the emoji does not appear in the messaging application.

[0122] FIG. **7**G illustrates the user **115** performing a tap gesture to navigate to a specific message (e.g., expand a conversation with a particular person). FIG. **7**G illustrates the user opening the messaging chain between the user and Mary by performing a tap gesture. In some embodiments, along with the message chain, a quick-action user interface element **711** is displayed. In some embodiments, when the user performs a navigation gesture to the quick-action user interface element **711**, the user interface navigates to the display shown in FIG. **7**F with the list of conversations between user **115** and other users (e.g., navigates to a home page associated with the messaging application). FIG. **7**G further illustrates happy face emoji **710** indicating that the user **115** they reacted to that particular message (in accordance with the gesture of FIG. **7**E). In some embodiments, the happy face emoji **710** is located elsewhere in the display but still indicates that the user **115** reacted to the particular message.

[0123] FIG. **7**H illustrates the user **115** maintaining a pinch gesture (e.g., to view quick response options for the message chain). In some embodiment, the user **115** maintains the pinch gesture (e.g., a pinch-and-hold gesture) while viewing an individual messaging conversation, and view a panel **709** of recommended quick response options is displayed. For example, in FIG. **7**H, the quick response options include phrases and emojis. In some embodiments, the quick responses include only phrases or emojis. In some embodiments, the response options are generated based on a history of how the user **115** has responded to similar messages in the past and/or is computer generated using machine learning to show the user **115** options of how a person may respond. In some embodiments, the user **115** is allowed to pre-program quick response options (e.g., based on a variety of messages the user **115** typically receives from other users). In some embodiments, the selection indicator **717** appears on the close icon **715** (as illustrated in FIG. **7**H) or on a quick response option. In some embodiments, the selection indicator **717** highlights the most likely response and/or the response recommended by the system.

[0124] FIG. **7**I illustrates the user **115** maintaining the pinch gesture from FIG. **7**H and translating their hand from one location to another to scroll through the quick response options. FIG. **7**I illustrates the translation of the user's **115** hand being inward (e.g., toward the user's body) and corresponds to a rightward direction from the perspective of the user **115**. In the example of FIG. **7**I, performing the hand translation while maintaining the pinch gesture moves the selection indicator **717** to the quick response "Can't wait!" (e.g., in a rightward direction). In some embodiments, the selection indicator **717** moves to the right a preset amount per amount of movement in the hand translation (e.g., regardless of how long the user **115** maintains the translation). In some embodiments, the user **115** translates their hand in an outward direction (e.g., away from the user's body) that corresponds to a leftward direction from the perspective of the user **115**. In accordance with some embodiments, a user performing the hand translation in an outward direction while maintaining the pinch gesture moves the selection indicator **717** in a leftward direction. In some embodiments, when the user **115** translates their hand beyond the bounds of the displayed quick responses, the selection indicator **717** moves to the other side of the panel **709**. For example, if the selection indicator **717** is highlighting the laughing emoji **713** and the user translates their hand in an inward direction corresponding to a rightward direction, the selection indicator **717** moves to the close icon **715**. In some embodiments, there are additional quick responses not shown, and thus while the user has laughing emoji **713** highlighted with the selection indicator **717** and the user translates their hand in an inward direction, the panel **709** will scroll to display additional quick responses to the user **115**. In some embodiments, if the selection indicator is highlighting the close icon **715** and the user translates their hand in an outward direction moving the selection indicator in a leftward direction, the selection indicator **717** will move to the end of the quick response options. In some embodiments, when the user **115** translates their hand beyond the bounds of the displayed quick responses, the selection indicator **717** ceases to move (e.g., stays at a leftmost or rightmost option).

[0125] FIG. **7**J illustrates the user **115** releasing the pinch gesture from FIG. **7**I which selects the quick response option "Can't wait!". FIG. **7**J further shows the result of the selection of the quick response on the display of both the wrist-wearable device and the head-wearable device **202**

(e.g., the "Can't wait!" message is added to the conversation). In some embodiments, the quick response selection action (e.g., releasing the pinch gesture) causes the response to be sent to the other user. In some embodiments, the quick response selection is displayed in the dialogue box **723** so that the user **115** can edit the response before sending, if desired.

[0126] FIG. **7**K illustrates the user **115** moving their thumb in a direction toward the user's wrist (e.g., a navigation gesture). FIG. **7**K further shows this navigational gesture causing activation of the messaging quick-action user interface element **711** (in FIG. **7**J) and results in the user interface returning to the messaging application page shown in FIG. **7**C, displaying messages from multiple people. In some embodiments, a most recent message in a conversation between the user and another person is displayed. For example, FIG. **7**K shows the user's quick response **721** "Can't wait!" in the message box with Mary. In other embodiments, no message is shown (e.g., the contact name and photo are displayed without a message).

[0127] FIG. **7**L illustrates the user **115** moving their thumb in a direction toward the user's wrist (e.g., a navigation gesture) a second time. FIG. **7**L further illustrates this navigational gesture activates the home screen quick-action user interface element **704** (shown in FIG. **7**K) and results in the user interface displaying a home screen (e.g., ceasing to display the messaging application or reducing the display of the messaging application). In some embodiments, the user interface in FIG. **7**L corresponds to the user interface **601** in FIG. **7**B.

[0128] FIG. **7**M illustrates the user **115** moving their thumb in a direction extending away from the back of the user's hand (e.g., a downward navigation gesture). As the user **115** moves their thumb away from the back of the user's hand, the indicator **410** updates to indicate that the user **115** is activating a downward direction on the virtual directional-pad. Navigating downward one the home screen activates the music application quick-action user interface element **602***b* shown in FIG. **7**L. FIG. **7**M displays a user interface corresponding to the music application as a result of navigating to the music application quick-action user interface element **602***b*. In some embodiments, the music application interface includes display of a volume icon **731**, a music album, a song title, and a home screen quick-action user interface element **704**. In some embodiments, other actions can be added as quick-action user interface elements and other information (e.g., about the music) are displayed with the music application interface. In some embodiments, the quick-action user interface elements are displayed in different locations than shown in FIGS. **7**A-**7**R. For example, the home screen quick-action user interface element **704** in FIG. **7**M may be displayed below or to a side of the music application interface (or in a corner of the scene **504**).

[0129] FIG. **7**N illustrates the user **115** maintaining a pinch gesture (e.g., a pinch-and-hold gesture) to activate a volume function (e.g., corresponding to the volume icon **731** in FIG. **7**M), as indicated by a volume indicator **732**. In some embodiments, in accordance with the user maintaining a pinch gesture for a threshold amount of time (e.g., 1-3 seconds), the volume indicator **732** is displayed and is responsive to further interactions with the user.

[0130] FIG. **7**O illustrates the user **115** performing a navigation gesture to increase the volume. FIG. **7**O illustrates the user **115** rotating their wrist (e.g., the navigation gesture) while maintaining the pinch gesture from FIG. **7**N. In accordance with movement of the navigation gesture, the volume of the music adjusts as indicated by the volume indicator **732**. In FIG. **7**O, the user **115** is rotating their wrist inward (e.g., toward the user's body) corresponding to a rightward direction from the perspective of the user **115**. Thus, as shown in FIG. **7**O, while the user **115** is rotating their wrist inward, the bar of the volume indicator **732** moves in the rightward direction (e.g., increasing volume of the music). In some embodiments, when the user **115** rotates their wrist outward (e.g., away from the user's body), it corresponds to a leftward direction from the perspective of the user **115**, resulting in the volume indicator **732** bar decreasing (e.g., lowering the volume of the music). In some embodiments, the volume is responsive to the navigation gesture only if audio media (e.g., music, a song, etc.) is currently playing. For example, the system does not respond to the user rotating their wrist if no audio media is currently playing. In some embodiments, the volume can be increased or decreased when audio media is not playing.

[0131] FIG. **7**P illustrates the user **115** releasing the pinch gesture shown in FIG. **7**O. FIG. **7**P further shows that the volume indicator **732** has ceased to be displayed (e.g., is closed or otherwise deactivated) in accordance with the release of the pinch gesture. In some embodiments, the volume change performed in FIG. **7**O is maintained (e.g., saved or stored in the system) after the pinch gesture is released.

[0132] FIG. **7**Q illustrates the user **115** maintaining a pinch gesture (e.g., performing a pinch-and-hold gesture) using the thumb and middle finger. In some embodiments, in accordance with the pinch gesture being held for a threshold amount of time (e.g., 1 or 2 seconds), the home screen is displayed (e.g., the music application is ceased to be displayed in accordance with an exit or go back command). In some embodiments, other gestures may be used for the exit and/or 'go back' action (e.g., an index finger or pinkie finger pinch gesture or a wrist flick gesture).

[0133] FIG. **7**R illustrates the user **115** continuing to maintain the pinch gesture from FIG. **7**Q using the thumb and middle finger. FIG. **7**R further shows, as a result of maintaining the pinch gesture, the scene **504** and display **204** of the wrist wearable device are updated to no longer show the home screen (e.g., corresponding to a sleep or shut down command). In some embodiments, maintaining the pinch gesture for at least a second threshold amount of time (e.g., 3-5 seconds) causes any user interface or overlay to cease to be displayed.

[0134] FIGS. **7**S-**7**U illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments. The user **115** in FIG. **7**S is wearing a head-wearable device **110** (e.g., a virtual reality headset) and a wrist-wearable device **120** (e.g., a smartwatch). In FIG. **7**S, the user **115** is viewing a scene **130** via the head-wearable device **110** and the user **115** is not performing a gesture.

[0135] In FIG. **7**T, the user **115** is performing a priming gesture (e.g., a pinch gesture) using the user's pointer finger contacting the thumb. FIG. **7**T further shows the scene **130** having updated in response to the pinch gesture. The scene **130** in FIG. **7**T includes a user interface **1220** (e.g., a list of numbers the user **115** can scroll through). The user interface **1220** includes one or more numbers and a focus **1222** which highlights the currently selected number (the number **15**). In

some embodiments, the focus **1222** appears on a number that was previously selected in response to detecting the priming gesture. In some embodiments, the focus **1222** appears on the start of the list of numbers (e.g., the leftmost number). In some embodiments, as the user **115** performs one or more hand gestures, the focus **1222** moves in accordance with the performed hand gesture. In some embodiments, the focus **1222** is a cursor that moves between the user interface elements. In some embodiments, the user interface **1220** is displayed while the priming gesture is maintained. In some embodiments, the user interface **1220** is displayed for a predetermined amount of time after the priming gesture is performed. In some embodiments, the focus **1222** is displayed (and manipulable) while the priming gesture is maintained. In some embodiments, the focus **1222** is displayed (and manipulable) for a predetermined amount of time after the priming gesture is performed. In some embodiments, a first predetermined amount of time after the priming gesture is performed the focus **1222** ceases to be manipulable and/or displayed. In some embodiments, a second predetermined amount of time after the priming gesture is performed the user interface **1220** ceases to be displayed. In some embodiments, the second predetermined amount of time is longer than the first predetermined amount of time.

[0136] FIG. **7**T further illustrates a graph **1290** showing a relationship between a translation distance of a navigation gesture and a navigation speed for the focus **1222**. The graph **1290** in FIG. **7**T corresponds to a first point in time (e.g., a point in time before the user **115** has performed a navigation gesture) and indicator **1292** indicates that the navigation speed is zero (e.g., no navigation is occurring at the first point in time). In some embodiments, the navigation speed of the focus **1222** corresponds to a translation distance of a navigation gesture from an initial position. In some embodiments, the relationship between the navigation speed and the translation distance is a linear relationship, as indicated by dotted line **1291**. In some embodiments, the position of the hand of the user **115** when the priming gesture is performed is set as an initial position (e.g., for use with subsequent navigation gestures).

[0137] FIG. **7**U illustrates the user **115** performing a navigation gesture (e.g., a drag gesture which is a horizontal translation). In the example of FIG. **7**U the priming gesture (e.g., the pinch gesture) is maintained during the navigation gesture. FIG. **7**U also illustrates the scene **130** updating responsive to the navigation gesture by scrolling through the user interface **1220** at a first speed and moving the focus **1222** from the number "15" to the number "19." In some embodiments, the distance of the translation corresponds to a speed of the navigation, as indicated by the graph **1290** in FIG. **7**U. In some embodiments, the navigation speed is based on one or more settings (e.g., set by the user **115** or set as a default by the system). For example, the user **115** may adjust a setting that adjusts the slope of the dotted line **1291**. More details regarding navigation speed that based on distance from an initial position can be found in co-owned U.S. patent application Ser. No. 18/359,855, entitled "Multi-Stage Gestures Detected Based on Neuromuscular-Signal Sensors of a Wearable Device to Activate User-Interface Interactions with Low-False Positive Rates, and Systems and Methods of Use Thereof," which is incorporated herein in its entirety.

[0138] Although the user scenarios described previously with respect to the series of FIGS. **1** through **7** describe operations being performed by the wrist-wearable device **120** and head-wearable devices **110** and **402**, in some embodiments, at least a subset of the operations are performed by an intermediary device, such as a smartphone or personal computer, that is in communication with the wearable devices. For example, detection of user movement may occur at the wearable devices, but interpretation of the movement (e.g., identifying a gesture to which the movement corresponds) optionally occurs at an intermediary device. In some embodiments, the wrist-wearable device **120** and the head-wearable devices **110** and **402** communication with one another via the intermediary device (e.g., each are communicatively coupled to the intermediary device and the intermediary device manages interactions between the devices).

[0139] Examples of intermediary devices can include the computing devices (e.g. servers **5030**, computers **5040**, mobile devices **5050**, etc.) described with reference to FIG. **11**. In some embodiments, data from sensors on multiple devices are combined (e.g., at the intermediary device) to detect an in-air gesture. For example, data from one or more optical sensors of a head-wearable device (e.g., the head-wearable device **402**) can be combined with EMG and/or IMU data from a wrist-worn device (e.g., the wrist-wearable device **120**) to identify a swipe gesture at a location that corresponds to a first scroll bar of a user interface rather than a second scroll bar displayed at a separate location.

[0140] Additionally, although the user scenarios described with respect to the series of FIGS. **1** through **7** are described as separate sequences, in some embodiments, the user scenarios are combined with one another. For example, the sequence described with respect to FIGS. **7**A-**7**R could occur before (or after) the sequences described with respect to FIGS. **4**A-**4**H and **2**A-**2**F (e.g., all three sequences could occur while the user **115** is on a morning walk).

[0141] The user scenarios described with respect to the series of FIGS. **1** through **7** involved specific user interface and applications, such as the messenger interface **108** in FIG. **1**A and the photo gallery interface **206** in FIG. **2**A. However, the sequences, gestures, actions, and operations can be used in conjunction with other types of menus and applications, such as web-browsing, note-taking, social media, word processing, data-entry, programming, and the like.

[0142] FIGS. **8**A-**8**B are flow diagrams illustrating a method **800** for using in-air gestures to control a point of focus in a user-interface in accordance with some embodiments. The method **800** is performed at a computing system (e.g., a wearable device or intermediary device) having one or more processors and memory. In some embodiments, the memory stores one or more programs configured for execution by the one or more processors. At least some of the operations shown in FIGS. **8**A-**8**B correspond to instructions stored in a computer memory or computer-readable storage medium (e.g., the memory **6050**, **6080**, and/or **7050**). In some embodiments, the computing system is a wearable device, such as the wrist-wearable device **120** or the head-wearable device **110** or **402**. In some embodiments, the computing system is, or includes, an intermediary device such as a smartphone (e.g., the HIPD **8000**).

[0143] The system receives (**802**), via one or more sensors (e.g., the sensors **6021**) of a wrist-wearable device worn by

a user, data generated from performance of an in-air gesture by the user (e.g., data generated from the pinch gesture shown in FIG. **2**B). In some embodiments, the one or more sensors include one or more IMU or EMG sensors.

[0144] The system determines (**804**), based on the sensor data, that the in-air hand gesture is a user interface control gesture. For example, the gesture is a priming gesture (e.g., the first gesture in FIG. **1**B), a navigation gesture (e.g., the wrist rotation gesture in FIG. **1**C), or an activation gesture (e.g., the tap gesture in FIG. **1**E). For example, one or more processors **1150** of a wearable device or intermediary device analyzes the data and determines whether the gesture is a user interface control gesture.

[0145] The system moves (**806**) a point of focus (e.g., via the processor(s) **6049** and/or **6079**) on the user interface in accordance with the user interface control gesture. For example, FIGS. **4**C-**4**F show the point of focus **408** moving in accordance with the user's thumb gestures.

[0146] In some embodiments, while the user-interface control gesture is maintained for the amount of time, the system scrolls (**808**) the point of focus (e.g., via the processor(s) **6049** and/or **6079**) through a plurality of selectable user interface elements. For example, FIGS. **2**D and **2**E show the user interface **206** scrolling photos in accordance with a held pinch gesture. In some embodiments, the system starts the scrolling after the gesture is held for at least a preset amount of time (e.g., 0.5, 1, or 2 seconds).

[0147] In some embodiments, the system ceases (**810**) scrolling the point of focus and select a nearest user interface element to the point of focus in accordance with a determination that the user-interface control gesture is released. For example, FIG. **2**F shows the user having released the pinch gesture and the image **216** is selected in accordance with the system ceasing to scroll.

[0148] The system selects (**812**) the user interface element by snapping the point of focus to the selectable user interface element in accordance with a determination that the point of focus is within a threshold distance of a selectable user interface element. For example, FIGS. **4**C and **4**D illustrate the point of focus **408** moving within the snapping boundary **412** and snapping to the user interface element **414**.

[0149] In some embodiments, the point of focus is presented (**814**) as a cursor (e.g., the point of focus in FIG. **4**B is presented to the user as a cursor). In some embodiments, the point of focus is presented as a cursor only when not snapped to a selectable user interface element.

[0150] In some embodiments, the system: (i) receives (**816**), via the one or more sensors of the wrist-wearable device worn by the user, data generated from performance of a second in-air gesture by the user; (ii) determines that the second in-air hand gesture is an execution gesture (also sometimes called a control gesture or an activation gesture); and (iii) executes a command corresponding to the execution gesture and the selected user interface element in accordance with the execution gesture. For example, FIG. **1**H shows the user **115** performing a thumb tap gesture and a corresponding insertion of the emoji **117** into the response box **121**.

[0151] In some embodiments, the system: (i) receives (**818**), via the one or more sensors of the wrist-wearable device worn by the user, data generated from performance of a third in-air gesture by the user; (ii) determines that the third in-air hand gesture is a navigation gesture; and (iii) snaps the point of focus to an adjacent selectable user interface element in accordance with the navigation gesture. For example, FIG. **3**B shows the user performing a pinch gesture and the point of focus **306** moving from the user interface element **308-1** (in FIG. **3**A) to the user interface element **308-2** (in FIG. **3**B).

[0152] In some embodiments, the system: (i) detects (**820**) a second user interface control gesture after selecting the user interface element; and (ii) deselects the user interface element in accordance with a determination that movement of the second user interface control gesture would cause the point of focus to move beyond a second threshold distance of the selected user interface element. For example, FIGS. **4**E and **4**F illustrate the point of focus **408** moving beyond the snapping boundary **412** and deselection of the user interface element **414**. In some embodiments the snapping threshold and un-snapping thresholds are different. For example, the snapping threshold may be closer to, or further from, the corresponding selectable user interface element than the un-snapping threshold.

[0153] In some embodiments, the system selects (**822**) a different selectable user interface element by snapping to the point of focus to the different selectable user interface element in accordance with deselecting the user interface element. For example, the point of focus **408** in FIG. **4**F could snap to the user interface element **416** in accordance with deselecting the user interface element **414**.

[0154] FIGS. **9**A-**9**B are flow diagrams illustrating a method **900** for using in-air gestures to control a point of focus in a user-interface in accordance with some embodiments. The method **900** is performed at a computing system (e.g., a wearable device or intermediary device) having one or more processors and memory. In some embodiments, the memory stores one or more programs configured for execution by the one or more processors. At least some of the operations shown in FIGS. **9**A-**9**B correspond to instructions stored in a computer memory or computer-readable storage medium (e.g., the memory **6050**, **6080**, and/or **7050**). In some embodiments, the computing system is a wearable device, such as the wrist-wearable device **120** or the head-wearable device **110** or **402**. In some embodiments, the computing system is, or includes, an intermediary device such as a smartphone (e.g., the HIPD **8000**).

[0155] The system receives (**910**) data generated from performance of a gesture by a user. For example, the system receives the data via one or more sensors (e.g., the sensors **6013** and/or **6021**). In some embodiments, the system receives data from one or more wearable devices (e.g., the wrist-wearable device **120** and/or the head-wearable device **110** or **402**).

[0156] The system determines (**912**) whether the gesture is a user interface control gesture (e.g., a priming, navigation, or execution/activation gesture). For example, one or more processors of a wearable device or intermediary device analyzes the data and determines whether the gesture is a user interface control gesture. In some embodiments, prior to determining that the gesture is a user interface control gesture, the system is in a low-power or sleep state and is responsive to only control gestures (e.g., not responsive to activation or execution gestures).

[0157] In accordance with a determination that the gesture is a user interface control gesture, the system moves (**914**) a point of focus on the user interface in accordance with the user interface control gesture. For example, the system determines that the gesture is a wrist rotation gesture and

moves the point of focus in accordance with the rotation of the user's wrist, e.g., as shown in FIG. **3**C.

[0158] In accordance with a determination that the gesture is not a user interface control gesture, the system forgoes moving the point of focus on the user interface (e.g., returns to a state responsive to user interface control gestures). For example, the system returns to the state it was in prior to receiving the data generated from performance of the gesture by the user.

[0159] The system determines (**916**) whether the point of focus is within a threshold distance (e.g., the snapping boundary **412**) of a selectable user interface element. For example, after, or during, the movement of the point of focus, the system determines whether a position of the point of focus overlaps with a selectable user interface element (or is within a threshold distance of the element).

[0160] In accordance with a determination that the point of focus is within the threshold distance, the system selects (**918**) the user interface element by snapping the point of focus to the selectable user interface element. For example, the user gesture would have moved the point of focus next to, but not overlaid with, the user interface element such that the user interface element would not be selected without the snapping action. The snapping action in this example moves the point of focus beyond the position where it otherwise would have stopped to a position that overlays the user interface element.

[0161] In accordance with a determination that the point of focus is not within the threshold distance, the system forgoes selecting the user interface element (e.g., returns to a state responsive to user interface control gestures). For example, the system returns to the state it was in prior to receiving the data generated from performance of the gesture by the user.

[0162] The system detects (**920**) a second user interface control gesture. For example, the system detects a navigation gesture (e.g., a wrist rotation, pinch, or thumb d-pad gesture) that moves the point of focus.

[0163] The system determines (**922**) whether the point of focus moves beyond a second threshold distance of the selected user interface element in accordance with the second user interface control gesture. For example, the system determines whether the point of focus move to a position that is not overlaid with the selectable user interface element.

[0164] In accordance with a determination that the point of focus has moved beyond the second threshold distance, the system deselects (**924**) the user interface element. For example, the system deselects the user interface element and displays a cursor that is not overlaid with the user interface element. As another example, the system deselects the user interface element and selects an adjacent user interface element that is in the direction of the second user interface control gesture.

[0165] In accordance with a determination that the point of focus has moved beyond the second threshold distance, the system forgoes deselecting the user interface element (e.g., returns to a state responsive to control gestures).

[0166] FIGS. **10**A-**10**B are flow diagrams illustrating a method **1000** for using wrist movements to control a user-interface in accordance with some embodiments. The method **1000** is performed at a computing system (e.g., a wearable device or intermediary device) having one or more processors and memory. In some embodiments, the memory stores one or more programs configured for execution by the one or more processors. At least some of the operations shown in FIGS. **10**A-**10**B correspond to instructions stored in a computer memory or computer-readable storage medium (e.g., the memory **6050**, **6080**, and/or **7050**). In some embodiments, the computing system is a wearable device, such as the wrist-wearable device **120** or the head-wearable device **110** or **402**. In some embodiments, the computing system is, or includes, an intermediary device such as a smartphone (e.g., the HIPD **8000**).

[0167] The system receives (**1002**), via one or more neuromuscular-signal sensors of a wrist-wearable device worn by a user, data generated during performance of an in-air wrist movement by the user. For example, the one or more sensors include the sensors **6021** and/or **6013** (e.g., EMG and/or IMU sensors).

[0168] The system moves (**1004**) a point of focus on the user interface in accordance with the in-air wrist movement. For example, FIG. **5**C illustrates the user rotating their wrist and the focus in the interface **506** switching from January 1st events (in FIG. **5**B) to January 8th events (in FIG. **5**C).

[0169] In some embodiments, the system: (i) identifies (**1006**) the in-air wrist movement as being part of a navigation gesture (e.g., via the processor(s) **6049** and/or **6079**); and (ii) moves the point of focus in accordance with the identification. For example, the system identifies the first gesture in FIG. **5**B as a priming gesture for the navigation and the wrist rotation gesture in FIG. **5**C as the movement control gesture for the navigation.

[0170] In some embodiments: (i) the in-air wrist movement includes the user's wrist rotating from an initial position to a rotated position, and the user's wrist is maintained in the rotated position for an amount of time; and (ii) the system scrolls (**1008**) the point of focus through a plurality of selectable user interface elements while the wrist of the user is maintained in the rotated position for the amount of time. For example, while the user maintains the downward wrist rotation shown in FIG. **1**G, the point of focus **105** moves downward through the emojis in the emoji menu. In some embodiments, the system ceases (**1010**) to scroll the point of focus and select a nearest user interface element to the point of focus in accordance with the wrist of the user returning to the initial position. For example, FIG. **2**F shows the user having released the pinch gesture and the image **216** is selected in accordance with the system ceasing to scroll.

[0171] In some embodiments, the point of focus moves (**1012**) at a speed that corresponds to a wrist angle of the wrist of the user. For example, the further the user rotates their wrist, the faster the point of focus moves. In some embodiments, the point of focus moves (**1014**) at a speed that corresponds to a speed of the in-air wrist movement. For example, if the user quickly flicks their wrist the point of focus moves faster than if the user slowly rotates their wrist. In some embodiments, the speed of the point of focus movement is based on both the angle and speed at which the gesture is performed.

[0172] In some embodiments, the system selects (**1018**) a user interface element by snapping the point of focus to the user interface element in accordance with a determination that the point of focus is within a threshold distance of the user interface element. For example, FIGS. **4**C and **4**D illustrate the point of focus **408** moving within the snapping boundary **412** and snapping to the user interface element **414**.

[0173] In some embodiments, the system: (i) detects (**1020**) a user-interface control gesture; and (ii) deselects the user interface element in accordance with a determination that movement of the user-interface control gesture would cause the point of focus to move beyond a threshold distance of the user interface element. For example, FIGS. **4**E and **4**F illustrate the point of focus **408** moving beyond the snapping boundary **412** and deselection of the user interface element **414**. In some embodiments the snapping threshold and un-snapping thresholds are different.

[0174] The system receives (**1022**), via the one or more neuromuscular-signal sensors, additional data generated during performance of an in-air gesture by the user. The system determines (**1024**) that the in-air gesture is an execution gesture. The system executes (**1026**) a command corresponding to the execution gesture. For example, FIG. **1**H shows the user **115** performing a thumb tap gesture and a corresponding insertion of the emoji **117** into the response box **121**.

[0175] As one of skill in the art will appreciate, aspects of the method **800** can be combined and/or replaced with aspects of the methods **900** and **1000**. For example, the method **800** can be performed prior to (or after) the method **1000**. The method **1000** can include the operations of method **900**, e.g., the operations **920**, **922**, and **924** can be performed after the operation **918**. As another example, the operation **802** can be replaced (or supplemented by) the operation **1002**.

[0176] Having thus described example sequences and methods of operation that make use of the example sequences, attention will now be directed to system-level depictions of hardware and software on which (or with which) the methods can be implemented.

Example Multi-Stage Gesture Scenarios

[0177] As a further example, suppose Robin wants to open a video player application to play audiovisual content via her augmented reality glasses. Conventionally, Robin would need to manipulate buttons on her glasses, or pull out a connected electronic device and navigate on a touch display or keyboard to open the video player application. Additionally, Robin would likely need to perform multiple discrete steps to find and open the application. Furthermore, if Robin is in a public space, it may be socially unacceptable to use voice commands or large gestures to open the application. With the systems described here, Robin could use a single multi-stage in-air hand gesture present a menu, navigate to the video player application within the menu, and open it. For example, performing a pinch gesture could display the menu, movement of the wrist could allow navigation through the menu, and releasing the pinch could activate the icon for the video player application. The gestures in this example are small and unobtrusive, not requiring an open space for Robin to maneuver or manipulation of handheld devices.

[0178] FIGS. **16**A-**16**F illustrate an example user scenario of interacting with an artificial-reality system in accordance with some embodiments. The user **115** in FIG. **16**A is wearing a head-wearable device **110** (e.g., a virtual reality headset) and a wrist-wearable device **120** (e.g., a smartwatch). In some embodiments, the wrist-wearable device **120** is an instance of the wrist-wearable device **6000**. In some embodiments, the head-wearable device **110** is an instance of the augmented-reality system **7000**. The user **115** in FIG. **16**A is viewing a scene **2130** that includes a radial menu **2131**. In the example of FIG. **16**A, the user **115** is not performing a gesture.

[0179] FIG. **16**B shows the user **115** performing a pinch gesture (e.g., a priming gesture) that involves the user's pinkie finger contacting the thumb. FIG. **16**B further shows the scene **2130** updating (responsive to the pinch gesture) to include multiple options (e.g., tooltips) for interacting with a user interface element **2133** (e.g., corresponding to a messenger application) on the radial menu **2131**. In the example of FIG. **16**B, the options include an option **2132-1** for closing the tooltips (by releasing the pinch gesture), an option **2132-2** for opening a settings menu (by tapping the index finger to the pinch), and an option **2132-3** for opening messages (by tapping the middle finger to the pinch).

[0180] FIG. **16**C shows the user **115** rotating their wrist (e.g., a navigation gesture) while maintaining the pinch gesture from FIG. **16**B. FIG. **16**C further shows selection of a user interface element **2135** (e.g., a music application) within the radial menu **2131** in accordance with wrist rotation. The options **2136** shown in FIG. **16**C correspond to interactions with the user interface element **2135** and include an option **2136-1** for closing the tooltips (by releasing the pinch gesture), an option **2136-2** for switching the playlist (by increasing a force of the pinch gesture to meet certain criteria), and an option **2136-3** for playing music (by tapping the index finger to the pinch).

[0181] FIG. **16**D shows selection of a user interface element **2137** (e.g., a camera application) within the radial menu **2131** in accordance with wrist rotation. The options **2138** shown in FIG. **16**D correspond to interactions with the user interface element **2137**, and include an option **2138-1** for opening a settings menu (by increasing a force of the pinch gesture to meet certain criteria), an option **2138-2** for viewing the user's gallery of images (by tapping the index finger to the pinch), and an option **2138-3** for opening the camera capture mode (by tapping the middle finger to the pinch). FIG. **16**D further shows the user **115** tapping their middle finger to the pinch to open the camera in capture mode (e.g., a control gesture).

[0182] The user **115** in FIG. **16**E is viewing the scene **2130** with the camera application user interface **2140** active (e.g., the camera application is active and in capture mode). In the example of FIG. **16**E, the user **115** is not performing a gesture (e.g., has released the pinch gesture). In some embodiments, the radial menu **2131** is no longer displayed in accordance with the user performing the tap gesture in FIG. **16**D (e.g., a completion of a multi-stage gesture). In some embodiments, the radial menu **2131** is no longer displayed in accordance with the user releasing the pinch gesture (e.g., the middle tap in FIG. **16**D opens the camera user interface **2140** and releasing the pinch gesture closes the radial menu **2131**).

[0183] FIG. **16**F illustrates an alternative from FIG. **16**D where the user is performing a deep pinch (having a corresponding force that meets one or more predefined criteria) instead of tapping their middle finger. The user **115** in FIG. **16**F is viewing the scene **2130** with the camera settings user interface **2142** active (e.g., the camera settings user interface is a menu with multiple settings options). In the example of FIG. **16**F, the user **115** is maintaining the pinch gesture and the radial menu **2131** is still displayed (behind the settings user interface **2142**). In some embodiments, the radial menu **2131** is no longer displayed in accordance with the user

performing the deep pinch gesture (e.g., the deep pinch gesture is a control gesture, and the radial menu ceases to be displayed in response to a control gesture being performed). Although FIGS. **16**A-**16**F are shown as being performed by the user **115** wearing the head-wearable device **110**, in some embodiments, the user **115** is wearing a different type of display (e.g., AR glasses or lenses) and in some embodiments, the user **115** is interacting with a user interface on a non-wearable display (e.g., a television or monitor display).

[0184] In some embodiments, the wrist-wearable device **120** and/or the head-wearable device **110** provides visual, audio, and/or haptic feedback to the user to indicate that a performed gesture stage has been detected (e.g., distinct feedback provided in response to each type of gesture).

[0185] FIGS. **17**A-**17**C illustrate another example user scenario of interacting with an artificial-reality system in accordance with some embodiments. The user **115** in FIG. **17**A is wearing a head-wearable device **202** (e.g., augmented reality glasses) and a wrist-wearable device **120** (e.g., a smartwatch). In some embodiments, the head-wearable device **202** is an instance of the augmented-reality system **7000**. The user **115** in FIG. **17**A is viewing a scene **2204** that includes a communication interface **2208** with a user message **2210** and a notification **2212**. The notification **2212** indicates to the user that a pinch gesture would cause the user message **2210** to be sent to a remote user (John). In the example of FIG. **17**A, the wrist-wearable device **120** includes a display with a user interface **2214** that corresponds to (duplicates) the communication interface **2208** (e.g., the user can view (and optionally interact) with either the interface **2208** or the interface **2214**). The user **115** in FIG. **17**A is not performing a gesture. In some embodiments, the user **115** is presented with multiple options for actions related to the user message **2210**. For example, a first priming gesture, such as the ring finger pinch gesture, for sending the message **2210** and a second priming gesture, such as a pinkie finger pinch gesture, for deleting the message **2210**.

[0186] FIG. **17**B shows the user **115** performing a pinch gesture (e.g., a priming gesture) that involves the user's ring finger contacting the thumb. FIG. **17**B further shows the scene **2204** updating (responsive to the pinch gesture) to replace the notification **2212** in FIG. **17**A with a notification **2216**. The notification **2216** indicates to the user that rotating their wrist would confirm that they want to send the user message **2210** to the remote user (John). In some embodiments, the user **115** is presented with multiple options corresponding to different control gestures associated with the priming gesture. For example, a first control gesture, such as the wrist rotation, for confirming the desire to send the message **2210** and a second control gesture, such as wrist/hand shake, for displaying send options (e.g., delayed send or conditional send).

[0187] FIG. **17**C shows the user **115** having rotated their wrist 90 degrees (e.g., a control gesture) while holding the pinch gesture. FIG. **17**C further shows the scene **2204** with (responsive to the control gesture) an updated communication interface **2208** with element **2220** indicating that the user message **2210** has been sent to the remote user (John). While FIG. **17**C shows the user **115** holding the pinch gesture (e.g., the priming gesture) while performing the wrist rotation (e.g., the control gesture), in some embodiments, the user releases the priming gesture prior to performing the control gesture. For example, performing the priming gesture triggers a timer during which the control gesture must occur to confirm the sending of the user message **2210**. Although FIGS. **17**A-**17**C are shown as being performed by the user **115** wearing the head-wearable device **202**, in some embodiments, the user **115** is wearing a different type of display (e.g., a VR headset), and in some embodiments, the user **115** is interacting with a user interface on a non-wearable display (e.g., a television or monitor display).

[0188] In some embodiments, the wrist-wearable device **120** and/or the head-wearable device **202** provides visual, audio, and/or haptic feedback to the user to indicate that a performed gesture stage has been detected (e.g., distinct feedback provided in response to each type of gesture).

[0189] FIGS. **18**A-**18**D illustrate another example user scenario of interacting with an artificial-reality system in accordance with some embodiments. The user **115** in FIG. **18**A is wearing a head-wearable device **202** (e.g., augmented reality glasses) and a wrist-wearable device **120** (e.g., a smartwatch). The user **115** in FIG. **18**A is viewing a scene **2302** that includes scenery for which the user wishes to capture a picture. The user **115** in FIG. **18**A is not performing a gesture.

[0190] FIG. **18**B shows the user **115** performing a pinch gesture (e.g., a priming gesture) that involves the user's middle finger contacting the thumb. Although FIG. **18**B does not show a change to the scene **2302** in response to the pinch gesture, in some embodiments, the scene **2302** (and/or a display of the wrist-wearable device **120**) updates to indicate to the user **115** that the pinch gesture was detected. For example, the scene **2302** can update to include a tooltip on what control gestures are available given the priming gesture. As another example, the wrist-wearable device **120** and/or the head-wearable device **202** may provide visual, audio, and/or haptic feedback to the user to indicate that the pinch gesture was detected.

[0191] FIG. **18**C shows the user **115** performing a tap gesture (e.g., a first stage of a multi-stage control gesture) that involves the user's index finger contacting the middle finger while the pinch gesture from FIG. **18**B is maintained. Although FIG. **18**C does not show a change to the scene **2302** in response to the tap gesture, in some embodiments, the scene **2302** (and/or a display of the wrist-wearable device **120**) updates to indicate to the user **115** that the tap gesture was detected. For example, the scene **2302** can update to include a tooltip on what control gestures are available given the priming and tap gestures. As another example, the wrist-wearable device **120** and/or the head-wearable device **202** may provide visual, audio, and/or haptic feedback to the user to indicate that the tap gesture was detected (e.g., distinct from feedback provided in response to the pinch gesture).

[0192] FIG. **18**D shows the user **115** performing a snap gesture (e.g., a second stage of a multi-stage control gesture) that involves the user's index finger and thumb sliding against one another with sufficient force (e.g., force above a preset threshold). FIG. **18**D further shows the scene **2302** updating to include a user interface element **2310** notifying the user **115** that an image has been captured in accordance with the multi-stage gesture. In some embodiments, the wrist-wearable device **120** notifies the user of the image capture (e.g., via an audio or visual alert).

[0193] In some embodiments, the wrist-wearable device **120** and/or the head-wearable device **202** provides visual,

audio, and/or haptic feedback to the user to indicate that a performed gesture stage has been detected (e.g., distinct feedback provided in response to each type of gesture).

[0194] FIGS. **19**A-**19**D illustrate another example user scenario of interacting with an artificial-reality system in accordance with some embodiments. The user **115** in FIG. **19**A is wearing a head-wearable device **202** (e.g., augmented reality glasses) and a wrist-wearable device **120** (e.g., a smartwatch). The user **115** in FIG. **19**A is viewing a scene **2402** that includes a bird for which the user wishes to capture a video. The user **115** in FIG. **19**A is not performing a gesture.

[0195] FIG. **19**B shows the user **115** performing a pinch gesture (e.g., a first stage of a multi-stage priming gesture) that involves the user's middle finger contacting the thumb. Although FIG. **19**B does not show a change to the scene **2402** in response to the pinch gesture, in some embodiments, the scene **2402** (and/or a display of the wrist-wearable device **120**) updates to indicate to the user **115** that the pinch gesture was detected. For example, the scene **2402** can update to include a tooltip on what control gestures are available given the priming gesture.

[0196] FIG. **19**C shows the user **115** performing a double tap gesture (e.g., a second stage of the multi-stage priming gesture) that involves the user's index finger contacting the middle finger twice while the pinch gesture from FIG. **19**B is maintained. Although FIG. **19**C does not show a change to the scene **2402** in response to the double tap gesture, in some embodiments, the wrist-wearable device **120** and/or the head-wearable device **202** provides visual, audio, and/or haptic feedback to the user to indicate that the double tap gesture was detected (e.g., distinct from feedback provided in response to the pinch gesture).

[0197] FIG. **19**D shows the user **115** performing a snap gesture (e.g., a control gesture) that involves the user's index finger and thumb sliding against one another with sufficient force (e.g., force above a preset threshold). FIG. **19**D further shows the scene **2402** updating to include a user interface element **2406** notifying the user **115** that the scene is being captured/recorded (e.g., by a camera on the head-wearable device **202**). In some embodiments, the wrist-wearable device **120** and/or the head-wearable device **202** provides visual, audio, and/or haptic feedback to the user to indicate that a performed gesture stage has been detected (e.g., distinct feedback provided in response to each type of gesture).

[0198] FIGS. **20**A-**20**D illustrate an example user scenario of interacting with a wearable device in accordance with some embodiments. The user **115** in FIG. **20**A is wearing a wrist-wearable device **120** (e.g., a smartwatch) that includes a display **2502** (e.g., showing the time of day in FIG. **20**A). The user **115** in FIG. **20**A is not performing a gesture.

[0199] FIG. **20**B shows the user **115** performing a pinch gesture (e.g., a priming gesture) that involves the user's index finger contacting the thumb. FIG. **20**B further shows the display **2502** updating (responsive to the pinch gesture) to present the radial menu **2504**. The radial menu **2504** includes multiple user interface elements (icons) that correspond to different applications on the wrist-wearable device **120**. The display **2502** in FIG. **20**B also shows a timer element **2506** to indicate to the user **115** a time period (e.g., 5, 10, or 20 seconds) for inputting a control gesture.

[0200] FIG. **20**C shows the user **115** maintaining the pinch gesture from FIG. **20**B. FIG. **20**C further shows the display **2502** presenting the radial menu **2504** and the timer element **2506**. The timer element **2506** in FIG. **20**C indicates that the time period for inputting the control gesture has nearly expired.

[0201] FIG. **20**D shows the user **115** maintaining the pinch gesture from FIGS. **20**B and **20**C. FIG. **20**D further shows the display **2502** showing the time of day to the user **115**, e.g., ceasing to present the radial menu **2504** and the timer element **2506** in accordance with the time period for inputting a control gesture having expired. Although FIGS. **20**B-**20**D show the user **115** maintaining the priming gesture (e.g., the pinch gesture), in some embodiments, the user does not maintain the priming gesture (e.g., performs a snap gesture) to trigger presentation of a menu and a timer for inputting a corresponding control gesture. In some embodiments, the available multi-stage gestures for the user **115** include one or more gestures that include three or more stages. In some embodiments, detection of each stage of a multi-stage gesture resets, adds time to, or starts a new time period for inputting the control gesture.

[0202] In some embodiments, the wrist-wearable device **120** provides audio and/or haptic feedback to the user **115** to indicate that a performed gesture stage has been detected and/or provide feedback in accordance with the time period for inputting the control gesture, such as haptic feedback to indicate that the time period expired without detection of a control gesture.

[0203] FIGS. **21**A-**21**D illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments. The user **115** in FIG. **21**A is wearing a wrist-wearable device **120** (e.g., a smartwatch) that includes a display **2502** presenting a user interface **2602** that corresponds to a messenger (e.g., e-mail) application, e.g., a message the user **115** is drafting in response to a remote user (Paul). The user **115** in FIG. **21**A is not performing a gesture.

[0204] FIG. **21**B shows the display **2502** updating to present a notification **2604** to the user **115**. The notification **2604** indicates to the user **115** an available gesture stage (e.g., a pinch gesture between the user's index finger and thumb) and corresponding action (e.g., presentation of available options). In some embodiments, the notification **2604** is presented in response to the wrist-wearable device **120** detecting that the user **115** has stopped providing input for the reply message. In some embodiments, the notification **2604** is presented in response to a voice command from the user. In some embodiments, the notification **2604** is presented in response to a gesture from the user (e.g., a priming gesture).

[0205] FIG. **21**C shows the user **115** performing a pinch gesture (e.g., a priming gesture) that involves the user's index finger contacting the thumb. FIG. **21**C further shows the display **2502** updating (responsive to the pinch gesture) to present the command options **2606**. The command options **2606** include an option **2606-1** for closing and saving the message (corresponding to a left rotation of the wrist), an option **2606-2** for closing the message without saving (corresponding to a right rotation of the wrist), and an option **2606-3** for sending the message (corresponding to an increase in force of the pinch gesture). In some embodiments, other options are presented, such as an option for executing a spellcheck operation (e.g., corresponding to a snap gesture). In the example of FIG. **21**C each option **2606**

corresponds to an available control gesture for the given priming gesture (the index finger pinch gesture).

[0206] FIG. **21**D shows the user **115** having rotated their wrist to the right (e.g., a control gesture) while holding the pinch gesture of FIG. **21**C. FIG. **21**D further shows an updated user interface **2602** (responsive to the control gesture) with the notification **2608** indicating to the user that the message has been saved (and closed). While FIG. **21**D shows the user **115** holding the pinch gesture (e.g., the priming gesture) while performing the wrist rotation (e.g., the control gesture), in some embodiments, the user releases the priming gesture prior to performing the control gesture.

[0207] FIGS. **22**A-**22**S illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments. The user **115** in FIG. **22**A is wearing a head-wearable device **202** (e.g., augmented reality glasses) and a wrist-wearable device **120** (e.g., a smartwatch). In some embodiments, the head-wearable device **202** is an instance of the augmented-reality system **7000**. The user **115** in FIG. **22**A is viewing a scene **2702** that includes a menu **2704**. The menu **2704** includes multiple user interface elements (icons) that correspond to different applications, including a user interface element **2706-1** for a music application that has focus in FIG. **22**A. In the example of FIG. **22**A, the wrist-wearable device **120** includes a display with a user interface **2708** that corresponds to (duplicates) the scene **2702** (e.g., the user can view (and optionally interact) with either the scene **2702** or the interface **2708**). The user interface **2708** includes a user interface element **2710-1** for the music application. The user **115** in FIG. **22**A is not performing a gesture.

[0208] FIG. **22**B shows the user **115** performing a pinch-and-roll gesture **2711** (e.g., a navigation gesture) that involves the user's index finger contacting the thumb while the user rotates their wrist in a first direction. In particular, the user's wrist is rotated in FIG. **22**B in accordance with the arrow **2712**. FIG. **22**B further shows the scene **2702** updating (responsive to the pinch-and-roll gesture) to scroll the menu **2704** to give focus to a user interface element **2706-2** for a phone application. In some embodiments, the amount of scroll of the menu **2704** corresponds to a speed of the user's wrist rotation (e.g., a quick flick motion causes more scroll than a slow turning motion). In some embodiments, the amount of scroll of the menu **2704** corresponds to an amount of rotation of the user's wrist (e.g., 90-degrees of rotation causes more scroll than 45-degrees of rotation). In accordance with some embodiments, the pinch-and-roll gesture is a multi-stage gesture where the pinch stage is a priming gesture and the roll stage is a navigation gesture.

[0209] FIG. **22**C shows the user **115** having ceased to maintain (released) the pinch-and-roll gesture shown in FIG. **22**B. As shown in FIG. **22**C, releasing the pinch-and-roll gesture does not activate the focused user interface element (user interface element **2706-2**). In some embodiments, releasing a navigation gesture results in activation of the user interface element that has focus within the menu **2704**. In some embodiments, whether releasing the navigation gesture results in activation of the user interface element depends on one or more settings (e.g., user preferences). In the example of FIG. **22**C, the wrist-wearable device **120** includes focus on a user interface element **2710-2** for the phone application.

[0210] FIG. **22**D shows the user **115** performing a pinch-and-roll gesture (e.g., a navigation gesture) that involves the user's index finger contacting the thumb while the user rotates their wrist in the first direction. In particular, the user's wrist is rotated in FIG. **22**D in accordance with the arrow **2722**. FIG. **22**D further shows the scene **2702** updating (responsive to the pinch-and-roll gesture) to scroll the menu **2704** to give focus to a user interface element **2706-3** for an exercise application. FIG. **22**D includes an arrow **2724** indicating an amount of scroll of the menu **2704** in response to the pinch-and-roll gesture (e.g., the longer arrow **2724** in FIG. **22**D indicates that more scrolling has occurred as compared to the shorter arrow **2714** in FIG. **22**B).

[0211] FIG. **22**E shows the user **115** performing a pinch-and-roll gesture (e.g., a navigation gesture) that involves the user's index finger contacting the thumb while the user rotates their wrist in a second direction (e.g., opposite of the first direction in FIG. **22**D). In particular, the user's wrist is rotated in FIG. **22**E in accordance with the arrow **2726**. FIG. **22**E further shows the scene **2702** updating (responsive to the pinch-and-roll gesture) to scroll the menu **2704** in accordance with arrow **2728** to give focus to a user interface element **2706-4** for a messenger application.

[0212] FIG. **22**F shows the user **115** having ceased to maintain (released) the pinch-and-roll gesture shown in FIG. **22**E. As shown in FIG. **22**F, releasing the pinch-and-roll gesture does not activate the focused user interface element (user interface element **2706-4**). In the example of FIG. **22**F, the wrist-wearable device **120** includes focus on a user interface element **2710-4** for the messenger application.

[0213] FIG. **22**G shows the user **115** performing a pinch gesture **2729** that involves the user's index finger contacting the thumb. FIG. **22**G further shows the scene **2702** updating (responsive to the pinch gesture) to display the messenger user interface **2730** with messages **2732-1** and **2732-2** (e.g., activation of the user interface element **2706-4** for the messenger application in FIG. **22**F). In some embodiments, the messenger application is activated in accordance with the pinch gesture **2729** having one or more characteristics that are distinct from the pinch-and-roll gesture **2711**. For example, no roll gesture is detected within a threshold amount of time of detecting the pinch gesture. As another example, the pinch gesture **2729** has a duration that is less than a threshold amount of time (e.g., quick pinch corresponds to an activation gesture and a long pinch corresponds to a priming gesture). As another example, the pinch gesture **2729** has a force component that meets one or more criteria for an activation gesture (e.g., a deep-press pinch gesture is an activation gesture).

[0214] FIG. **22**H shows the user **115** performing a pinch-and-roll gesture **2740** (e.g., a navigation gesture) that involves the user's index finger contacting the thumb while the user rotates their wrist in the first direction. In particular, the user's wrist is rotated in FIG. **22**H in accordance with the arrow **2742**. FIG. **22**H further shows the scene **2702** updating (responsive to the pinch-and-roll gesture) to scroll the messenger user interface **2730** in accordance with arrow **2744** (e.g., scrolling down through messages from various people), such that the message **2732-3** has focus.

[0215] FIG. **22**I shows the user **115** having ceased to maintain (released) the pinch-and-roll gesture **2740** shown in FIG. **22**H. As shown in FIG. **22**I, releasing the pinch-and-roll gesture does not activate the focused message **2732-3**. In the example of FIG. **22**I, the wrist-wearable

device **120** includes focus on a message **2748** (e.g., corresponding to focused message **2732-3**) in the messenger application.

[0216] FIG. **22**J shows the user **115** performing a pinch gesture **2750** that involves the user's index finger contacting the thumb. FIG. **22**J further shows the scene **2702** updating (responsive to the pinch gesture) to activate a function associated with the message **2732-3**. For example, in response to the pinch gesture **2750** an emoji menu **2752** is displayed and an emoji **2754-1** is given focus. In some embodiments, the message function is activated in accordance with the pinch gesture **2750** having one or more characteristics that are distinct from a pinch-and-roll gesture.

[0217] FIG. **22**K shows the user **115** performing a pinch-and-drag gesture (e.g., a navigation gesture) that involves the user horizontally translating their arm in a first direction while maintaining the pinch gesture **2750**. In particular, the user's arm moves in a horizontal translation in FIG. **22**K in accordance with the arrow **2760**. FIG. **22**K further shows the scene **2702** updating (responsive to the pinch-and-drag gesture) to move focus from the emoji **2754-1** (in FIG. **22**J) to the emoji **2754-2** in the emoji menu **2752** in accordance with arrow **2758** (e.g., scrolling right through the emoji response options). In some embodiments, a pinch-and-roll gesture can be replaced with a pinch-and-drag gesture (and vice versa). For example, the system is responsive (in the same way) to both navigation gestures. In some embodiments, each pinch-and-roll gesture is replaced with a pinch-and-drag gesture. In some embodiments, each pinch-and-drag gesture is replaced with a pinch-and-roll gesture.

[0218] FIG. **22**L shows the user **115** having ceased to maintain (released) the pinch-and-drag gesture shown in FIG. **22**K. As shown in FIG. **22**L, releasing the pinch-and-drag gesture selects the focused emoji (e.g., the emoji **2754-2** in FIG. **22**K). As shown in FIG. **22**L the emoji **2754-2** is sent in response to the message **2732-3** (as illustrated by emoji **2762**) in accordance with the user releasing the pinch-and-drag gesture while the emoji **2754-2** has focus. In some embodiments, the emoji **2754-2** is not selected in accordance with the pinch-and-drag gesture being released (e.g., selection of the emoji **2754-2** requires a separate gesture or gesture stage, such as a deep press). In the example of FIG. **22**L, the wrist-wearable device **120** displays the focused message **2748** with the emoji response **2764** (corresponding to the emoji **2762**).

[0219] FIG. **22**M shows the user **115** performing a pinch-and-roll gesture **2765** (e.g., a navigation gesture) that involves the user's index finger contacting the thumb while the user rotates their wrist in the second direction (opposite the first direction in FIG. **22**H). In particular, the user's wrist is rotated in FIG. **22**M in accordance with the arrow **2766**. FIG. **22**M further shows the scene **2702** updating (responsive to the pinch-and-roll gesture) to scroll the messenger user interface **2730** in accordance with arrow **2768** (e.g., scrolling up through the messages from various people), such that the message **2732-1** has focus.

[0220] FIG. **22**N shows the user **115** having ceased to maintain (released) the pinch-and-roll gesture **2765** shown in FIG. **22**M. As shown in FIG. **22**N, releasing the pinch-and-roll gesture does not activate the focused message **2732-1**. In the example of FIG. **22**N, the wrist-wearable device **120** includes focus on a message **2770** (e.g., corresponding to focused message **2732-1**) in the messenger application.

[0221] FIG. **22**O shows the user **115** performing a pinch gesture **2771** that involves the user's index finger contacting the thumb. FIG. **22**O further shows the scene **2702** updating (responsive to the pinch gesture **2771**) to display the messenger user interface **2772** with messages **2774-1** and **2774-2** (e.g., corresponding to activation of the message **2732-1** in FIG. **22**N). For example, the messages **2774** are messages between the user **115** and a person named Mary. In some embodiments, a function associated with the message **2732-1** is activated in accordance with the pinch gesture **2771** having one or more characteristics that are distinct from a pinch-and-roll gesture and distinct from the pinch gesture **2750** in FIG. **22**J. For example, the pinch gesture **2771** has an associated force that is greater than a preset force threshold (e.g., a deep press) and the pinch gesture **2750** has an associated force that is less than the preset force threshold (e.g., a light press).

[0222] FIG. **22**P shows the user **115** performing a pinch-and-drag gesture (e.g., a navigation gesture) that involves the user horizontally translating their arm in the first direction while maintaining the pinch gesture **2771**. In particular, the user's arm moves in a horizontal translation in FIG. **22**P in accordance with the arrow **2776**. FIG. **22**P further shows the scene **2702** updating (responsive to the pinch-and-drag gesture) to move focus to a quick response option **2780-3** in a quick response menu **2778** (e.g., scrolling right through quick response options).

[0223] FIG. **22**Q shows the user **115** having ceased to maintain (released) the pinch-and-drag gesture shown in FIG. **22**P. As shown in FIG. **22**Q, releasing the pinch-and-drag gesture selects the focused quick response option (e.g., the quick response option **2780-3** in FIG. **22**P). As shown in FIG. **22**Q the quick response **2782** is sent in response to the message **2774-2** in accordance with the user releasing the pinch-and-drag gesture while the quick response option **2780-3** has focus. In some embodiments, the quick response option **2780-3** is not selected in accordance with the pinch-and-drag gesture being released (e.g., selection of the quick response option **2780-3** requires a separate gesture or gesture stage, such as a deep press). In the example of FIG. **22**Q, the wrist-wearable device **120** displays the focused message **2784** corresponding to the quick response **2782**.

[0224] FIG. **22**R shows the user **115** performing a pinch gesture **2790** that involves the user's middle finger contacting the thumb. FIG. **22**R further shows the scene **2702** updating (responsive to the pinch gesture **2790**) to display the messenger user interface **2730** (e.g., corresponding to an 'exit' and/or 'go back' command) with message **2791** (e.g., corresponding to quick response **2782**) and message **2732-2**.

[0225] FIG. **22**S shows the user **115** performing a pinch gesture **2794** that involves the user's middle finger contacting the thumb (e.g., corresponding to the 'exit' and/or 'go back' command). FIG. **22**S further shows the menu **2704** that includes the multiple user interface elements (icons) that correspond to different applications, including the user interface element **2706-4** for the messenger application. In the example of FIG. **22**S, the wrist-wearable device **120** includes display of the user interface element **2710-4** for the messenger application.

[0226] Although the user scenarios described previously with respect to the series of FIGS. **21** through **27** describe

operations being performed by the wrist-wearable device **120** and head-wearable devices **110** and **202**, in some embodiments, at least a subset of the operations are performed by an intermediary device, such as a smartphone or personal computer, that is in communication with the wearable devices. For example, detection of user movement may occur at the wearable devices, but interpretation of the movement (e.g., identifying a gesture to which the movement corresponds) optionally occurs at an intermediary device. In some embodiments, the wrist-wearable device **120** and the head-wearable devices **110** and **202** communication with one another via the intermediary device (e.g., each are communicatively coupled to the intermediary device and the intermediary device manages interactions between the devices).

[0227] In some embodiments, data from sensors on multiple devices are combined (e.g., at the intermediary device) to detect an in-air gesture. For example, data from one or more optical sensors of a head-wearable device (e.g., the head-wearable device **202**) can be combined with EMG and/or IMU data from a wrist-worn device (e.g., the wrist-wearable device **120**) to identify a swipe gesture at a location that corresponds to a first scroll bar of a user interface rather than a second scroll bar displayed at a separate location.

[0228] Additionally, although the user scenarios described with respect to the series of FIGS. **21** through **27** are described as separate sequences, in some embodiments, the user scenarios are combined with one another. For example, the sequence described with respect to FIGS. **17**A-**2**C could occur before (or after) the sequences described with respect to FIGS. **18**A-**18**D, **19**A-**19**D, and **22**A-**22**S (e.g., all four sequences could occur while the user **115** is on a morning walk).

[0229] The user scenarios described with respect to the series of FIGS. **21** through **27** involved specific menus and applications, such as the radial menu **2131** in FIG. **16**A and the messenger application in FIG. **21**A. However, the sequences, gestures, actions, and operations can be used in conjunction with other types of menus and applications, such as web-browsing, note-taking, social media, word processing, data-entry, programming, and the like.

[0230] FIGS. **23**A-**23**B are flow diagrams illustrating a method **2800** for activating user-interface interactions in accordance with some embodiments. The method **2800** is performed at a computing system (e.g., a wearable device or intermediary device) having one or more processors and memory. In some embodiments, the memory stores one or more programs configured for execution by the one or more processors. At least some of the operations shown in FIGS. **23**A-**23**B correspond to instructions stored in a computer memory or computer-readable storage medium (e.g., the memory **6080** or the memory **7050**). In some embodiments, the computing system is a wearable device, such as the wrist-wearable device **120** or the head-wearable device **110** or **202**. In some embodiments, the computing system is, or includes, an intermediary device such as a smartphone or controller.

[0231] The system receives (**2802**), via one or more sensors of a wrist-wearable device (e.g., the wrist-wearable device **120**) worn by a user, data generated from performance of an in-air gesture by the user. For example, the one or more sensors include the sensors **6021** (e.g., EMG and/or IMU sensors).

[0232] The system activates (**2804**) a user interface (e.g., via processor(s) **6079**) in accordance with a determination that a first portion (stage) of the in-air gesture is a priming gesture. In some embodiments, activating the user interface includes making the user interface response to control gestures. In some embodiments, activating the user interface includes presenting at least one element on the user interface that was not presented prior to activation. For example, the options **2132** are presented in response to a pinch gesture as illustrated in FIG. **16**B.

[0233] In some embodiments, activating the user interface includes (**2806**) making the user interface responsive to additional gestures. For example, the pinch gesture in FIG. **17**B causes the interface **2208** to be responsive to a wrist rotation gesture (to which it was not previously responsive). In some embodiments, activating the user interface includes changing an operating state of the wrist-wearable device or the head-wearable device (e.g., from a display mode to an input-responsive mode).

[0234] In some embodiments, the system activates (**2808**) a display of the wrist-wearable device in response to the priming gesture. In some embodiments, the system activates a display of a head-wearable device in response to the priming gesture. In some embodiments, a wearable device (e.g., the wrist-wearable device **120** or the head-wearable device **202**) is in a low-power or sleep state prior to receipt of the priming gesture and the wearable device transitions to a full power or awake state in response to the priming gesture. In some embodiments, the display is dimmed or turned off prior to receipt of the priming gesture and is turned on or illumination is increased in response to the priming gesture.

[0235] In some embodiments, activating the user interface includes (**2810**) displaying a menu (e.g., the radial menu **2131**) within the user interface. In some embodiments, the menu is available (**2812**) for only a predetermined amount of time (e.g., as illustrated in FIGS. **20**A-**20**D). In some embodiments, the system ceases (**2814**) to display the menu within the user interface in accordance with a determination that a control gesture is not detected within a predetermined amount of time (e.g., as described previously with reference to FIG. **20**D).

[0236] The system executes (**2816**) a command (e.g., via the processor(s) **6079**) for the user interface that corresponds to a control gesture in accordance with a determination that a second portion (stage) of the in-air hand gesture is the control gesture. For example, the user interface **2140** for the camera application is presented in FIG. **16**E in response to the user tap gesture (e.g., a control gesture) in FIG. **16**D.

[0237] In some embodiments, the system identifies (**2818**) the command for the user interface based on a combination of the priming gesture and the control gesture. For example, the multiple commands may be responsive to the same priming gesture with distinct control gestures. As another example, multiple commands may be responsive to the same control gesture with different priming gestures. In these examples, the combination of priming gesture and control gesture is utilized to determine which command to execute.

[0238] In some embodiments, the system receives (**2820**) data generated from performance of a second in-air gesture by the user; activates the user interface in accordance with a determination that a first portion of the second in-air gesture is a second priming gesture; and deactivates the user interface in accordance with a determination that a second

control gesture is not detected within a predetermined amount of time (e.g., as illustrated in FIGS. **20**A-**20**D). In some embodiments, the system is only responsive to a subset of control gestures that correspond to the priming gesture and deactivates the user interface in accordance with a determination that a control gesture from the subset of control gestures is not detected within the predetermined amount of time. In some embodiments, the subset of control gestures corresponds to an operating state of the system and the priming gesture performed (e.g., the subset of control gestures is based on an active application on the system).

[0239] FIGS. **23**C-**23**D are flow diagrams illustrating a method **2850** for activating user-interface interactions in accordance with some embodiments. The method **2850** is performed at a computing system (e.g., a wearable device or intermediary device) having one or more processors and memory. In some embodiments, the memory stores one or more programs configured for execution by the one or more processors. At least some of the operations shown in FIGS. **23**C-**23**D correspond to instructions stored in a computer memory or computer-readable storage medium (e.g., the memory **6080** or the memory **7050**). In some embodiments, the computing system is a wearable device, such as the wrist-wearable device **120** or the head-wearable device **110** or **202**. In some embodiments, the computing system is, or includes, an intermediary device such as a smartphone.

[0240] The system receives (**2852**) data generated from performance of a gesture by a user. For example, the system receives the data via one or more sensors (e.g., the sensors **6021**). In some embodiments, the system receives data from one or more wearable devices (e.g., the wrist-wearable device **120** and/or the head-wearable device **110** or **202**).

[0241] The system determines (**2854**) whether the first portion of the gesture is a priming gesture. For example, one or more processors **6079** of a wearable device (or an intermediary device) analyzes the data and determines whether the gesture is, or includes, a priming gesture. In some embodiments, prior to determining that the first portion of the gesture is a priming gesture, the system is in a low-power or sleep state and is responsive to only priming gestures (e.g., not responsive to control or navigation gestures).

[0242] In accordance with a determination that the first portion of the gesture is a priming gesture, the system activates (**2856**) a user interface. In some embodiments, activating the user interface includes one or more of: making the user interface responsive to more gestures/commands; updating the user interface to include one or more elements not previously shown; and increasing a brightness, opacity, and/or size of the user interface.

[0243] In accordance with a determination that the first portion of the gesture is not a priming gesture, the system forgoes activating the user interface (e.g., returns to a state responsive to only priming gestures).

[0244] The system determines (**2860**) whether a second portion of the gesture is detected within a preset amount of time. For example, the system initiates a timer (e.g., 5, 15, or 30 seconds) in response to identifying the priming gesture.

[0245] In accordance with a determination that the second portion of the gesture is not detected within the preset amount of time, the system deactivates (**2858**) the user interface (e.g., and returns to a state responsive to priming gestures). For example, the system (and user interface) returns to the state it was in prior to receiving the data generated from performance of the gesture by the user.

[0246] In accordance with a determination that the second portion of the gesture is detected within the preset amount of time, the system determines (**2862**) whether the second portion of the gesture is a control gesture. In some embodiments, the system determines whether the second portion is part of a same multi-stage gesture as the first portion (e.g., whether the second portion is a valid second stage of a multi-stage gesture given the priming gesture).

[0247] In accordance with a determination that the second portion of the gesture is a control gesture, the system executes (**2864**) a command for the user interface that corresponds to the control gesture. In some embodiments, the system identifies the command based on both the priming gesture and the control gesture. In some embodiments, the system identifies the command based on a combination of stages of the multi-stage gesture that includes the priming gesture and the control gesture. In some embodiments, the system deactivates (**2858**) the user interface after executing the command. In some embodiments, the system updates the user interface in accordance with the command.

[0248] In accordance with a determination that the second portion of the gesture is not a control gesture, the system deactivates (**2858**) the user interface (e.g., and returns to a state responsive to priming gestures).

[0249] In some embodiments, a particular set of gestures detected based on sensed neuromuscular signals (e.g., sensed using neuromuscular-signal sensors, such as EMG-sensing electrodes of a wrist-wearable device) is associated with a respective action (e.g., that can be performed at a device that is the same or different than the wrist-wearable device on which the neuromuscular-signal sensors can be positioned). In one example, at least seven distinct gestures are each associated with a different respective action, in particular, (i) a double index tap (e.g., an in-air hand gesture in which the user's thumb and index finger make contact twice) is associated with a first action (e.g., taking a photo); (ii) an index finger press and hold (e.g., an in-air hand gesture in which the user's thumb and index finger make contact and then maintain that contact for at least 0.15 seconds) is associated with a second action (e.g., starting or stopping a video); (iii) a double middle pinch (e.g., an in-air hand gesture in which the user's thumb makes contact with the user's middle finger twice) is associated with a third action (e.g., playing or pausing music); (iv) a thumb swipe in an upward direction (e.g., an in-air hand gesture in which the user's thumb moves in an upward direction away from the user's body across a part of the user's index finger) is associated with a fourth action (e.g., increasing volume); (v) a thumb swipe in a downward direction (e.g., an in-air hand gesture in which the user's thumb moves in a downward direction toward the user's body across a part of the user's index finger) is associated with a fifth action (e.g., decreasing volume); (vi) a thumb swipe in a leftward direction (e.g., an in-air hand gesture in which the user's thumb moves in a right-to-left direction across a part of the user's index finger) is associated with a sixth action (e.g., switching to a previously-played song, or switching to a prior content item such as a previously-viewed webpage or photo); and (vii) a thumb swipe in a rightward direction (e.g., an in-air hand gesture in which the user's thumb moves in a left-to-right direction across a part of the user's index finger) is associated with a seventh action (e.g., switching to a next song, or

switching to a next content item such as a next webpage or photo). This example gesture space can also be made available only after a wake gesture is received and that wake gesture can be detected using sensors other than the neuromuscular-signal sensors, such as using sensors from an inertial measurement unit. Often, the IMU-based sensors can be less power-intensive and thus, gating the EMG gesture space until after the IMU-based wake gesture is received can help to ensure that the device makes efficient use of limited power and computing resources.

[0250] As one of skill in the art will appreciate, aspects of the method **2800** can be combined and/or replaced with aspects of the method **2850**. For example, the method **2800** can be performed prior to (or after) the method **2850**. The method **2800** can include the operations of method **2850**, e.g., operations from method **2800** can be performed after operation **2862**. As another example, the operation **2804** can be replaced with the operation **2854**.

[0251] FIGS. **24**A-**24**E illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments. The user **115** in FIG. **24**A is wearing a head-wearable device **110** (e.g., a virtual reality headset) and a wrist-wearable device **120** (e.g., a smartwatch). In FIG. **24**A, the user **115** is viewing a scene **2130** via the head-wearable device **110** and the user **115** is not performing a gesture.

[0252] In FIG. **24**B, the user **115** is performing a priming gesture (e.g., a pinch gesture) using the user's pointer finger contacting the thumb. FIG. **24**B further shows the scene **2130** having updated in response to the pinch gesture. The scene **2130** in FIG. **24**B includes a user interface **1220** (e.g., a list of numbers the user **115** can scroll through). The user interface **1220** includes one or more numbers and a focus **1222** which highlights the currently selected number (the number **15**). In some embodiments, the focus **1222** appears on a number that was previously selected in response to detecting the priming gesture. In some embodiments, the focus **1222** appears on the start of the list of numbers (e.g., the leftmost number). In some embodiments, as the user **115** performs one or more hand gestures, the focus **1222** moves in accordance with the performed hand gesture (e.g., further described in FIGS. **24**B-**24**E). In some embodiments, the focus **1222** is a cursor. In some embodiments, the user interface **1220** is displayed while the priming gesture is maintained. In some embodiments, the user interface **1220** is displayed for a predetermined amount of time after the priming gesture is performed. In some embodiments, the focus **1222** is displayed (and manipulable) while the priming gesture is maintained. In some embodiments, the focus **1222** is displayed (and manipulable) for a predetermined amount of time after the priming gesture is performed. In some embodiments, a first predetermined amount of time after the priming gesture is performed the focus **1222** ceases to be manipulable and/or displayed. In some embodiments, a second predetermined amount of time after the priming gesture is performed the user interface **1220** ceases to be displayed. In some embodiments, the second predetermined amount of time is longer than the first predetermined amount of time.

[0253] FIG. **24**B further illustrates a graph **1290** showing a relationship between a translation distance of a navigation gesture and a navigation speed for the focus **1222**. The graph **1290** in FIG. **24**B corresponds to a first point in time (e.g., a point in time before the user **115** has performed a navigation gesture) and indicator **1292** indicates that the navigation speed is zero (e.g., no navigation is occurring at the first point in time). In some embodiments, the navigation speed of the focus **1222** corresponds to a translation distance of a navigation gesture from an initial. In some embodiments, the relationship between the navigation speed and the translation distance is a linear relationship, as indicated by dotted line **1291**. In some embodiments, the position of the hand of the user **115** when the priming gesture is performed is set as an initial position (e.g., for use with subsequent navigation gestures).

[0254] FIG. **24**C illustrates the user **115** performing a navigation gesture (e.g., a drag gesture which is a horizontal translation, also shown and described in FIG. **22**K). In the example of FIG. **24**C the priming gesture (e.g., the pinch gesture) is maintained during the navigation gesture. FIG. **24**C also illustrates the scene **2130** updating responsive to the navigation gesture by scrolling through the user interface **1220** at a first speed and moving the focus **1222** from the number "15" to the number "19." In some embodiments, the distance of the translation corresponds to a speed of the navigation, as indicated by the graph **1290** in FIG. **24**C. In some embodiments, the navigation speed is based on one or more settings (e.g., set by the user **115** or set as a default by the system). For example, the user **115** may adjust a setting that adjusts the slope of the dotted line **1291**.

[0255] The graph **1290** in FIG. **24**C illustrates a navigation speed of the focus **1222** at a second point in time, as indicated by indicator **1292**. The navigation speed of the focus **1222** is based on the translation distance of the navigation gesture in accordance with some embodiments. The indicator **1292** illustrates that the user **115** has translated their hand a first distance and is scrolling through elements on the user interface **1220** at a corresponding first speed. For example, as the user **115** translates their hand farther, they are able to scroll more quickly and if the user **115** holds their hand at a set distance from the initial distance the focus **1222** will scroll at a constant speed based on the set distance.

[0256] FIG. **24**D illustrates the user **115** releasing the pinch gesture (e.g., the priming gesture) and returning their hand to the initial starting position. In some embodiments, the release of the pinch gesture causes the navigation gesture to end and subsequent movement back to the initial position does not cause the navigation of the user interface **1220**. In some embodiments, the system does not detect and/or respond to navigation gestures in the absence of a priming gesture, as indicated by the graph **1290** in FIG. **24**D. Accordingly, the system does not respond to the user **115** moving their hand after releasing the pinch gesture in FIG. **24**D. In some embodiments, the user **115** performs an additional priming gesture and a subsequent navigation gesture to resume scrolling through the user interface **1220**. For example, the user **115** can continue performing the actions illustrated in FIGS. **24**B-**24**C to continue scrolling through the user interface **1220**.

[0257] FIG. **24**E illustrates the user **115** performing a priming gesture (e.g., a pinch gesture) and a subsequent navigation gesture (e.g., an additional horizontal translation of their hand) at a third point in time. In the example of FIG. **24**E, the user **115** is translating their hand a further distance than the previous translation shown in FIG. **24**C. The graph **1290** in FIG. **24**E illustrates a navigation speed of the focus **1222** at the third point in time, as indicated by the position of the indicator **1292**. FIG. **24**E further shows the focus **1222**

moving from the number **19** (in FIG. **24**E) to the number **40** in accordance with the subsequent navigation gesture. In some embodiments, the navigation speed of the focus **1222** is based on a distance of the translation. In some embodiments, the navigation speed of the focus **1222** is independent of a speed of the translation. In some embodiments, the navigation distance through the user interface **1220** is based on a distance, speed, and/or duration of the navigation gesture. The indicator **1292** in FIG. **24**E indicates that the user **115** translated their hand a second distance and is scrolling through the user interface **1220** at a corresponding second speed. In some embodiments, as the user **115** continues to translate their hand farther, the speed of the navigation increases.

[0258] FIGS. **24**A-**24**E illustrate examples of a user navigating horizontally. In some embodiments, the user navigates vertically using the gestures shown and described in FIGS. **24**A-**24**E. In some embodiments, the gesture translations are horizontal and/or vertical. FIGS. **24**A-**24**E illustrate examples of a user translating their arm in particular directions. In some embodiments, the user navigates by translating their hand, but not their arm (e.g., a translation associated with bending of the user's wrist), in a similar manner as shown and described in FIGS. **24**A-**24**E. In some embodiments, the user is able to navigate a two-dimensional user interface by translating their hand and/or arm along two different axes. In some embodiments, the user navigates by rotating their wrist (e.g., as shown in FIGS. **25**A-**25**H). In some embodiments, the navigation includes controlling movement of a cursor between elements (e.g., icons) on a user interface. In some embodiments, the navigation includes moving a focus from one element to another (e.g., without moving the focus to a position that does not corresponds to an element).

[0259] FIG. **25**A illustrates the user **115** performing a pinch-and-hold gesture to perform a priming gesture and assign an initial position θ for a subsequent hand gesture. In the example of FIG. **25**A, the focus **1222** is on the number **40** of the user interface **1220** (e.g., as a result of the sequence of FIGS. **24**A-**24**E). As illustrated in FIGS. **24**A-**24**E, while the priming gesture is maintained, the user interface **1220** is displayed in the scene **2130**. FIG. **25**A further illustrates graph **1394** which shows the speed of scrolling versus position of the user's hand gesture with reference to the assigned initial position, at a first point in time (e.g., before the user **115** has performed a navigation gesture). For example, FIG. **25**A illustrates the user's hand gesture still maintained at the initial position and thus no scrolling has occurred. The indicator **1396** in FIG. **25**A indicates that the hand gesture is still at the initial position θ and thus the scrolling speed is zero. In the example of FIGS. **25**A-**25**H, the relationship between navigation speed and hand position is a step function with steps at a first threshold, T**1**, and a second threshold, T**2**. In some embodiments, the first and second thresholds are evenly spaced (e.g., the steps have a same size). In some embodiments, the first and second thresholds are not evenly spaced (e.g., the steps have different sizes). In some embodiments, the focus **1222** starts moving when the navigation gesture leaves the initial position (e.g., a non-zero speed corresponds to the distance between the initial position and the first threshold, T**1**).

[0260] In some embodiments, the step function contains a dead zone (in which no scrolling occurs) such that the focus **1222** move while the hand position is within the dead zone. For example, there may be a third threshold, T**0**, between the initial position θ and the first threshold T**1**. In this example, a navigation gesture with a distance from the initial position (e.g., a wrist rotation distance or hand translation distance) that is less than the third threshold, TO, does not cause movement of the focus **1222**.

[0261] FIG. **25**B illustrates the user **115** rotating their wrist (e.g., a navigation gesture) in a first direction past the initial position θ while maintaining the pinch gesture from FIG. **25**A. In some embodiments, as the user **115** rotates their wrist past the initial position θ, the focus **1222** scrolls through the numbers in the user interface **1220** at a first speed (e.g., 25% of a maximum speed) corresponding to the step between the initial position θ and the first threshold, T**1**. FIG. **25**B further shows the focus **1222** moving from the number **40** (in FIG. **25**A) to the number **44** in accordance with the navigation gesture (the wrist rotation). In the example of FIG. **25**B a scrolling speed user interface element **1326** is displayed. In some embodiments, the scrolling speed user interface element **1326** is displayed in response to detecting the navigation gesture. In some embodiments, the scrolling speed user interface element **1326** is displayed in response to detecting the priming gesture. In some embodiments, the scrolling speed user interface element **1326** is displayed in accordance with a corresponding setting being enabled (e.g., the user **115** may set a preference to toggle display of the scrolling speed user interface element **1326**). In some embodiments, the scrolling speed user interface element **1326** is displayed at a different location in the scene **2130** (e.g., a top or lateral side of the scene **2130**). In some embodiments, the position of the scrolling speed user interface element **1326** is based on a user preference and/or a device setting (e.g., a device setting set by an active application or function of the head-wearable device **110**).

[0262] The scrolling speed user interface element **1326** provides a visual indicator **1328** and a numerical indicator **1330** indicating to the user **115** their current navigation (scrolling) speed. In some embodiments, the scrolling speed user interface element **1326** includes a different type of speed indication (e.g., a raw speed number and/or a color indicator). In some embodiments, as the user **115** rotates their hand clockwise passing the initial position θ, the focus **1222** moves from left to right through the numbers of the user interface **1220**. Furthermore, as the user **115** scrolls through the numbers in the user interface **1220** by rotating their hand from the initial position θ in the first direction (e.g., clockwise), the numbers increase in value. In some embodiments, as the user **115** rotates their hand from the initial position θ in the second direction (e.g., counter-clockwise), the focus **1222** moves from left to right through the numbers in the user interface **1220**. The graph **1394** in FIG. **25**B illustrates a navigation speed versus a wrist rotation angle at a second point in time. For example, as illustrated in FIG. **25**B, the user **115** has rotated their wrist past the initial position θ but not past the first threshold T**1**. Thus, the user **115** is scrolling through the numbers in the user interface **1220** at a first speed (S**1**) in FIG. **25**B.

[0263] FIG. **25**C illustrates the user **115** rotating their wrist in the second direction back to the initial position θ while maintaining the pinch gesture from FIG. **25**B. In some embodiments, when the user **115** rotates their wrist back to the initial position θ, the navigation speed returns to zero (e.g., the navigation gesture ends). FIG. **25**C further shows the focus **1222** moving from the number **44** (in FIG. **25**B) to

the number **46** in accordance with the navigation gesture (e.g., the wrist rotation). For example, the focus **1222** continues to move to the right as the user **115** rotates their wrist back toward the initial position θ and stops moving once the user **115** returns their wrist to the initial position θ. As illustrated in FIG. **25**C the relative position of the wrist of the user **115** determines the direction of movement of the focus **1222**. For example, the direction of movement of the wrist of the user **115**-counter-clockwise back to the initial position in FIG. **25**C does not change the direction of movement of the focus **1222** while the relative position is clockwise of the initial position. In some embodiments, a subsequent rotation of the wrist away from the initial position θ (while maintaining the pinch gesture) corresponds to a continuation of the navigation gesture or a start of a new navigation gesture. The indicator **1396** on the graph **1394** shows the user **115** has returned their wrist to the initial position θ and the scrolling speed has decreased to zero, at a third point in time. Accordingly, the visual indicator **1328** and the numerical indicator **1330** on the scrolling speed user interface element **1326** indicate that the navigation speed is zero in FIG. **25**C.

[0264] FIG. **25**D illustrates the user **115** rotating their wrist in the second direction past a third threshold, denoted-T**1**, while maintaining the pinch gesture from FIG. **25**B at a fourth point in time. In some embodiments, as the navigation gesture passes the third threshold, −T**1**, the focus **1222** navigates (e.g., scrolls through the numerals) at a second speed, denoted S**2**, faster than the first speed. In some embodiments, the third threshold, −T**1**, corresponds to a same distance as the first threshold, T**1**, in an opposite direction (e.g., a counter-clockwise rotation rather than a clockwise rotation). In some embodiments, the third threshold, −T**1**, corresponds to a difference distance than the first threshold, T**1**. The speed S**2** in FIG. **25**D is in the second direction (e.g., has a negative angular velocity as compared to the speed S**1** in FIG. **25**B). FIG. **25**D further shows the focus **1222** moving from the number **46** (in FIG. **25**C) to the number **25** in accordance with the navigation gesture (e.g., the counter-clockwise wrist rotation). The indicator **1396** on the graph **1394** in FIG. **25**D indicates that the rotational position of the wrist of the user **115** is between the third threshold, −T**1**, and a fourth threshold, denoted −T**2**, and the navigation speed of the focus **1222** corresponds to a second step in the counter-clockwise direction. Additionally, the numerical indicator **1330** and the visual indicator **1328** have updated to indicate that the navigation speed is 75% of the maximum speed in a leftward direction.

[0265] FIG. **25**E illustrates the user **115** rotating their wrist in the first direction back to the initial position θ (e.g., similar to FIG. **25**C) while maintaining the pinch gesture from FIG. **25**B. In some embodiments, when the user **115** rotates their wrist back to the initial position θ, the navigation speed returns to zero (e.g., the navigation gesture ends). FIG. **25**E further shows the focus **1222** moving from the number **25** (in FIG. **25**D) to the number **23** in accordance with the navigation gesture (e.g., the wrist rotation). For example, the focus **1222** continues to move to the left as the user **115** rotates their wrist back toward the initial position θ and stops moving once the user **115** returns their wrist to the initial position θ. As illustrated in FIG. **25**E the relative position of the wrist of the user **115** determines the direction of movement of the focus **1222**. For example, the direction of movement of the wrist of the user **115**-clockwise back to the initial position in FIG. **25**E does not change the direction of movement of the focus **1222** while the relative position is clockwise of the initial position.

[0266] In some embodiments, a subsequent rotation of the wrist away from the initial position θ (while maintaining the pinch gesture) corresponds to a continuation of the navigation gesture or a start of a new navigation gesture. The indicator **1396** on the graph **1394** shows the user **115** has returned their wrist to the initial position θ and the scrolling speed has decreased to zero, at a fifth point in time. Accordingly, the visual indicator **1328** and the numerical indicator **1330** on the scrolling speed user interface element **1326** indicate that the navigation speed is zero in FIG. **25**E.

[0267] FIG. **25**F illustrates the user **115** rotating their wrist in the first direction past the second threshold, T**2**, while maintaining the pinch gesture from FIG. **25**B at a sixth time. In some embodiments, as the navigation gesture passes the second threshold, T**2**, the focus **1222** navigates (e.g., scrolls through the numerals) at a third speed, denoted S**3**, faster than the first speed (shown in FIG. **25**B), and faster than the second speed, S**2**. The speed S**3** in FIG. **25**F is in the first direction (e.g., has a negative angular velocity as compared to the speed S**2** in FIG. **25**D). FIG. **25**E further shows the focus **1222** moving from the number **23** (in FIG. **25**E) to the number **52** in accordance with the navigation gesture (e.g., the clockwise wrist rotation). The indicator **1396** on the graph **1394** in FIG. **25**F indicates that the rotational position of the wrist of the user **115** is beyond the second threshold, T**2**, and the navigation speed of the focus **1222** corresponds to a second step in the clockwise direction. In some embodiments, the second speed is the maximum scrolling speed. For example, if the user continues to rotate their wrist in the first direction, the navigation (scrolling) speed does not increase beyond the second speed. In some embodiments, in accordance with the user **115** scrolling at the maximum speed, a user interface element **1332** is displayed, e.g., visually indicating to the user **115** they have achieved the maximum speed. In some embodiments, other feedback is provided to the user **115** (e.g., haptics or auditory feedback) in addition to, or alternatively to, providing the user interface element **1332**. Additionally, the numerical indicator **1330** and the visual indicator **1328** have updated to indicate that the navigation speed is 100% of the maximum speed in a rightward direction.

[0268] FIG. **25**G illustrates the user **115** rotating their wrist in the second direction back to the initial position θ while maintaining the pinch gesture from FIG. **25**B at a seventh time. In some embodiments, when the user **115** rotates their wrist back to the initial position θ, the navigation speed returns to zero (e.g., the navigation gesture ends). FIG. **25**G further shows the focus **1222** moving from the number **52** (in FIG. **25**F) to the number **56** in accordance with the navigation gesture (e.g., the wrist rotation). For example, the focus **1222** continues to move to the right as the user **115** rotates their wrist back toward the initial position θ and stops moving once the user **115** returns their wrist to the initial position θ. As illustrated in FIG. **25**G the relative position of the wrist of the user **115** determines the direction of movement of the focus **1222**. For example, the direction of movement of the wrist of the user **115**-counter-clockwise back to the initial position in FIG. **25**G does not change the direction of movement of the focus **1222** while the relative position is clockwise of the initial position. In some embodiments, a subsequent rotation of the wrist away from the

initial position θ (while maintaining the pinch gesture) corresponds to a continuation of the navigation gesture or a start of a new navigation gesture. The indicator **1396** on the graph **1394** shows the user **115** has returned their wrist to the initial position θ and the scrolling speed has decreased to zero, at the seventh point in time. Accordingly, the visual indicator **1328** and the numerical indicator **1330** on the scrolling speed user interface element **1326** indicate that the navigation speed is zero in FIG. **25**G.

[0269] FIG. **25**H illustrates the user **115** rotating their wrist in the second direction past the third threshold, −T**1**, in the second direction while maintaining the pinch gesture from FIG. **25**B. In some embodiments, as the navigation gesture passes the third threshold, −T**1**, the focus **1222** navigates (e.g., scrolls through the numerals) at a second speed, denoted S**2**, faster than the first speed. The speed S**2** in FIG. **25**H is in the second direction (e.g., has a negative angular velocity as compared to the speed S**3** in FIG. **25**F). FIG. **25**H further shows the focus **1222** moving from the number **56** (in FIG. **25**G) to the number **47** in accordance with the navigation gesture (e.g., the counter-clockwise wrist rotation). The indicator **1396** on the graph **1394** in FIG. **25**H indicates that the rotational position of the wrist of the user **115** is between the third threshold, −T**1**, and the fourth threshold, denoted-T**2**, and the navigation speed of the focus **1222** corresponds to the second step in the counter-clockwise direction. Additionally, the numerical indicator **1330** and the visual indicator **1328** have updated to indicate that the navigation speed is 75% of the maximum speed in a leftward direction. In some embodiments, in response to the user **115** rotating their wrist in the second direction past the fourth threshold, −T**2**, in the second direction, a maximum navigation speed in the second direction is achieved (e.g., corresponding to S**3**).

[0270] FIGS. **25**A-**25**H illustrate examples of a user navigating horizontally. In some embodiments, the user navigates vertically using the gestures shown and described in FIGS. **25**A-**25**H. In some embodiments, the navigation includes controlling movement of a cursor between elements (e.g., icons) on a user interface. In some embodiments, the navigation includes moving a focus from one element to another (e.g., without moving the focus to a position that does not corresponds to an element).

[0271] FIGS. **26**A-**26**C illustrate graphs representing example relationships between navigation speed and gesture distance in accordance with some embodiments. Each graph shows a relationship between a navigation speed and a gesture distance (e.g., representing different functions that can be used by the system). In some embodiments, the different functions are selectable by active applications and/or system functions. For example, a first application may select a linear function and a second application may select a step function.

[0272] FIG. **26**A illustrates a linear function between navigation speed and gesture distance from an initial position (e.g., an initial position set by a priming gesture). The linear function in FIG. **26**A is bounded by a maximum velocity in each direction. For example, the user translates their hand or arm a distance DMAX in a first direction (e.g., to the right of the user) and, in response, a focus moves at a corresponding maximum velocity in a first navigation direction (e.g., toward the right of a display). As another example, the user rotates their wrist a distance-DMAX in a second direction (e.g., counter-clockwise) and, in response, a focus moves at a corresponding maximum velocity in a second navigation direction (e.g., toward the bottom of a display). In some embodiments, the linear function is unbounded. Applying the linear function allows the user **115** to scroll through user interface elements at a speed proportional to their movement. For example, as the user **115** increases rotation of their wrist, the speed of navigation increases (or decreases) proportionally. Using a linear function may provide a smooth and responsive scrolling experience. For example, the user **115** is able to speed up and slow down quickly in a manner similar to using a throttle on a motorcycle, e.g., throttling up to increase the speed of the motorcycle and throttling down to decrease the speed.

[0273] FIG. **26**B illustrates a step function between navigation speed and gesture distance. In some embodiments, such as illustrated in FIGS. **25**A-**25**H, there are one or more thresholds (e.g., steps) along the gesture distance, and each threshold is associated with an increase (or decrease) in the navigation speed. In some embodiments, the distance between the initial position and the first threshold operates as a dead zone (e.g., as illustrated in FIG. **26**B), in which the navigation speed stays at zero. For example, for a user **115** to start navigating through user interface elements, they gesture past the first threshold before any navigation movement occurs. Including a dead zone may benefit the user **115** by preventing unintentional movements from causing inadvertent navigation. A step function similar to the one shown in FIG. **26**B can be beneficial by providing consistent scrolling while requiring less precision from the user (e.g., consistent scrolling even if the user has small unintentional movements). In some embodiments, the step function is symmetric in both directions (e.g., when the user **115** rotates their wrist in either the first or second direction, they receive similar results with the direction being different). In some embodiments, the step function has equal steps. In some embodiments, the step function includes one or more steps that are a different size than other steps (e.g., correspond to a greater change in distance and/or a greater change in speed). In some embodiments, the step function contains different values depending on an application or user preference. For example, the user **115** may want to scroll quickly in one direction and have finer tuning when scrolling the opposite direction (e.g., to more quickly and precisely select a particular element). In some embodiments, the step between the first and second threshold corresponds to more fine-tuning movement and the step after the second threshold corresponds to quicker scrolling. For example, the user **115** may rotate past the second threshold to scroll through multiple pages of a document, then rotate between the first and second thresholds to select a particular element on a particular page.

[0274] FIG. **26**C illustrates a cubic function between navigation speed and gesture distance. The cubic function in FIG. **26**C includes a dead zone and is bounded by a maximum velocity in each direction. For example, the user translates their hand or arm a distance DMIN in a first direction (e.g., to the right of the user) and, in response, a focus moves at a corresponding minimum velocity in a first navigation direction (e.g., toward the right of a display). As the user continues to translate their hand or arm toward DMAX in the first direction, the speed of the focus increases cubically until the maximum velocity is reached at a distance of DMAX. In some embodiments, the linear function is unbounded. In some embodiments, the cubic function

does not include a dead zone. The cubic function shown in FIG. **26**C may benefit a user who wants to navigate quickly without large gesture distances.

[0275] The functions illustrated in FIGS. **26**A-**26**C are examples of functions that may be used by a system for navigation. In some embodiments, other functions are used (e.g., a quadratic or exponential function). In some embodiments, a function includes a combination of the functions shown in FIGS. **26**A-**26**C (e.g., a function that is linear between the initial position and a first threshold distance and is cubic between the first threshold and a second threshold).

[0276] FIGS. **27**A-**27**D illustrate another example user scenario of interacting with a wearable device in accordance with some embodiments. The user **115** in FIG. **27**A is wearing a head-wearable device **110** (e.g., a virtual-reality headset) and a wrist-wearable device **120** (e.g., a smart-watch). The user **115** in FIG. **27**A is viewing a scene **2130** via the head-wearable device **110** and the user **115** is not performing a gesture in FIG. **27**A. In accordance with some embodiments the user interface **1220** is displayed in the scene **2130** (e.g., is displayed prior to the user **115** performing a priming gesture). In some embodiments, the user interface **1220** is displays in accordance with a first application being active on the head-wearable device **110**.

[0277] FIG. **27**B illustrates the user **115** performing a priming gesture (e.g., a pinch gesture) using the user's pointer finger contacting the thumb. FIG. **27**B further shows the scene **2130** update in response to the pinch gesture to include display of focus **1522** (e.g., a highlight of the number **15** to indicate that it is the active/selected element). In some embodiments, the number **15** is given focus based on a previous gesture (e.g., a previous navigation gesture resulted in the number **15** being given the focus). In some embodiments, the number **15** is given focus in accordance with one or more system settings. For example, the system may be configured to give the leftmost element focus in response to detecting a priming gesture.

[0278] FIG. **27**B further illustrates graph **1590** which shows a linear relationship between a gesture translation distance and navigation speed (e.g., corresponding to a second type of navigation gesture) and graph **1594** which shows a step function relationship between a gesture wrist rotation distance and navigation speed (e.g., corresponding to a first type of navigation gesture). In the example of FIG. **27**B, an indicator **1592** indicates that the user **115** has not translated their hand/arm from an initial translation position at a first point in time, and an indicator **1596** indicates that the user has not rotated their wrist from an initial rotation position at the first point in time.

[0279] FIG. **27**C illustrates the user **115** performing a navigation gesture by rotating their wrist (e.g., performing a first type of navigation gesture). In the example of FIG. **27**C, the user has rotated their wrist in a clockwise direction. FIG. **27**C illustrates the focus **1522** moving from the number **15** in FIG. **27**B to the number **19** in response to the user **115** performing the navigation gesture. In addition, the visual appearance of the focus **1522** has updated in FIG. **27**C to indicate the direction of navigation (e.g., thicker on the right than on the left to indicate navigation to the right). For example, the focus **1522** includes a thicker white border to indicate which direction the user **115** is navigating. In some embodiments, the visual appearance of the focus **1522** is based on a direction of navigation and/or a speed of navigation. In some embodiments, the edge of the focus on the respective side that is the same direction as the navigation is visually different than other edges of the focus. FIG. **27**C illustrates the user **115** rotating their wrist between the first and second thresholds (e.g., corresponding to a speed, S**1**). In FIG. **27**C, the navigation speed assigned to the wrist rotation navigation gesture is 25% of a maximum navigation speed. In some embodiments, the user interface element **1326** and/or the numerical indicator **1330** are not displayed (e.g., the focus visual appearance is used to indicate navigation speed rather than the user interface element **1326** and/or the numerical indicator **1330**). In some embodiments, the system is responsive to the user **115** performing other types of navigation gestures (e.g., as illustrated in FIG. **27**D).

[0280] The graph **1594** in FIG. **27**C shows the distance of the rotational navigation gesture and the navigation speed through the user interface **1220**, at a second point in time. The indicator **1596** in FIG. **27**C indicates that the user **115** has rotated their wrist between the first and second threshold. The graph **1590** in FIG. **27**C indicates that the translation distance is zero (e.g., the user has not performed a translation-based navigation gesture).

[0281] FIG. **27**D illustrates the user **115** performing a navigation gesture by translating their hand a first distance (e.g., performing a second type of navigation gesture). FIG. **27**D illustrates the focus **1522** moving from the number **19** in FIG. **27**C to the number **10** in response to the user **115** performing the translation-based navigation gesture. In addition, the visual appearance of the focus **1522** has updated in FIG. **27**D to indicate the direction of navigation (e.g., thicker on the left than on the right to indicate navigation to the left). FIG. **27**D illustrates the translation distance corresponding to a speed, S**4** (e.g., 80% of a maximum translation-based navigation speed). In FIG. **27**D, the navigation speed assigned to the translation-based navigation gesture is 80% of a maximum (translation-based) navigation speed. The graph **1594** in FIG. **27**D shows the distance of the rotational navigation gesture and corresponding the navigation speed (e.g., zero), at a third point in time. The indicator **1596** in FIG. **27**D indicates that the user **115** has returned their wrist to the initial position and the corresponding navigation speed is therefore zero. The indicator **1592** in the graph **1590** in FIG. **27**D indicates that the translation distance corresponds to a speed of S**4**.

[0282] Thus, FIGS. **27**A-**27**D illustrate an example where the user **115** uses different types of navigation gestures to move the focus **1522** within the user interface **1220**. In some embodiments, the navigation speed and/or the navigation acceleration is different for different types of navigation gestures. For example, a translation-based navigation gesture is used to navigate between pages in a document and a rotational navigation gesture is used to navigate between sentences in the document. In some embodiments, the function that sets the relationship between distance and navigation speed is different for different types of navigation gestures (e.g., a step function is used for one type of gesture and a linear or cubic function is used for another type of gesture). In some embodiments, a first type of navigation gesture is used to navigate along a first axis and a second type of navigation gesture is used to navigate along a second axis.

[0283] FIG. **28** is a flow diagram illustrating a method **1600** for using a multi-stage in-air hand gesture for user interface interactions in accordance with some embodi-

ments. The method **1600** is performed at a computing system (e.g., a wearable device, a mobile device, and/or intermediary device) having one or more processors and memory. In some embodiments, the memory stores one or more programs configured for execution by the one or more processors. At least some of the operations shown in FIG. **28** correspond to instructions stored in a computer memory or computer-readable storage medium (e.g., the memory **6080** and/or the memory **7050**). In some embodiments, the computing system is, or includes, a wearable device, such as the wrist-wearable device **120** or the head-wearable device **110** or **202**. In some embodiments, the computing system is, or includes, an intermediary device such as a smartphone.

[0284] The system receives (**1602**) via one or more sensors of a wrist-wearable device worn by a user, data generated from performance of a multi-stage gesture by the user. For example, the one or more sensors include the sensors **6021** (e.g., EMG and/or IMU sensors). In some embodiments, the multi-stage gesture is a multi-stage in-air hand gesture. In some embodiments, the multi-stage gesture is a hand gesture that has a component in the air and a component on a surface.

[0285] In some embodiments, the system identifies (**1604**) an initial position of a body part of the user in accordance with a determination that a first stage of the multi-stage gesture is a priming gesture. For example, the system detects the user performing a pinch-and-hold gesture and the pinch-and-hold gesture is designated as a priming gesture (e.g., FIGS. **24**B, **25**A, and **27**B). In some embodiments, multiple types of gestures are designated as priming gestures (e.g., a pointer-finger-based pinch gesture, a middle-finger-based pinch gesture, a double-tap gesture, and/or a fist-clench gesture). In some embodiments, the priming gesture is a maintained gesture performed by at least two phalanges of the user.

[0286] In some embodiments, the system navigates (**1606**) through a user interface based on a change in position of the body part from the initial position during performance of the navigation gesture in accordance with a determination that a second stage of the multi-stage gesture is a navigation gesture, where a navigation speed is based on the change in position of the body part. For example, when the user rotates their wrist past a specific threshold or translates their hand a certain distance, the user is able to navigate through user interface elements as illustrated in FIGS. **24**A-**24**E, **25**A-**25**H, and **27**A-**27**D. In some embodiments, navigating through the user interface based on the change in the position of the body part includes navigating in a first manner.

[0287] In some embodiments, in accordance with the determination that the first stage of the multi-stage in-air hand gesture is a priming gesture, the system displays a plurality of selectable user interface elements (e.g., displays the numbers within user interface **1220**) within the user interface and/or provides feedback to the user indicating the user can perform additional gestures (e.g., displays command options **606**).

[0288] In some embodiments, in accordance with a determination that a third stage of the multi-stage in-air hand gesture is another navigation gesture, the system navigates through the user interface in a second manner based on a change in position of the body part from the initial position during performance of the another navigation gesture. In some embodiments, in accordance with a determination that a fourth stage of the multi-stage in-air hand gesture is a control gesture, the system executes a command for the user interface that corresponds to the control gesture. For example, the system executes a function that corresponds to a user interface element that has focus when the control gesture is detected. In some embodiments, the navigation gesture is distinct from the another navigation gesture. In some embodiments, the navigation gesture is a first type of gesture (e.g., a wrist rotation gesture) and the another navigation gesture is a second type of gesture (e.g., a translational gesture).

[0289] In some embodiments, the priming gesture is a maintained gesture (e.g., a pinch-and-hold gesture or a maintained fist-clench gesture). In some embodiments, in response to the priming gesture, the system activates a user interface; and, in accordance with a determination that a third stage of the multi-stage in-air hand gesture includes a release of the maintained gesture, deactivates the user interface. In some embodiments, a release of a maintained gesture is interpreted by the system as a control gesture (e.g., activating a function of a selected user interface element).

[0290] In some embodiments, the system: (i) receives via the one or more sensors of the wrist-wearable device, data generated from performance of a second multi-stage in-air hand gesture; (ii) in accordance with a determination a first stage of the second multi-stage in-air hand gesture is another priming gesture, determines a second initial position of the body part of the user and activating the user interface; and, (iii) in accordance with a determination that a second stage of the second multi-stage in-air hand gesture is another navigation gesture, navigates through the user interface based on a change in position of the body part from the second initial position during performance of the navigation gesture, where a navigation speed for the another navigation gesture is based on the change in position of the body part from the second initial position.

[0291] In some embodiments, the navigation gesture includes translation of a hand of the user from the initial position to a second position. In some embodiments, a navigation speed through the user interface is proportional to a speed and/or distance in which the user translates their hand from the initial position to the second position. In some embodiments, the navigation gesture comprises a rotation of a wrist of the user in a first or second direction. In some embodiments, the navigation speed is proportional to a rotation angle of the wrist of the user. In some embodiments, the navigation speed is based on a cubic function of the change in position of the body part. In some embodiments, the navigation speed is based on a step function of the change in position of the body part. In some embodiments, the navigation speed is based on a linear function of the change in position of the body part.

[0292] In some embodiments, navigating through the user interface includes: (i) while detecting the navigation gesture, forgoing navigating through the user interface in accordance with the change in position of the body part being less than a first threshold; and (ii) navigating through the user interface in accordance with the change in position of the body part being greater than the first threshold.

[0293] In some embodiments, navigating through the user interface further includes: (i) in accordance with a determination that the change in position of the body part is greater than the first threshold and less than a second threshold, navigating through the user interface at a first speed; and (ii)

in accordance with a determination that the change in position of the body part is greater than the second threshold, navigating through the user interface at a second speed greater than the first speed.

[0294] In some embodiments, in accordance with a determination that the second stage of the multi-stage in-air hand gesture is the navigation gesture, the system causes display of a navigation indicator in the user interface, where the navigation indicator indicates the navigation speed.

[0295] In some embodiments, in accordance with a determination the change in position of the body part meets one or more criteria, the system ceases to increase the navigation speed and providing feedback to the user indicating that the navigation speed is at an upper limit.

[0296] In some embodiments, in accordance with a determination that the first stage of the multi-stage in-air hand gesture is the priming gesture, the system starts a predetermined window of time for detecting one or more subsequent multi-stage gestures. In some embodiments, detecting a subsequent gesture (e.g., a navigation gesture or a control gesture) resets the predetermined window of time for detecting another subsequent gesture. In some embodiments, certain types of subsequent gestures reset the predetermined window of time (e.g., navigation gesture reset the predetermined window of time, but control gesture do not).

[0297] Embodiments of this disclosure can include or be implemented in conjunction with various types or embodiments of artificial-reality systems. Artificial-reality (AR), as described herein, is any superimposed functionality and or sensory-detectable presentation provided by an artificial-reality system within a user's physical surroundings. Such artificial-realities can include and/or represent virtual reality (VR), augmented reality, mixed artificial-reality (MAR), or some combination and/or variation one of these. For example, a user can perform a swiping in-air hand gesture to cause a song to be skipped by a song-providing API providing playback at, for example, a home speaker. An AR environment, as described herein, includes, but is not limited to, VR environments (including non-immersive, semi-immersive, and fully immersive VR environments); augmented-reality environments (including marker-based augmented-reality environments, markerless augmented-reality environments, location-based augmented-reality environments, and projection-based augmented-reality environments); hybrid reality; and other types of mixed-reality environments.

[0298] Artificial-reality content can include completely generated content or generated content combined with captured (e.g., real-world) content. The artificial-reality content can include video, audio, haptic events, or some combination thereof, any of which can be presented in a single channel or in multiple channels (such as stereo video that produces a three-dimensional effect to a viewer). Additionally, in some embodiments, artificial reality can also be associated with applications, products, accessories, services, or some combination thereof, which are used, for example, to create content in an artificial reality and/or are otherwise used in (e.g., to perform activities in) an artificial reality.

[0299] A hand gesture, as described herein, can include an in-air gesture, a surface-contact gesture, and or other gestures that can be detected and determined based on movements of a single hand (e.g., a one-handed gesture performed with a user's hand that is detected by one or more sensors of a wearable device (e.g., electromyography (EMG) and/or inertial measurement units (IMU) s of a wrist-wearable device) and/or detected via image data captured by an imaging device of a wearable device (e.g., a camera of a head-wearable device)) or a combination of the user's hands. In-air means, in some embodiments, that the user hand does not contact a surface, object, or portion of an electronic device, in other words the gesture is performed in open air in 3D space and without contacting a surface, an object, or an electronic device. Surface-contact gestures (contacts at a surface, object, body part of the user, or electronic device) more generally are also contemplated in which a contact (or an intention to contact) is detected at a surface (e.g., a single or double finger tap on a table, on a user's hand or another finger, on the user's leg, a couch, a steering wheel, etc.). The different hand gestures disclosed herein can be detected using image data and/or sensor data (e.g., neuromuscular signals sensed by one or more biopotential sensors (e.g., EMG sensors) or other types of data from other sensors, such as proximity sensors, time-of-flight sensors, sensors of an inertial measurement unit, etc.) detected by a wearable device worn by the user and/or other electronic devices in the user's possession (e.g., smartphones, laptops, imaging devices, intermediary devices, and/or other devices described herein).

[0300] Artificial-reality systems may be implemented in a variety of different form factors and configurations. Some artificial-reality systems include a near-eye display (NED), which provides visibility into the real world (e.g., the augmented-reality system **7000** in FIG. **13**A) or that visually immerses a user in an artificial reality (e.g., the virtual-reality system **7010** in FIG. **13**B). While some artificial-reality devices are self-contained systems, other artificial-reality devices communicate and/or coordinate with external devices to provide an artificial-reality experience to a user. Examples of such external devices include handheld controllers, mobile devices, desktop computers, devices worn by a user (e.g., the wearable device **6000** in FIG. **12**A), devices worn by one or more other users, and/or any other suitable external system.

Example Systems

[0301] FIGS. **11**A-**11**D illustrate example AR systems in accordance with some embodiments. FIG. **11**A shows an AR system **5000***a* and first example user interactions using a wrist-wearable device **6000**, a head-wearable device (e.g., AR system **7000**), and/or a handheld intermediary processing device (HIPD) **8000**. FIG. **11**B shows an AR system **5000***b* and second example user interactions using the wrist-wearable device **6000**, the AR system **7000**, and/or an HIPD **8000**. FIGS. **11**C-**1** and **11**C-**2** show an AR system **5000***c* and third example user interactions using a wrist-wearable device **6000**, a head-wearable device (e.g., VR headset **7010**), and/or an HIPD **8000**. FIGS. **11**D-**1** and **11**D-**2** show a fourth AR system **5000***d* and fourth example user interactions using a wrist-wearable device **6000**, VR headset **7010**, and/or device **9000** (e.g., wearable haptic gloves). The above-example AR systems (described in detail below) can perform the various functions and/or operations described above with reference to FIGS. **1**-**10** and FIGS. **16**-**28**.

[0302] The wrist-wearable device **6000** and its components are described below in reference to FIGS. **12**A-**12**B; the head-wearable devices and their components are described below in reference to FIGS. **13**A-**13**D; and the

HIPD **8000** and its components are described below in reference to FIGS. **14**A-**14**B. Wearable gloves and their components are described below in reference to FIGS. **15**A-**15**C. As shown in FIG. **11**A, the wrist-wearable device **6000**, the head-wearable devices, and/or the HIPD **8000** can communicatively couple via a network **5025** (e.g., cellular, near field, Wi-Fi, personal area network, or wireless LAN). Additionally, the wrist-wearable device **6000**, the head-wearable devices, and/or the HIPD **8000** can also communicatively couple with one or more servers **5030**, computers **5040** (e.g., laptops, computers, etc.), mobile devices **5050** (e.g., smartphones, tablets, etc.), and/or other electronic devices via the network **5025** (e.g., cellular, near field, Wi-Fi, personal area network, wireless LAN, etc.) Similarly, the device **9000** can also communicatively couple with the wrist-wearable device **6000**, the head-wearable devices, the HIPD **8000**, the one or more servers **5030**, the computers **5040**, the mobile devices **5050**, and/or other electronic devices via the network **5025**.

[0303] Turning to FIG. **11**A, a user **5002** is shown wearing the wrist-wearable device **6000** and the AR system **7000** and having the HIPD **8000** on their desk. The wrist-wearable device **6000**, the AR system **7000**, and the HIPD **8000** facilitate user interaction with an AR environment. In particular, as shown by the AR system **5000***a*, the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000** cause presentation of one or more avatars **5004**, digital representations of contacts **5006**, and virtual objects **5008**. As discussed below, the user **5002** can interact with the one or more avatars **5004**, digital representations of the contacts **5006**, and virtual objects **5008** via the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000**.

[0304] The user **5002** can use any of the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000** to provide user inputs. For example, the user **5002** can perform one or more hand gestures that are detected by the wrist-wearable device **6000** (e.g., using one or more EMG sensors and/or IMUs, described below in reference to FIGS. **12**A-**12**B) and/or AR system **7000** (e.g., using one or more image sensor or camera, described below in reference to FIGS. **13**A-**13**B) to provide a user input. Alternatively, or additionally, the user **5002** can provide a user input via one or more touch surfaces of the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000**, and/or voice commands captured by a microphone of the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000**. In some embodiments, the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000** include a digital assistant to help the user in providing a user input (e.g., completing a sequence of operations, suggesting different operations or commands, providing reminders, or confirming a command). In some embodiments, the user **5002** provides a user input via one or more facial gestures and/or facial expressions. For example, cameras of the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000** can track the user **5002**'s eyes for navigating a user interface.

[0305] The wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000** can operate alone or in conjunction to allow the user **5002** to interact with the AR environment. In some embodiments, the HIPD **8000** is configured to operate as a central hub or control center for the wrist-wearable device **6000**, the AR system **7000**, and/or another communicatively coupled device. For example, the user **5002** can provide an input to interact with the AR environment at any of the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000**, and the HIPD **8000** can identify one or more back-end and front-end tasks to cause the performance of the requested interaction and distribute instructions to cause the performance of the one or more back-end and front-end tasks at the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000**. In some embodiments, a back-end task is background processing task that is not perceptible by the user (e.g., rendering content, decompression, or compression), and a front-end task is a user-facing task that is perceptible to the user (e.g., presenting information to the user or providing feedback to the user). As described below in reference to FIGS. **14**A-**14**B, the HIPD **8000** can perform the back-end tasks and provide the wrist-wearable device **6000** and/or the AR system **7000** operational data corresponding to the performed back-end tasks such that the wrist-wearable device **6000** and/or the AR system **7000** can perform the front-end tasks. In this way, the HIPD **8000**, which can have more computational resources and greater thermal headroom than the wrist-wearable device **6000** and/or the AR system **7000**, performs computationally intensive tasks and reduces the computer resource utilization and/or power usage of the wrist-wearable device **6000** and/or the AR system **7000**.

[0306] In the example shown by the AR system **5000***a*, the HIPD **8000** identifies one or more back-end tasks and front-end tasks associated with a user request to initiate an AR video call with one or more other users (represented by the avatar **5004** and the digital representation of the contact **5006**) and distributes instructions to cause the performance of the one or more back-end tasks and front-end tasks. In particular, the HIPD **8000** performs back-end tasks for processing and/or rendering image data (and other data) associated with the AR video call and provides operational data associated with the performed back-end tasks to the AR system **7000** such that the AR system **7000** perform front-end tasks for presenting the AR video call (e.g., presenting the avatar **5004** and the digital representation of the contact **5006**).

[0307] In some embodiments, the HIPD **8000** operates as a focal or anchor point for causing the presentation of information. This allows the user **5002** to be generally aware of where information is presented. For example, as shown in the AR system **5000***a*, the avatar **5004** and the digital representation of the contact **5006** are presented above the HIPD **8000**. In particular, the HIPD **8000** and the AR system **7000** operate in conjunction to determine a location for presenting the avatar **5004** and the digital representation of the contact **5006**. In some embodiments, information can be presented a predetermined distance from the HIPD **8000** (e.g., within 5 meters). For example, as shown in the AR system **5000***a*, virtual object **5008** is presented on the desk some distance from the HIPD **8000**. Similar to the above example, the HIPD **8000** and the AR system **7000** can operate in conjunction to determine a location for presenting the virtual object **5008**. Alternatively, in some embodiments, presentation of information is not bound by the HIPD **8000**. More specifically, the avatar **5004**, the digital representation of the contact **5006**, and the virtual object **5008** do not have to be presented within a predetermined distance of the HIPD **8000**.

[0308] User inputs provided at the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000** are coordinated such that the user can use any device to initiate,

continue, and/or complete an operation. For example, the user **5002** can provide a user input to the AR system **7000** to cause the AR system **7000** to present the virtual object **5008** and, while the virtual object **5008** is presented by the AR system **7000**, the user **5002** can provide one or more hand gestures via the wrist-wearable device **6000** to interact and/or manipulate the virtual object **5008**.

[0309] FIG. **11**B shows the user **5002** wearing the wrist-wearable device **6000** and the AR system **7000** and holding the HIPD **8000**. In the AR system **5000***b*, the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000** are used to receive and/or provide one or more messages to a contact of the user **5002**. In particular, the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000** detect and coordinate one or more user inputs to initiate a messaging application and prepare a response to a received message via the messaging application.

[0310] In some embodiments, the user **5002** initiates, via a user input, an application on the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000** that causes the application to initiate on at least one device. For example, in the AR system **5000***b* the user **5002** performs a hand gesture associated with a command for initiating a messaging application (represented by messaging user interface **5012**); the wrist-wearable device **6000** detects the hand gesture; and, based on a determination that the user **5002** is wearing AR system **7000**, causes the AR system **7000** to present a messaging user interface **5012** of the messaging application. The AR system **7000** can present the messaging user interface **5012** to the user **5002** via its display (e.g., as shown by user **5002**'s field of view **5010**). In some embodiments, the application is initiated and ran on the device (e.g., the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000**) that detects the user input to initiate the application, and the device provides another device operational data to cause the presentation of the messaging application. For example, the wrist-wearable device **6000** can detect the user input to initiate a messaging application; initiate and run the messaging application; and provide operational data to the AR system **7000** and/or the HIPD **8000** to cause presentation of the messaging application. Alternatively, the application can be initiated and ran at a device other than the device that detected the user input. For example, the wrist-wearable device **6000** can detect the hand gesture associated with initiating the messaging application and cause the HIPD **8000** to run the messaging application and coordinate the presentation of the messaging application.

[0311] Further, the user **5002** can provide a user input provided at the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000** to continue and/or complete an operation initiated are at another device. For example, after initiating the messaging application via the wrist-wearable device **6000** and while the AR system **7000** present the messaging user interface **5012**, the user **5002** can provide an input at the HIPD **8000** to prepare a response (e.g., shown by the swipe gesture performed on the HIPD **8000**). The user **5002**'s gestures performed on the HIPD **8000** can be provided and/or displayed on another device. For example, the user **5002**'s swipe gestured performed on the HIPD **8000** are displayed on a virtual keyboard of the messaging user interface **5012** displayed by the AR system **7000**.

[0312] In some embodiments, the wrist-wearable device **6000**, the AR system **7000**, the HIPD **8000**, and/or other communicatively couple device presents one or more notifications to the user **5002**. The notification can be an indication of a new message, an incoming call, an application update, or a status update. The user **5002** can select the notification via the wrist-wearable device **6000**, the AR system **7000**, the HIPD **8000**, and cause presentation of an application or operation associated with the notification on at least one device. For example, the user **5002** can receive a notification that a message was received at the wrist-wearable device **6000**, the AR system **7000**, the HIPD **8000**, and/or other communicatively couple device and provide a user input at the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000** to review the notification, and the device detecting the user input can cause an application associated with the notification to be initiated and/or presented at the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000**.

[0313] While the above example describes coordinated inputs used to interact with a messaging application, the skilled artisan will appreciate upon reading the descriptions that user inputs can be coordinated to interact with any number of applications including, but not limited to, gaming applications, social media applications, camera applications, web-based applications, and financial applications. For example, the AR system **7000** can present to the user **5002** game application data and the HIPD **8000** can use a controller to provide inputs to the game. Similarly, the user **5002** can use the wrist-wearable device **6000** to initiate a camera of the AR system **7000**, and the user can use the wrist-wearable device **6000**, the AR system **7000**, and/or the HIPD **8000** to manipulate the image capture (e.g., zoom in or out, apply filters, etc.) and capture image data.

[0314] Having discussed example AR systems, devices for interacting with such AR systems, and other computing systems more generally, will now be discussed in greater detail below. Some definitions of devices and components that can be included in some or all of the example devices discussed below are defined here for ease of reference. A skilled artisan will appreciate that certain types of the components described below may be more suitable for a particular set of devices, and less suitable for a different set of devices. But subsequent reference to the components defined here should be considered to be encompassed by the definitions provided.

[0315] In some embodiments discussed below example devices and systems, including electronic devices and systems, will be discussed. Such example devices and systems are not intended to be limiting, and one of skill in the art will understand that alternative devices and systems to the example devices and systems described herein may be used to perform the operations and construct the systems and device that are described herein.

[0316] As described herein, an electronic device is a device that uses electrical energy to perform one or more functions. It can be any physical object that contains electronic components such as transistors, resistors, capacitors, diodes, and integrated circuits. Examples of electronic devices include smartphones, laptops, digital cameras, televisions, gaming consoles, and music players, as well as the example electronic devices discussed herein. As described herein, an intermediary electronic device is a device that sits between two other electronic devices, and/or a subset of components of one or more electronic devices and facilitates

communication, and/or data processing and/or data transfer between the respective electronic devices and/or electronic components.

[0317] As described herein, a processor (e.g., a central processing unit (CPU)), is an electronic component that is responsible for executing instructions and controlling the operation of an electronic device (e.g., a computer). There are various types of processors that may be used interchangeably, or may be specifically required, by embodiments described herein. For example, a processor may be: (i) a general processor designed to perform a wide range of tasks, such as running software applications, managing operating systems, and performing arithmetic and logical operations; (ii) a microcontroller designed for specific tasks such as controlling electronic devices, sensors, and motors; (iii) a graphics processing unit (GPU) designed to accelerate the creation and rendering of images, videos, and animations (e.g., virtual-reality animations, such as three-dimensional modeling); (iv) a field-programmable gate array (FPGA) that can be programmed and reconfigured after manufacturing, and/or can be customized to perform specific tasks, such as signal processing, cryptography, and machine learning; (v) a digital signal processor (DSP) designed to perform mathematical operations on signals such as audio, video, and radio waves. One of skill in the art will understand that one or more processors of one or more electronic devices may be used in various embodiments described herein.

[0318] As described herein, memory refers to electronic components in a computer or electronic device that store data and instructions for the processor to access and manipulate. Examples of memory can include: (i) random access memory (RAM) configured to store data and instructions temporarily; (ii) read-only memory (ROM) configured to store data and instructions permanently (e.g., one or more portions of system firmware, and/or boot loaders); (iii) flash memory, which can be configured to store data in electronic devices (e.g., USB drives, memory cards, and/or solid-state drives (SSDs); and (iv) cache memory configured to temporarily store frequently accessed data and instructions. Memory, as described herein, can include structured data (e.g., SQL databases, MongoDB databases, GraphQL data, and/or JSON data). Other examples of memory can include: (i) profile data, including user account data, user settings, and/or other user data stored by the user; (ii) sensor data detected and/or otherwise obtained by one or more sensors; (iii) media content data including stored image data, audio data, documents, and the like; (iv) application data, which can include data collected and/or otherwise obtained and stored during use of an application; and/or any other types of data described herein.

[0319] As described herein, controllers are electronic components that manage and coordinate the operation of other components within an electronic device (e.g., controlling inputs, processing data, and/or generating outputs). Examples of controllers can include: (i) microcontrollers, including small, low-power controllers that are commonly used in embedded systems and Internet of Things (IoT) devices; (ii) programmable logic controllers (PLCs) which may be configured to be used in industrial automation systems to control and monitor manufacturing processes; (iii) system-on-a-chip (SoC) controllers that integrate multiple components such as processors, memory, I/O interfaces, and other peripherals into a single chip; and/or DSPs.

[0320] As described herein, a power system of an electronic device is configured to convert incoming electrical power into a form that can be used to operate the device. A power system can include various components, including: (i) a power source, which can be an alternating current (AC) adapter or a direct current (DC) adapter power supply; (ii) a charger input, and can be configured to use a wired and/or wireless connection (which may be part of a peripheral interface, such as a USB, micro-USB interface, near-field magnetic coupling, magnetic inductive and magnetic resonance charging, and/or radio frequency (RF) charging); (iii) a power-management integrated circuit, configured to distribute power to various components of the device and to ensure that the device operates within safe limits (e.g., regulating voltage, controlling current flow, and/or managing heat dissipation); and/or (iv) a battery configured to store power to provide usable power to components of one or more electronic devices.

[0321] As described herein, peripheral interfaces are electronic components (e.g., of electronic devices) that allow electronic devices to communicate with other devices or peripherals, and can provide a means for input and output of data and signals. Examples of peripheral interfaces can include: (i) universal serial bus (USB) and/or micro-USB interfaces configured for connecting devices to an electronic device; (ii) Bluetooth interfaces configured to allow devices to communicate with each other, including Bluetooth low energy (BLE); (iii) near field communication (NFC) interfaces configured to be short-range wireless interface for operations such as access control; (iv) POGO pins, which may be small, spring-loaded pins configured to provide a charging interface; (v) wireless charging interfaces; (vi) GPS interfaces; (vii) Wi-Fi interfaces for providing a connection between a device and a wireless network; (viii) sensor interfaces.

[0322] As described herein, sensors are electronic components (e.g., in and/or otherwise in electronic communication with electronic devices, such as wearable devices) configured to detect physical and environmental changes and generate electrical signals. Examples of sensors can includer: (i) imaging sensors for collecting imaging data (e.g., including one or more cameras disposed on a respective electronic device); (ii) biopotential-signal sensors; (iii) inertial measurement unit (e.g., IMUs) for detecting, for example, angular rate, force, magnetic field, and/or changes in acceleration; (iv) heart rate sensors for measuring a user's heart rate; (v) SpO2 sensors for measuring blood oxygen saturation and/or other biometric data of a user; (vi) capacitive sensors for detecting changes in potential at a portion of a user's body (e.g., a sensor-skin interface); light sensors (e.g., time-of-flight sensors, infrared light sensors, visible light sensors, etc.); . . . . As described herein biopotential-signal-sensing components are devices used to measure electrical activity within the body (e.g., biopotential-signal sensors). Some types of biopotential-signal sensors include: (i) electroencephalography (EEG) sensors configured to measure electrical activity in the brain to diagnose neurological disorders; (ii) electrocardiograma (ECG or EKG) sensors configured to measure electrical activity of the heart to diagnose heart problems; (iii) electromyography (EMG) sensors configured to measure the electrical activity of muscles and to diagnose neuromuscular disorders; (iv) elec-

trooculography (EOG) sensors conFigure to measure the electrical activity of eye muscles to detect eye movement and diagnose eye disorders.

[0323] As described herein, an application stored in memory of an electronic device (e.g., software) includes instructions stored in the memory. Examples of such applications include: (i) games; (ii) word processors; messaging applications; media-streaming applications; financial applications; calendars; clocks; communication interface modules for enabling wired and/or wireless connections between different respective electronic devices (e.g., IEEE 802.15.4, Wi-Fi, ZigBee, 6LoWPAN, Thread, Z-Wave, Bluetooth Smart, ISA100.11a, WirelessHART, or MiWi), custom or standard wired protocols (e.g., Ethernet or HomePlug), and/or any other suitable communication protocols);

[0324] As described herein, a communication interface is a mechanism that enables different systems or devices to exchange information and data with each other, including hardware, software, or a combination of both hardware and software. For example, a communication interface can refer to a physical connector and/or port on a device that enables communication with other devices (e.g., USB, Ethernet, HDMI, Bluetooth). In some embodiments, a communication interface can refer to a software layer that enables different software programs to communicate with each other (e.g., application programming interfaces (APIs) and/or protocols like HTTP and TCP/IP).

[0325] As described herein, a graphics module is a component or software module that is designed to handle graphical operations and/or processes and can include a hardware module and/or a software module.

[0326] As described herein, non-transitory computer-readable storage media are physical devices or storage medium that can be used to store electronic data in a non-transitory form (e.g., such that the data is stored permanently until it is intentionally deleted or modified).

Example Wrist-Wearable Devices

[0327] FIGS. **12**A and **12**B illustrate the wrist-wearable device **6000** in accordance with some embodiments. FIG. **12**A illustrates components of the wrist-wearable device **6000**, which can be used individually or in combination, including combinations that include other electronic devices and/or electronic components.

[0328] FIG. **12**A shows a wearable band **6010** and a watch body **6020** (or capsule) being coupled, as discussed below, to form the wrist-wearable device **6000**. The wrist-wearable device **6000** can perform various functions and/or operations associated with navigating through user interfaces and selectively opening applications, as well as the functions and/or operations described above with reference to FIGS. **1-10** and FIGS. **16-28**.

[0329] As will be described in more detail below, operations executed by the wrist-wearable device **6000** can include: (i) presenting content to a user (e.g., displaying visual content via a display **6005**); (ii) detecting (e.g., sensing) user input (e.g., sensing a touch on peripheral button **6023** and/or at a touch screen of the display **6005**, a hand gesture detected by sensors (e.g., biopotential sensors); (iii) sensing biometric data via one or more sensors **6013** (e.g., neuromuscular signals, heart rate, temperature, and/or sleep); messaging (e.g., text, speech, and/or video); image capture via one or more imaging devices or cameras **6025**; wireless communications (e.g., cellular, near field, Wi-Fi, and/or personal area network); location determination; financial transactions; providing haptic feedback; alarms; notifications; biometric authentication; health monitoring; sleep monitoring; etc.

[0330] The above-example functions can be executed independently in the watch body **6020**, independently in the wearable band **6010**, and/or via an electronic communication between the watch body **6020** and the wearable band **6010**. In some embodiments, functions can be executed on the wrist-wearable device **6000** while an AR environment is being presented (e.g., via one of the AR systems **5000***a* to **5000***d*). As the skilled artisan will appreciate upon reading the descriptions provided herein, the novel wearable devices described herein can be used with other types of AR environments.

[0331] The wearable band **6010** can be configured to be worn by a user such that an inner surface of the wearable band **6010** is in contact with the user's skin. When worn by a user, sensors **6013** contact the user's skin. The sensors **6013** can sense biometric data such as a user's heart rate, saturated oxygen level, temperature, sweat level, neuromuscular signal sensors, or a combination thereof. The sensors **6013** can also sense data about a user's environment including a user's motion, altitude, location, orientation, gait, acceleration, position, or a combination thereof. In some embodiment, the sensors **6013** are configured to track a position and/or motion of the wearable band **6010**. The one or more sensors **6013** can include any of the sensors defined above and/or discussed below with respect to FIG. **12**B.

[0332] The one or more sensors **6013** can be distributed on an inside and/or an outside surface of the wearable band **6010**. In some embodiments, the one or more sensors **6013** are uniformly spaced along the wearable band **6010**. Alternatively, in some embodiments, the one or more sensors **6013** are positioned at distinct points along the wearable band **6010**. As shown in FIG. **12**A, the one or more sensors **6013** can be the same or distinct. For example, in some embodiments, the one or more sensors **6013** can be shaped as a pill (e.g., sensor **6013***a*), an oval, a circle a square, an oblong (e.g., sensor **6013***c*) and/or any other shape that maintains contact with the user's skin (e.g., such that neuromuscular signal and/or other biometric data can be accurately measured at the user's skin). In some embodiments, the one or more sensors **6013** are aligned to form pairs of sensors (e.g., for sensing neuromuscular signals based on differential sensing within each respective sensor). For example, sensor **6013***b* is aligned with an adjacent sensor to form sensor pair **6014***a* and sensor **6013***d* aligned with an adjacent sensor to form sensor pair **6014***b*. In some embodiments, the wearable band **6010** does not have a sensor pair. Alternatively, in some embodiments, the wearable band **6010** has a predetermined number of sensor pairs (e.g., one pair of sensors, three pairs of sensors, four pairs of sensors, six pairs of sensors, or sixteen pairs of sensors).

[0333] The wearable band **6010** can include any suitable number of sensors **6013**. In some embodiments, the number and arrangement of sensors **6013** depends on the particular application for which the wearable band **6010** is used. For instance, a wearable band **6010** configured as an armband, wristband, or chest-band may include a plurality of sensors **6013** with different number of sensors **6013** and different arrangement for each use case, such as medical use cases as compared to gaming or general day-to-day use cases.

[0334] In accordance with some embodiments, the wearable band **6010** further includes an electrical ground electrode and a shielding electrode. The electrical ground and shielding electrodes, like the sensors **6013**, can be distributed on the inside surface of the wearable band **6010** such that they contact a portion of the user's skin. For example, the electrical ground and shielding electrodes can be at an inside surface of coupling mechanism **6016** or an inside surface of a wearable structure **6011**. The electrical ground and shielding electrodes can be formed and/or use the same components as the sensors **6013**. In some embodiments, the wearable band **6010** includes more than one electrical ground electrode and more than one shielding electrode.

[0335] The sensors **6013** can be formed as part of the wearable structure **6011** of the wearable band **6010**. In some embodiments, the sensors **6013** are flush or substantially flush with the wearable structure **6011** such that they do not extend beyond the surface of the wearable structure **6011**. While flush with the wearable structure **6011**, the sensors **6013** are still configured to contact the user's skin (e.g., via a skin-contacting surface). Alternatively, in some embodiments, the sensors **6013** extend beyond the wearable structure **6011** a predetermined distance (e.g., 0.1-2 mm) to make contact and depress into the user's skin. In some embodiment, the sensors **6013** are coupled to an actuator (not shown) configured to adjust an extension height (e.g., a distance from the surface of the wearable structure **6011**) of the sensors **6013** such that the sensors **6013** make contact and depress into the user's skin. In some embodiments, the actuators adjust the extension height between 0.01 mm-1.2 mm. This allows the user to customize the positioning of the sensors **6013** to improve the overall comfort of the wearable band **6010** when worn while still allowing the sensors **6013** to contact the user's skin. In some embodiments, the sensors **6013** are indistinguishable from the wearable structure **6011** when worn by the user.

[0336] The wearable structure **6011** can be formed of an elastic material, elastomers, etc. configured to be stretched and fitted to be worn by the user. In some embodiments, the wearable structure **6011** is a textile or woven fabric. As described above, the sensors **6013** can be formed as part of a wearable structure **6011**. For example, the sensors **6013** can be molded into the wearable structure **6011** or be integrated into a woven fabric (e.g., the sensors **6013** can be sewn into the fabric and mimic the pliability of fabric (e.g., the sensors **6013** can be constructed from a series of woven strands of fabric)).

[0337] The wearable structure **6011** can include flexible electronic connectors that interconnect the sensors **6013**, the electronic circuitry, and/or other electronic components (described below in reference to FIG. **12**B) that are enclosed in the wearable band **6010**. In some embodiments, the flexible electronic connectors are configured to interconnect the sensors **6013**, the electronic circuitry, and/or other electronic components of the wearable band **6010** with respective sensors and/or other electronic components of another electronic device (e.g., watch body **6020**). The flexible electronic connectors are configured to move with the wearable structure **6011** such that the user adjustment to the wearable structure **6011** (e.g., resizing, pulling, and/or folding) does not stress or strain the electrical coupling of components of the wearable band **6010**.

[0338] As described above, the wearable band **6010** is configured to be worn by a user. In particular, the wearable band **6010** can be shaped or otherwise manipulated to be worn by a user. For example, the wearable band **6010** can be shaped to have a substantially circular shape such that it can be configured to be worn on the user's lower arm or wrist. Alternatively, the wearable band **6010** can be shaped to be worn on another body part of the user, such as the user's upper arm (e.g., around a bicep), forearm, chest, or legs. The wearable band **6010** can include a retaining mechanism **6012** (e.g., a buckle or a hook and loop fastener) for securing the wearable band **6010** to the user's wrist or other body part. While the wearable band **6010** is worn by the user, the sensors **6013** sense data (referred to as sensor data) from the user's skin. In particular, the sensors **6013** of the wearable band **6010** obtain (e.g., sense and record) neuromuscular signals.

[0339] The sensed data (e.g., sensed neuromuscular signals) can be used to detect and/or determine the user's intention to perform certain motor actions. In particular, the sensors **6013** sense and record neuromuscular signals from the user as the user performs muscular activations (e.g., movements and/or gestures). The detected and/or determined motor actions (e.g., phalange (or digits) movements, wrist movements, hand movements, and/or other muscle intentions) can be used to determine control commands or control information (instructions to perform certain commands after the data is sensed) for causing a computing device to perform one or more input commands. For example, the sensed neuromuscular signals can be used to control certain user interfaces displayed on the display **6005** of the wrist-wearable device **6000** and/or can be transmitted to a device responsible for rendering an artificial-reality environment (e.g., a head-mounted display) to perform an action in an associated artificial-reality environment, such as to control the motion of a virtual device displayed to the user. The muscular activations performed by the user can include static gestures, such as placing the user's hand palm down on a table; dynamic gestures, such as grasping a physical or virtual object; and covert gestures that are imperceptible to another person, such as slightly tensing a joint by co-contracting opposing muscles or using sub-muscular activations. The muscular activations performed by the user can include symbolic gestures (e.g., gestures mapped to other gestures, interactions, or commands, for example, based on a gesture vocabulary that specifies the mapping of gestures to commands).

[0340] The sensor data sensed by the sensors **6013** can be used to provide a user with an enhanced interaction with a physical object (e.g., devices communicatively coupled with the wearable band **6010**) and/or a virtual object in an artificial-reality application generated by an artificial-reality system (e.g., user interface objects presented on the display **6005**, or another computing device (e.g., a smartphone)).

[0341] In some embodiments, the wearable band **6010** includes one or more haptic devices **6046** (FIG. **12**B, e.g., a vibratory haptic actuator) that are configured to provide haptic feedback (e.g., a cutaneous and/or kinesthetic sensation) to the user's skin. The sensors **6013**, and/or the haptic devices **6046** can be configured to operate in conjunction with multiple applications including, without limitation, health monitoring, social media, games, and artificial reality (e.g., the applications associated with artificial reality).

[0342] The wearable band **6010** can also include coupling mechanism **6016** (e.g., a cradle or a shape of the coupling mechanism can correspond to shape of the watch body **6020**

of the wrist-wearable device **6000**) for detachably coupling a capsule (e.g., a computing unit) or watch body **6020** (via a coupling surface of the watch body **6020**) to the wearable band **6010**. In particular, the coupling mechanism **6016** can be configured to receive a coupling surface proximate to the bottom side of the watch body **6020** (e.g., a side opposite to a front side of the watch body **6020** where the display **6005** is located), such that a user can push the watch body **6020** downward into the coupling mechanism **6016** to attach the watch body **6020** to the coupling mechanism **6016**. In some embodiments, the coupling mechanism **6016** can be configured to receive a top side of the watch body **6020** (e.g., a side proximate to the front side of the watch body **6020** where the display **6005** is located) that is pushed upward into the cradle, as opposed to being pushed downward into the coupling mechanism **6016**. In some embodiments, the coupling mechanism **6016** is an integrated component of the wearable band **6010** such that the wearable band **6010** and the coupling mechanism **6016** are a single unitary structure. In some embodiments, the coupling mechanism **6016** is a type of frame or shell that allows the watch body **6020** coupling surface to be retained within or on the wearable band **6010** coupling mechanism **6016** (e.g., a cradle, a tracker band, a support base, or a clasp).

[0343] The coupling mechanism **6016** can allow for the watch body **6020** to be detachably coupled to the wearable band **6010** through a friction fit, magnetic coupling, a rotation-based connector, a shear-pin coupler, a retention spring, one or more magnets, a clip, a pin shaft, a hook and loop fastener, or a combination thereof. A user can perform any type of motion to couple the watch body **6020** to the wearable band **6010** and to decouple the watch body **6020** from the wearable band **6010**. For example, a user can twist, slide, turn, push, pull, or rotate the watch body **6020** relative to the wearable band **6010**, or a combination thereof, to attach the watch body **6020** to the wearable band **6010** and to detach the watch body **6020** from the wearable band **6010**. Alternatively, as discussed below, in some embodiments, the watch body **6020** can be decoupled from the wearable band **6010** by actuation of the release mechanism **6029**.

[0344] The wearable band **6010** can be coupled with a watch body **6020** to increase the functionality of the wearable band **6010** (e.g., converting the wearable band **6010** into a wrist-wearable device **6000**, adding an additional computing unit and/or battery to increase computational resources and/or a battery life of the wearable band **6010**, adding additional sensors to improve sensed data, etc.). As described above, the wearable band **6010** (and the coupling mechanism **6016**) is configured to operate independently (e.g., execute functions independently) from watch body **6020**. For example, the coupling mechanism **6016** can include one or more sensors **6013** that contact a user's skin when the wearable band **6010** is worn by the user and provide sensor data for determining control commands.

[0345] A user can detach the watch body **6020** (or capsule) from the wearable band **6010** in order to reduce the encumbrance of the wrist-wearable device **6000** to the user. For embodiments in which the watch body **6020** is removable, the watch body **6020** can be referred to as a removable structure, such that in these embodiments the wrist-wearable device **6000** includes a wearable portion (e.g., the wearable band **6010**) and a removable structure (the watch body **6020**).

[0346] Turning to the watch body **6020**, the watch body **6020** can have a substantially rectangular or circular shape. The watch body **6020** is configured to be worn by the user on their wrist or on another body part. More specifically, the watch body **6020** is sized to be easily carried by the user, attached on a portion of the user's clothing, and/or coupled to the wearable band **6010** (forming the wrist-wearable device **6000**). As described above, the watch body **6020** can have a shape corresponding to the coupling mechanism **6016** of the wearable band **6010**. In some embodiments, the watch body **6020** includes a single release mechanism **6029** or multiple release mechanisms (e.g., two release mechanisms **6029** positioned on opposing sides of the watch body **6020**, such as spring-loaded buttons) for decoupling the watch body **6020** and the wearable band **6010**. The release mechanism **6029** can include, without limitation, a button, a knob, a plunger, a handle, a lever, a fastener, a clasp, a dial, a latch, or a combination thereof.

[0347] A user can actuate the release mechanism **6029** by pushing, turning, lifting, depressing, shifting, or performing other actions on the release mechanism **6029**. Actuation of the release mechanism **6029** can release (e.g., decouple) the watch body **6020** from the coupling mechanism **6016** of the wearable band **6010**, allowing the user to use the watch body **6020** independently from wearable band **6010**, and vice versa. For example, decoupling the watch body **6020** from the wearable band **6010** can allow the user to capture images using rear-facing camera **6020**B. Although the is shown positioned at a corner of watch body **6020**, the release mechanism **6029** can be positioned anywhere on watch body **6020** that is convenient for the user to actuate. In addition, in some embodiments, the wearable band **6010** can also include a respective release mechanism for decoupling the watch body **6020** from the coupling mechanism **6016**. In some embodiments, the release mechanism **6029** is optional and the watch body **6020** can be decoupled from the coupling mechanism **6016** as described above (e.g., via twisting or rotating).

[0348] The watch body **6020** can include one or more peripheral buttons **6023** and **6027** for performing various operations at the watch body **6020**. For example, the peripheral buttons **6023** and **6027** can be used to turn on or wake (e.g., transition from a sleep state to an active state) the display **6005**, unlock the watch body **6020**, increase or decrease a volume, increase or decrease a brightness, interact with one or more applications, and/or interact with one or more user interfaces. Additionally, or alternatively, in some embodiments, the display **6005** operates as a touch screen and allows the user to provide one or more inputs for interacting with the watch body **6020**.

[0349] In some embodiments, the watch body **6020** includes one or more sensors **6021**. The sensors **6021** of the watch body **6020** can be the same or distinct from the sensors **6013** of the wearable band **6010**. The sensors **6021** of the watch body **6020** can be distributed on an inside and/or an outside surface of the watch body **6020**. In some embodiments, the sensors **6021** are configured to contact a user's skin when the watch body **6020** is worn by the user. For example, the sensors **6021** can be placed on the bottom side of the watch body **6020** and the coupling mechanism **6016** can be a cradle with an opening that allows the bottom side of the watch body **6020** to directly contact the user's skin. Alternatively, in some embodiments, the watch body **6020** does not include sensors that are configured to contact

the user's skin (e.g., including sensors internal and/or external to the watch body **6020** that configured to sense data of the watch body **6020** and the watch body **6020**'s surrounding environment). In some embodiment, the sensors **6013** are configured to track a position and/or motion of the watch body **6020**.

[0350] The watch body **6020** and the wearable band **6010** can share data using a wired communication method (e.g., a Universal Asynchronous Receiver/Transmitter (UART) or a USB transceiver) and/or a wireless communication method (e.g., near field communication or Bluetooth). For example, the watch body **6020** and the wearable band **6010** can share data sensed by the sensors **6013** and **6021**, as well as application and device specific information (e.g., active and/or available applications, output devices (e.g., display and/or speakers), input devices (e.g., touch screen, microphone, and/or imaging sensors).

[0351] In some embodiments, the watch body **6020** can include, without limitation, a front-facing camera **6020**A and/or a rear-facing camera **6020**B, sensors **6021** (e.g., a biometric sensor, an IMU, a heart rate sensor, a saturated oxygen sensor, a neuromuscular signal sensor, an altimeter sensor, a temperature sensor, a bioimpedance sensor, a pedometer sensor, an optical sensor (e.g., imaging sensor **6063**; FIG. **12**B), a touch sensor, a sweat sensor, etc.). In some embodiments, the watch body **6020** can include one or more haptic devices **6076** (FIG. **12**B; a vibratory haptic actuator) that is configured to provide haptic feedback (e.g., a cutaneous and/or kinesthetic sensation) to the user. The sensors **6021** and/or the haptic device **6076** can also be configured to operate in conjunction with multiple applications including, without limitation, health monitoring applications, social media applications, game applications, and artificial reality applications (e.g., the applications associated with artificial reality).

[0352] As described above, the watch body **6020** and the wearable band **6010**, when coupled, can form the wrist-wearable device **6000**. When coupled, the watch body **6020** and wearable band **6010** operate as a single device to execute functions (operations, detections, and/or communications) described herein. In some embodiments, each device is provided with particular instructions for performing the one or more operations of the wrist-wearable device **6000**. For example, in accordance with a determination that the watch body **6020** does not include neuromuscular signal sensors, the wearable band **6010** can include alternative instructions for performing associated instructions (e.g., providing sensed neuromuscular signal data to the watch body **6020** via a different electronic device). Operations of the wrist-wearable device **6000** can be performed by the watch body **6020** alone or in conjunction with the wearable band **6010** (e.g., via respective processors and/or hardware components) and vice versa. In some embodiments, operations of the wrist-wearable device **6000**, the watch body **6020**, and/or the wearable band **6010** can be performed in conjunction with one or more processors and/or hardware components of another communicatively coupled device (e.g., the HIPD **8000**; FIGS. **14**A-**14**B).

[0353] As described below with reference to the block diagram of FIG. **12**B, the wearable band **6010** and/or the watch body **6020** can each include independent resources required to independently execute functions. For example, the wearable band **6010** and/or the watch body **6020** can each include a power source (e.g., a battery), a memory, data storage, a processor (e.g., a central processing unit (CPU)), communications, a light source, and/or input/output devices.

[0354] FIG. **12**B shows block diagrams of a computing system **6030** corresponding to the wearable band **6010**, and a computing system **6060** corresponding to the watch body **6020**, according to some embodiments. A computing system of the wrist-wearable device **6000** includes a combination of components of the wearable band computing system **6030** and the watch body computing system **6060**, in accordance with some embodiments.

[0355] The watch body **6020** and/or the wearable band **6010** can include one or more components shown in watch body computing system **6060**. In some embodiments, a single integrated circuit includes all or a substantial portion of the components of the watch body computing system **6060** are included in a single integrated circuit. Alternatively, in some embodiments, components of the watch body computing system **6060** are included in a plurality of integrated circuits that are communicatively coupled. In some embodiments, the watch body computing system **6060** is configured to couple (e.g., via a wired or wireless connection) with the wearable band computing system **6030**, which allows the computing systems to share components, distribute tasks, and/or perform other operations described herein (individually or as a single device).

[0356] The watch body computing system **6060** can include one or more processors **6079**, a controller **6077**, a peripherals interface **6061**, a power system **6095**, and memory (e.g., a memory **6080**), each of which are defined above and described in more detail below.

[0357] The power system **6095** can include a charger input **6057**, a power-management integrated circuit (PMIC) **6097**, and a battery **6096**, each are which are defined above. In some embodiments, a watch body **6020** and a wearable band **6010** can have respective batteries (e.g., battery **6098** and **6059**), and can share power with each other. The watch body **6020** and the wearable band **6010** can receive a charge using a variety of techniques. In some embodiments, the watch body **6020** and the wearable band **6010** can use a wired charging assembly (e.g., power cords) to receive the charge. Alternatively, or in addition, the watch body **6020** and/or the wearable band **6010** can be configured for wireless charging. For example, a portable charging device can be designed to mate with a portion of watch body **6020** and/or wearable band **6010** and wirelessly deliver usable power to a battery of watch body **6020** and/or wearable band **6010**. The watch body **6020** and the wearable band **6010** can have independent power systems (e.g., power system **6095** and **6056**) to enable each to operate independently. The watch body **6020** and wearable band **6010** can also share power (e.g., one can charge the other) via respective PMICs (e.g., PMICs **6097** and **6058**) that can share power over power and ground conductors and/or over wireless charging antennas.

[0358] In some embodiments, the peripherals interface **6061** can include one or more sensors **6021**, many of which listed below are defined above. The sensors **6021** can include one or more coupling sensor **6062** for detecting when the watch body **6020** is coupled with another electronic device (e.g., a wearable band **6010**). The sensors **6021** can include imaging sensors **6063** (one or more of the cameras **6025**, and/or separate imaging sensors **6063** (e.g., thermal-imaging sensors)). In some embodiments, the sensors **6021** include one or more SpO2 sensors **6064**. In some embodiments, the sensors **6021** include one or more biopo-

tential-signal sensors (e.g., EMG sensors **6065** and **6035**, which may be disposed on a user-facing portion of the watch body **6020** and/or the wearable band **6010**). In some embodiments, the sensors **6021** include one or more capacitive sensors **6066**. In some embodiments, the sensors **6021** include one or more heart rate sensors **6067**. In some embodiments, the sensors **6021** include one or more IMU sensors **6068**. In some embodiments, one or more IMU sensors **6068** can be configured to detect movement of a user's hand or other location that the watch body **6020** is placed or held).

[0359] In some embodiments, the peripherals interface **6061** includes a near-field communication (NFC) component **6069**, a global-position system (GPS) component **6070**, a long-term evolution (LTE) component **6071**, and/or a Wi-Fi and/or Bluetooth communication component **6072**. In some embodiments, the peripherals interface **6061** includes one or more buttons **6073** (e.g., the peripheral buttons **6023** and **6027** in FIG. **12**A), which, when selected by a user, cause operation to be performed at the watch body **6020**. In some embodiments, the peripherals interface **6061** includes one or more indicators, such as a light emitting diode (LED), to provide a user with visual indicators (e.g., message received, low battery, active microphone and/or camera).

[0360] The watch body **6020** can include at least one display **6005**, for displaying visual representations of information or data to the user, including user-interface elements and/or three-dimensional virtual objects. The display can also include a touch screen for inputting user inputs, such as touch gestures, swipe gestures, and the like. The watch body **6020** can include at least one speaker **6074** and at least one microphone **6075** for providing audio signals to the user and receiving audio input from the user. The user can provide user inputs through the microphone **6075** and can also receive audio output from the speaker **6074** as part of a haptic event provided by the haptic controller **6078**. The watch body **6020** can include at least one camera **6025**, including a front camera **6020**A and a rear camera **6020**B. The cameras **6025** can include ultra-wide-angle cameras, wide angle cameras, fish-eye cameras, spherical cameras, telephoto cameras, a depth-sensing cameras, or other types of cameras.

[0361] The watch body computing system **6060** can include one or more haptic controllers **6077** and associated componentry (e.g., haptic devices **6076**) for providing haptic events at the watch body **6020** (e.g., a vibrating sensation or audio output in response to an event at the watch body **6020**). The haptic controllers **6078** can communicate with one or more haptic devices **6076**, such as electroacoustic devices, including a speaker of the one or more speakers **6074** and/or other audio components and/or electromechanical devices that convert energy into linear motion such as a motor, solenoid, electroactive polymer, piezoelectric actuator, electrostatic actuator, or other tactile output generating component (e.g., a component that converts electrical signals into tactile outputs on the device). The haptic controller **6078** can provide haptic events to that are capable of being sensed by a user of the watch body **6020**. In some embodiments, the one or more haptic controllers **6078** can receive input signals from an application of the applications **6082**.

[0362] In some embodiments, the computing system **6030** and/or the computing system **6060** can include memory **6080**, which can be controlled by a memory controller of the one or more controllers **6077**. In some embodiments, software components stored in the memory **6080** include one or more applications **6082** configured to perform operations at the watch body **6020**. In some embodiments, the one or more applications **6082** include games, word processors, messaging applications, calling applications, web browsers, social media applications, media streaming applications, financial applications, calendars, and/or clocks. In some embodiments, software components stored in the memory **6080** include one or more communication interface modules **6083** as defined above. In some embodiments, software components stored in the memory **6080** include one or more graphics modules **6084** for rendering, encoding, and/or decoding audio and/or visual data; and one or more data management modules **6085** for collecting, organizing, and/or providing access to the data **6087** stored in memory **6080**. In some embodiments, one or more of applications **6082** and/or one or more modules can work in conjunction with one another to perform various tasks at the watch body **6020**.

[0363] In some embodiments, software components stored in the memory **6080** can include one or more operating systems **6081** (e.g., a Linux-based operating system or an Android operating system). The memory **6080** can also include data **6087**. The data **6087** can include profile data **6088**A, sensor data **6089**A, media content data **6090**, and application data **6091**.

[0364] It should be appreciated that the watch body computing system **6060** is an example of a computing system within the watch body **6020**, and that the watch body **6020** can have more or fewer components than shown in the watch body computing system **6060**, combine two or more components, and/or have a different configuration and/or arrangement of the components. The various components shown in watch body computing system **6060** are implemented in hardware, software, firmware, or a combination thereof, including one or more signal processing and/or application-specific integrated circuits.

[0365] Turning to the wearable band computing system **6030**, one or more components that can be included in the wearable band **6010** are shown. The wearable band computing system **6030** can include more or fewer components than shown in the watch body computing system **6060**, combine two or more components, and/or have a different configuration and/or arrangement of some or all of the components. In some embodiments, all, or a substantial portion of the components of the wearable band computing system **6030** are included in a single integrated circuit. Alternatively, in some embodiments, components of the wearable band computing system **6030** are included in a plurality of integrated circuits that are communicatively coupled. As described above, in some embodiments, the wearable band computing system **6030** is configured to couple (e.g., via a wired or wireless connection) with the watch body computing system **6060**, which allows the computing systems to share components, distribute tasks, and/or perform other operations described herein (individually or as a single device).

[0366] The wearable band computing system **6030**, similar to the watch body computing system **6060**, can include one or more processors **6049**, one or more controllers **6047** (including one or more haptics controller **6048**), a peripherals interface **6031** that can includes one or more sensors **6013** and other peripheral devices, power source (e.g., a power system **6056**), and memory (e.g., a memory **6050**) that includes an operating system (e.g., an operating system

6051), data (e.g., data **6054** including profile data **6088**B and/or sensor data **6089**B), and one or more modules (e.g., a communications interface module **6052** and/or a data management module **6053**).

[0367] The one or more sensors **6013** can be analogous to sensors **6021** of the computing system **6060** and in light of the definitions above. For example, sensors **6013** can include one or more coupling sensors **6032**, one or more SpO2 sensor **6034**, one or more EMG sensors **6035**, one or more capacitive sensor **6036**, one or more heart rate sensor **6037**, and one or more IMU sensor **6038**.

[0368] The peripherals interface **6031** can also include other components analogous to those included in the peripheral interface **6061** of the computing system **6060**, including an NFC component **6039**, a GPS component **6040**, an LTE component **6041**, a Wi-Fi and/or Bluetooth communication component **6042**, and/or one or more haptic devices **6076** as described above in reference to peripherals interface **6061**. In some embodiments, the peripherals interface **6061** includes one or more buttons **6043**, a display **6033**, a speaker **6044**, a microphone **6045**, and a camera **6055**. In some embodiments, the peripherals interface **6061** includes one or more indicators, such as an LED.

[0369] It should be appreciated that the wearable band computing system **6030** is an example of a computing system within the wearable band **6010**, and that the wearable band **6010** can have more or fewer components than shown in the wearable band computing system **6030**, combine two or more components, and/or have a different configuration and/or arrangement of the components. The various components shown in wearable band computing system **6030** can be implemented in one or a combination of hardware, software, firmware, including one or more signal processing and/or application-specific integrated circuits.

[0370] The wrist-wearable device **6000** with respect to FIG. **12**A is an example of the wearable band **6010** and the watch body **6020** coupled, so the wrist-wearable device **6000** will be understood to include the components shown and described for the wearable band computing system **6030** and the watch body computing system **6060**. In some embodiments, wrist-wearable device **6000** has a split architecture (e.g., a split mechanical architecture, a split electrical architecture) between the watch body **6020** and the wearable band **6010**. In other words, all of the components shown in the wearable band computing system **6030** and the watch body computing system **6060** can be housed or otherwise disposed in a combined watch device **6000**, or within individual components of the watch body **6020**, wearable band **6010**, and/or portions thereof (e.g., a coupling mechanism **6016** of the wearable band **6010**).

[0371] The techniques described above can be used with any device for sensing neuromuscular signals, including the arm-wearable devices of FIG. **12**A-**12**B, but could also be used with other types of wearable devices for sensing neuromuscular signals (such as body-wearable or head-wearable devices that might have neuromuscular sensors closer to the brain or spinal column).

[0372] In some embodiments, a wrist-wearable device **6000** can be used in conjunction with a head-wearable device described below (e.g., AR system **7000** and VR headset **7010**) and/or an HIPD **8000**; and the wrist-wearable device **6000** can also be configured to be used to allow a user to control aspect of the artificial reality (e.g., by using EMG-based gestures to control user interface objects in the artificial reality and/or by allowing a user to interact with the touchscreen on the wrist-wearable device to also control aspects of the artificial reality). In some embodiments, a wrist-wearable device **6000** can also be used in conjunction with a wearable garment, such as the wearable gloves described below in reference to FIGS. **15**A-**15**C. Having thus described example wrist-wearable device, attention will now be turned to example head-wearable devices, such AR system **7000** and VR headset **7010**.

Example Head-Wearable Devices

[0373] FIGS. **13**A to **13**C show example artificial-reality systems, including the AR system **7000**. In some embodiments, the AR system **7000** is an eyewear device as shown in FIG. **13**A. In some embodiments, the VR system **7010** includes a head-mounted display (HMD) **7012**, as shown in FIGS. **13**B-**1** and **13**B-**2**. In some embodiments, the AR system **7000** and the VR system **7010** include one or more analogous components (e.g., components for presenting interactive artificial-reality environments, such as processors, memory, and/or presentation devices, including one or more displays and/or one or more waveguides), some of which are described in more detail with respect to FIG. **13**C. As described herein, a head-wearable device can include components of the eyewear device **7002**, and/or the head-mounted display **7012**. Some embodiments of head-wearable devices do not include any displays, including any of the displays described with respect to the AR system **7000** and/or the VR system **7010**. While the example artificial-reality systems are respectively described herein as the AR system **7000** and the VR system **7010**, either or both of the example AR systems described herein can be configured to present fully-immersive VR scenes presented in substantially all of a user's field of view, additionally or alternatively to, subtler augmented-reality scenes that are presented within a portion, less than all, of the user's field of view.

[0374] FIG. **13**A show an example visual depiction of the AR system **7000** (which may also be described herein as augmented-reality glasses, and/or smart glasses). The AR system **7000** can include additional electronic components that are not shown in FIGS. **13**A, such as a wearable accessory device and/or an intermediary processing device, in electronic communication or otherwise configured to be used in conjunction with the eyewear device. In some embodiments, the wearable accessory device and/or the intermediary processing device may be configured to couple with the eyewear device via a coupling mechanism in electronic communication with a coupling sensor **7024**, where the coupling sensor **7024** can detect when an electronic device becomes physically or electronically coupled with the eyewear device. In some embodiments, the eyewear device is configured to couple to a housing **7090**, which may include one or more additional coupling mechanisms configured to couple with additional accessory devices. The components shown in FIG. **13**A can be implemented in hardware, software, firmware, or a combination thereof, including one or more signal-processing components and/or application-specific integrated circuits (ASICs).

[0375] The eyewear device includes mechanical glasses components, including a frame **7004** configured to hold one or more lenses (e.g., one or both lenses **7006-1** and **7006-2**). One of ordinary skill in the art will appreciate that the eyewear device can include additional mechanical components, such as hinges configured to allow portions of the

frame **7004** of the eyewear device **7002** to be folded and unfolded, a bridge configured to span the gap between the lenses **7006-1** and **7006-2** and rest on the user's nose, nose pads configured to rest on the bridge of the nose and provide support for the eyewear device, earpieces configured to rest on the user's ears and provide additional support for the eyewear device, temple arms configured to extend from the hinges to the earpieces of the eyewear device, and the like. One of ordinary skill in the art will further appreciate that some examples of the AR system **7000** can include none of the mechanical components described herein. For example, smart contact lenses configured to present artificial reality to users may not include any components of the eyewear device.

[0376] The eyewear device includes electronic components, many of which will be described in more detail below with respect to FIG. **13**C. Some example electronic components are illustrated in FIG. **13**A, including acoustic sensors **7025-1**, **7025-2**, **7025-3**, **7025-4**, **7025-5**, and **7025-1**, which can be distributed along a substantial portion of the frame **7004** of the eyewear device. The eyewear device also includes a left camera **7039**A and a right camera **7039**B, which are located on different sides of the frame **7004**. And the eyewear device includes a processor **7048** (e.g., an integral microprocessor, such as an ASIC) that is embedded into a portion of the frame **7004**.

[0377] FIGS. **13**B-**1** and **13**B-**2** show a VR system **7010** that includes a head-mounted display (HMD) **7012** (e.g., also referred to herein as an artificial-reality headset, a head-wearable device, or a VR headset), in accordance with some embodiments. As noted, some artificial-reality systems may (e.g., the AR system **7000**), instead of blending an artificial reality with actual reality, substantially replace one or more of a user's sensory perceptions of the real world with a virtual experience (e.g., the AR systems **5000***c* and **5000***d*).

[0378] The HMD **7012** includes a front body **7014** and a frame **7016** (e.g., a strap or band) shaped to fit around a user's head. In some embodiments, the front body **7014** and/or the frame **7016** includes one or more electronic elements for facilitating presentation of and/or interactions with an AR and/or VR system (e.g., displays, IMUs, tracking emitter or detectors). In some embodiments, the HMD **7012** includes output audio transducers (e.g., an audio transducer **7018-1**), as shown in FIG. **13**B-**2**. In some embodiments, one or more components, such as the output audio transducer(s) **7018-1** and the frame **7016**, can be configured to attach and detach (e.g., are detachably attachable) to the HMD **7012** (e.g., a portion or all of the frame **7016**, and/or the audio transducer **7018-1**), as shown in FIG. **13**B-**2**. In some embodiments, coupling a detachable component to the HMD **7012** causes the detachable component to come into electronic communication with the HMD **7012**.

[0379] FIG. **13**B-**1** to **13**B-**2** also show that the VR system **7010** one or more cameras, such as the left camera **7039**A and the right camera **7039**B, which can be analogous to the left and right cameras on the frame **7004** of the eyewear device **7002**. In some embodiments, the VR system **7010** includes one or more additional cameras (e.g., cameras **7039**C and **7039**D), which can be configured to augment image data obtained by the cameras **7039**A and **7039**B by providing more information. For example, the camera **7039**C can be used to supply color information that is not discerned by cameras **7039**A and **7039**B. In some embodiments, one or more of the cameras **7039**A to **7039**D can include an optional IR cut filter configured to remove IR light from being received at the respective camera sensors.

[0380] FIG. **13**C illustrates a computing system **7020** and an optional housing **7090**, each of which show components that can be included in the AR system **7000** and/or the VR system **7010**. In some embodiments, more or less components can be included in the optional housing **7090** depending on practical restraints of the respective AR system being described.

[0381] In some embodiments, the computing system **7020** and/or the optional housing **7090** can include one or more peripheral interfaces **7022**, one or more power systems **7042**, one or more controllers **7046** (including one or more haptic controllers **7047**), one or more processors **7048** (as defined above, including any of the examples provided), and memory **7050**, which can all be in electronic communication with each other. For example, the one or more processors **7048** can be configured to execute instructions stored in the memory **7050**, which can cause a controller of the one or more controllers **7046** to cause operations to be performed at one or more peripheral devices of the peripherals interface **7022**. In some embodiments, each operation described can occur based on electrical power provided by the power system **7042**.

[0382] In some embodiments, the peripherals interface **7022** can include one or more devices configured to be part of the computing system **7020**, many of which have been defined above and/or described with respect to wrist-wearable devices shown in FIGS. **12**A and **12**B. For example, the peripherals interface can include one or more sensors **7023**. Some example sensors include: one or more coupling sensors **7024**, one or more acoustic sensors **7025**, one or more imaging sensors **7026**, one or more EMG sensors **7027**, one or more capacitive sensors **7028**, and/or one or more IMU sensors **7029**; and/or any other types of sensors defined above or described with respect to any other embodiments discussed herein.

[0383] In some embodiments, the peripherals interface can include one or more additional peripheral devices, including one or more NFC devices **7030**, one or more GPS devices **7031**, one or more LTE devices **7032**, one or more Wi-Fi and/or Bluetooth devices **7033**, one or more buttons **7034** (e.g., including buttons that are slidable or otherwise adjustable), one or more displays **7035**, one or more speakers **7036**, one or more microphones **7037**, one or more cameras **7038** (e.g., including the left camera **7039**A and/or a right camera **7039**B), and/or one or more haptic devices **7040**; and/or any other types of peripheral devices defined above or described with respect to any other embodiments discussed herein.

[0384] AR systems can include a variety of types of visual feedback mechanisms (e.g., presentation devices). For example, display devices in the AR system **7000** and/or the VR system **7010** can include one or more liquid-crystal displays (LCDs), light emitting diode (LED) displays, organic LED (OLED) displays, and/or any other suitable types of display screens. Artificial-reality systems can include a single display screen (e.g., configured to be seen by both eyes), and/or can provide separate display screens for each eye, which can allow for additional flexibility for varifocal adjustments and/or for correcting a refractive error associated with the user's vision. Some embodiments of AR systems also include optical subsystems having one or more

lenses (e.g., conventional concave or convex lenses, Fresnel lenses, or adjustable liquid lenses) through which a user can view a display screen.

[0385] For example, respective displays can be coupled to each of the lenses **7006-1** and **7006-2** of the AR system **7000**. The displays coupled to each of the lenses **7006-1** and **7006-2** can act together or independently to present an image or series of images to a user. In some embodiments, the AR system **7000** includes a single display (e.g., a near-eye display) or more than two displays. In some embodiments, a first set of one or more displays can be used to present an augmented-reality environment, and a second set of one or more display devices can be used to present a virtual-reality environment. In some embodiments, one or more waveguides are used in conjunction with presenting artificial-reality content to the user of the AR system **7000** (e.g., as a means of delivering light from one or more displays to the user's eyes). In some embodiments, one or more waveguides are fully or partially integrated into the eyewear device **7002**. Additionally, or alternatively to display screens, some artificial-reality systems include one or more projection systems. For example, display devices in the AR system **7000** and/or the virtual-reality system **7010** can include micro-LED projectors that project light (e.g., using a waveguide) into display devices, such as clear combiner lenses that allow ambient light to pass through. The display devices can refract the projected light toward a user's pupil and can enable a user to simultaneously view both artificial-reality content and the real world. Artificial-reality systems can also be configured with any other suitable type or form of image projection system. In some embodiments, one or more waveguides are provided additionally or alternatively to the one or more display(s).

[0386] The computing system **7020** and/or the optional housing **7090** of the AR system **7000** or the VR system **7010** can include some or all of the components of a power system **7042**. The power system **7042** can include one or more charger inputs **7043**, one or more PMICs **7044**, and/or one or more batteries **7045**.

[0387] The memory **7050** includes instructions and data, some or all of which may be stored as non-transitory computer-readable storage media within the memory **7050**. For example, the memory **7050** can include one or more operating systems **7051**; one or more applications **7052**; one or more communication interface applications **7053**; one or more graphics applications **7054**; one or more AR processing applications **7055**; and/or any other types of data defined above or described with respect to any other embodiments discussed herein.

[0388] The memory **7050** also includes data **7060** which can be used in conjunction with one or more of the applications discussed above. The data **7060** can include: profile data **7061**; sensor data **7062**; media content data **7063**; AR application data **7064**; and/or any other types of data defined above or described with respect to any other embodiments discussed herein.

[0389] In some embodiments, the controller **7046** of the eyewear device **7002** processes information generated by the sensors **7023** on the eyewear device **7002** and/or another electronic device within the AR system **7000**. For example, the controller **7046** can process information from the acoustic sensors **7025-1** and **7025-2**. For each detected sound, the controller **7046** can perform a direction of arrival (DOA) estimation to estimate a direction from which the detected sound arrived at the eyewear device **7002** of the AR system **7000**. As one or more of the acoustic sensors **7025** detects sounds, the controller **7046** can populate an audio data set with the information (e.g., represented in FIG. **13**C as sensor data **7062**).

[0390] In some embodiments, a physical electronic connector can convey information between the eyewear device and another electronic device, and/or between one or more processors of the AR system **7000** or the VR system **7010** and the controller **7046**. The information can be in the form of optical data, electrical data, wireless data, or any other transmittable data form. Moving the processing of information generated by the eyewear device to an intermediary processing device can reduce weight and heat in the eyewear device, making it more comfortable and safer for a user. In some embodiments, an optional wearable accessory device (e.g., an electronic neckband) is coupled to the eyewear device via one or more connectors. The connectors can be wired or wireless connectors and can include electrical and/or non-electrical (e.g., structural) components. In some embodiments, the eyewear device and the wearable accessory device can operate independently without any wired or wireless connection between them.

[0391] In some situations, pairing external devices, such as an intermediary processing device (e.g., the HIPD **8000**) with the eyewear device **7002** (e.g., as part of the AR system **7000**) enables the eyewear device **7002** to achieve a similar form factor of a pair of glasses while still providing sufficient battery and computation power for expanded capabilities. Some, or all, of the battery power, computational resources, and/or additional features of the AR system **7000** can be provided by a paired device or shared between a paired device and the eyewear device **7002**, thus reducing the weight, heat profile, and form factor of the eyewear device **7002** overall while allowing the eyewear device **7002** to retain its desired functionality. For example, the wearable accessory device can allow components that would otherwise be included on an eyewear device **7002** to be included in the wearable accessory device and/or intermediary processing device, thereby shifting a weight load from the user's head and neck to one or more other portions of the user's body. In some embodiments, the intermediary processing device has a larger surface area over which to diffuse and disperse heat to the ambient environment. Thus, the intermediary processing device can allow for greater battery and computation capacity than might otherwise have been possible on the eyewear device **7002**, standing alone. Because weight carried in the wearable accessory device can be less invasive to a user than weight carried in the eyewear device **7002**, a user may tolerate wearing a lighter eyewear device and carrying or wearing the paired device for greater lengths of time than the user would tolerate wearing a heavier eyewear device standing alone, thereby enabling an artificial-reality environment to be incorporated more fully into a user's day-to-day activities.

[0392] AR systems can include various types of computer vision components and subsystems. For example, the AR system **7000** and/or the VR system **7010** can include one or more optical sensors such as two-dimensional (2D) or three-dimensional (3D) cameras, time-of-flight depth sensors, single-beam or sweeping laser rangefinders, 3D LiDAR sensors, and/or any other suitable type or form of optical sensor. An AR system can process data from one or more of these sensors to identify a location of a user and/or

aspects of the use's real-world physical surroundings, including the locations of real-world objects within the real-world physical surroundings. In some embodiments, the methods described herein are used to map the real world, to provide a user with context about real-world surroundings, and/or to generate digital twins (e.g., interactable virtual objects), among a variety of other functions. For example, FIGS. **13**B-**1** and **13**B-**2** show the VR system **7010** having cameras **7039**A to **7039**D, which can be used to provide depth information for creating a voxel field and a two-dimensional mesh to provide object information to the user to avoid collisions.

[0393] In some embodiments, the AR system **7000** and/or the VR system **7010** can include haptic (tactile) feedback systems, which may be incorporated into headwear, gloves, body suits, handheld controllers, environmental devices (e.g., chairs or floormats), and/or any other type of device or system, such as the wearable devices discussed herein. The haptic feedback systems may provide various types of cutaneous feedback, including vibration, force, traction, shear, texture, and/or temperature. The haptic feedback systems may also provide various types of kinesthetic feedback, such as motion and compliance. The haptic feedback may be implemented using motors, piezoelectric actuators, fluidic systems, and/or a variety of other types of feedback mechanisms. The haptic feedback systems may be implemented independently of other artificial-reality devices, within other artificial-reality devices, and/or in conjunction with other artificial-reality devices (e.g., the haptic feedback system described with respect to FIGS. **15**A to **15**C).

[0394] In some embodiments of an AR system, such as the AR system **7000** and/or the VR system **7010**, ambient light (e.g., a live feed of the surrounding environment that a user would normally see) can be passed through a display element of a respective head-wearable device presenting aspects of the AR system. In some embodiments, ambient light can be passed through a portion less than all, of an AR environment presented within a user's field of view (e.g., a portion of the AR environment co-located with a physical object in the user's real-world environment that is within a designated boundary (e.g., a guardian boundary) configured to be used by the user while they are interacting with the AR environment. For example, a visual user interface element (e.g., a notification user interface element) can be presented at the head-wearable device, and an amount of ambient light (e.g., 15-50% of the ambient light) can be passed through the user interface element, such that the user can distinguish at least a portion of the physical environment over which the user interface element is being displayed.

Example Handheld Intermediary Processing Devices

[0395] FIGS. **14**A and **14**B illustrate an example handheld intermediary processing device (HIPD) **8000**, in accordance with some embodiments. The HIPD **8000** is an instance of the intermediary device described herein, such that the HIPD **8000** should be understood to have the features described with respect to any intermediary device defined above or otherwise described herein, and vice versa. FIG. **14**A shows a top view **8005** and a side view **8025** of the HIPD **8000**. The HIPD **8000** is configured to communicatively couple with one or more wearable devices (or other electronic devices) associated with a user. For example, the HIPD **8000** is configured to communicatively couple with a user's wrist-wearable device **6000** (or components thereof, such as the watch body **6020** and the wearable band **6010**), AR system **7000**, and/or VR headset **7010**. The HIPD **8000** can be configured to be held by a user (e.g., as a handheld controller), carried on the user's person (e.g., in their pocket, in their bag, etc.), placed in proximity of the user (e.g., placed on their desk while seated at their desk, on a charging dock, etc.), and/or placed at or within a predetermined distance from a wearable device or other electronic device (e.g., where, in some embodiments, the predetermined distance is the maximum distance (e.g., 10 meters) at which the HIPD **8000** can successfully be communicatively coupled with an electronic device, such as a wearable device).

[0396] The HIPD **8000** can perform various functions independently and/or in conjunction with one or more wearable devices (e.g., wrist-wearable device **6000**, AR system **7000**, and/or VR headset **7010**). The HIPD **8000** is configured to increase and/or improve the functionality of communicatively coupled devices, such as the wearable devices. The HIPD **8000** is configured to perform one or more functions or operations associated with interacting with user interfaces and applications of communicatively coupled devices, interacting with an AR environment, interacting with VR environment, and/or operating as a human-machine interface controller. Additionally, as will be described in more detail below, functionality and/or operations of the HIPD **8000** can include, without limitation, task offloading and/or handoffs; thermals offloading and/or handoffs; 6 degrees of freedom (6DoF) raycasting and/or gaming (e.g., using imaging devices or cameras **8014**, which can be used for simultaneous localization and mapping (SLAM) and/or with other image processing techniques); portable charging; messaging; image capturing via one or more imaging devices or cameras **8022**; sensing user input (e.g., sensing a touch on a touch input surface **8002**); wireless communications and/or interlining (e.g., cellular, near field, Wi-Fi, personal area network, etc.); location determination; financial transactions; providing haptic feedback; alarms; notifications; biometric authentication; health monitoring; sleep monitoring; etc. The above-example functions can be executed independently in the HIPD **8000** and/or in communication between the HIPD **8000** and another wearable device described herein. In some embodiments, functions can be executed on the HIPD **8000** in conjunction with an AR environment. As the skilled artisan will appreciate upon reading the descriptions provided herein, the novel the HIPD **8000** described herein can be used with any type of suitable AR environment.

[0397] While the HIPD **8000** is communicatively coupled with a wearable device and/or other electronic device, the HIPD **8000** is configured to perform one or more operations initiated at the wearable device and/or the other electronic device. In particular, one or more operations of the wearable device and/or the other electronic device can be offloaded to the HIPD **8000** to be performed. The HIPD **8000** performs the one or more operations of the wearable device and/or the other electronic device and provides to data corresponded to the completed operations to the wearable device and/or the other electronic device. For example, a user can initiate a video stream using AR system **7000** and back-end tasks associated with performing the video stream (e.g., video rendering) can be offloaded to the HIPD **8000**, which the HIPD **8000** performs and provides corresponding data to the AR system **7000** to perform remaining front-end tasks associated with the video stream (e.g., presenting the ren-

dered video data via a display of the AR system **7000**). In this way, the HIPD **8000**, which has more computational resources and greater thermal headroom than a wearable device, can perform computationally intensive tasks for the wearable device improving performance of an operation performed by the wearable device.

[0398] The HIPD **8000** includes a multi-touch input surface **8002** on a first side (e.g., a front surface) that is configured to detect one or more user inputs. In particular, the multi-touch input surface **8002** can detect single tap inputs, multi-tap inputs, swipe gestures and/or inputs, force-based and/or pressure-based touch inputs, held taps, and the like. The multi-touch input surface **8002** is configured to detect capacitive touch inputs and/or force (and/or pressure) touch inputs. The multi-touch input surface **8002** includes a touch-input surface **8004** defined by a surface depression, and a touch-input surface **8006** defined by a substantially planar portion. The touch-input surface **8004** can be disposed adjacent to the touch-input surface **8006**. In some embodiments, the touch-input surface **8004** and the touch-input surface **8006** can be different dimensions, shapes, and/or cover different portions of the multi-touch input surface **8002**. For example, the touch-input surface **8004** can be substantially circular and the touch-input surface **8006** is substantially rectangular. In some embodiments, the surface depression of the multi-touch input surface **8002** is configured to guide user handling of the HIPD **8000**. In particular, the surface depression is configured such that the user holds the HIPD **8000** upright when held in a single hand (e.g., such that the using imaging devices or cameras **8014**A and **8014**B are pointed toward a ceiling or the sky). Additionally, the surface depression is configured such that the user's thumb rests within the touch-input surface **8004**.

[0399] In some embodiments, the different touch-input surfaces include a plurality of touch-input zones. For example, the touch-input surface **8006** includes at least a touch-input zone **8008** within a touch-input zone **8006** and a touch-input zone **8010** within the touch-input zone **8008**. In some embodiments, one or more of the touch-input zones are optional and/or user defined (e.g., a user can specific a touch-input zone based on their preferences). In some embodiments, each touch-input surface and/or touch-input zone is associated with a predetermined set of commands. For example, a user input detected within the touch-input zone **8008** causes the HIPD **8000** to perform a first command and a user input detected within the touch-input zone **8006** causes the HIPD **8000** to perform a second command, distinct from the first. In some embodiments, different touch-input surfaces and/or touch-input zones are configured to detect one or more types of user inputs. The different touch-input surfaces and/or touch-input zones can be configured to detect the same or distinct types of user inputs. For example, the touch-input zone **8008** can be configured to detect force touch inputs (e.g., a magnitude at which the user presses down) and capacitive touch inputs, and the touch-input zone **8006** can be configured to detect capacitive touch inputs.

[0400] The HIPD **8000** includes one or more sensors **8051** for sensing data used in the performance of one or more operations and/or functions. For example, the HIPD **8000** can include an IMU sensor that is used in conjunction with cameras **8014** for 3-dimensional object manipulation (e.g., enlarging, moving, or destroying an object) in an AR or VR environment. Non-limiting examples of the sensors **8051** included in the HIPD **8000** include a light sensor, a magnetometer, a depth sensor, a pressure sensor, and a force sensor. Additional examples of the sensors **8051** are provided below in reference to FIG. **14**B.

[0401] The HIPD **8000** can include one or more light indicators **8012** to provide one or more notifications to the user. In some embodiments, the light indicators are LEDs or other types of illumination devices. The light indicators **8012** can operate as a privacy light to notify the user and/or others near the user that an imaging device and/or microphone are active. In some embodiments, a light indicator is positioned adjacent to one or more touch-input surfaces. For example, a light indicator can be positioned around the touch-input surface **8004**. The light indicators can be illuminated in different colors and/or patterns to provide the user with one or more notifications and/or information about the device. For example, a light indicator positioned around the touch-input surface **8004** can flash when the user receives a notification (e.g., a message), change red when the HIPD **8000** is out of power, operate as a progress bar (e.g., a light ring that is closed when a task is completed (e.g., 0% to 100%)), operates as a volume indicator, etc.).

[0402] In some embodiments, the HIPD **8000** includes one or more additional sensors on another surface. For example, as shown FIG. **14**A, HIPD **8000** includes a set of one or more sensors (e.g., sensor set **8020**) on an edge of the HIPD **8000**. The sensor set **8020**, when positioned on an edge of the of the HIPD **8000**, can be pe positioned at a predetermined tilt angle (e.g., 26 degrees), which allows the sensor set **8020** to be angled toward the user when placed on a desk or other flat surface. Alternatively, in some embodiments, the sensor set **8020** is positioned on a surface opposite the multi-touch input surface **8002** (e.g., a back surface). The one or more sensors of the sensor set **8020** are discussed in detail below.

[0403] The side view **8025** of the of the HIPD **8000** shows the sensor set **8020** and camera **8014**B. The sensor set **8020** includes one or more cameras **8017**A and **8017**B, a depth projector **8024**, an ambient light sensor **8028**, and a depth receiver **8030**. In some embodiments, the sensor set **8020** includes a light indicator **8026**. The light indicator **8026** can operate as a privacy indicator to let the user and/or those around them know that a camera and/or microphone is active. The sensor set **8020** is configured to capture a user's facial expression such that the user can puppet a custom avatar (e.g., showing emotions, such as smiles and/or laughter on the avatar or a digital representation of the user). The sensor set **8020** can be configured as a side stereo RGB system, a rear indirect Time-of-Flight (iToF) system, or a rear stereo RGB system. As the skilled artisan will appreciate upon reading the descriptions provided herein, the HIPD **8000** described herein can use different sensor set **8020** configurations and/or sensor set **8020** placements.

[0404] In some embodiments, the HIPD **8000** includes one or more haptic devices **8071** (e.g., a vibratory haptic actuator) that are configured to provide haptic feedback (e.g., kinesthetic sensation). The sensors **8051**, and/or the haptic devices **8071** can be configured to operate in conjunction with multiple applications and/or communicatively coupled devices including, without limitation, wearable devices, health monitoring applications, social media applications, game applications, and artificial reality applications (e.g., the applications associated with artificial reality).

[0405] The HIPD **8000** is configured to operate without a display. However, in optional embodiments, the HIPD **8000** can include a display **8068** (FIG. **14**B). The HIPD **8000** can also income one or more optional peripheral buttons **8067** (FIG. **14**B). For example, the peripheral buttons **8067** can be used to turn on or turn off the HIPD **8000**. Further, the HIPD **8000** housing can be formed of polymers and/or elastomer elastomers. The HIPD **8000** can be configured to have a non-slip surface to allow the HIPD **8000** to be placed on a surface without requiring a user to watch over the HIPD **8000**. In other words, the HIPD **8000** is designed such that it would not easily slide off surfaces. In some embodiments, the HIPD **8000** include one or magnets to couple the HIPD **8000** to another surface. This allows the user to mount the HIPD **8000** to different surfaces and provide the user with greater flexibility in use of the HIPD **8000**.

[0406] As described above, the HIPD **8000** can distribute and/or provide instructions for performing the one or more tasks at the HIPD **8000** and/or a communicatively coupled device. For example, the HIPD **8000** can identify one or more back-end tasks to be performed by the HIPD **8000** and one or more front-end tasks to be performed by a communicatively coupled device. While the HIPD **8000** is configured to offload and/or handoff tasks of a communicatively coupled device, the HIPD **8000** can perform both back-end and front-end tasks (e.g., via one or more processors, such as CPU **8077**; FIG. **14**B). The HIPD **8000** can, without limitation, can be used to perform augmenting calling (e.g., receiving and/or sending 3D or 2.5D live volumetric calls, live digital human representation calls, and/or avatar calls), discreet messaging, 6DoF portrait/landscape gaming, AR/VR object manipulation, AR/VR content display (e.g., presenting content via a virtual display), and/or other AR/VR interactions. The HIPD **8000** can perform the above operations alone or in conjunction with a wearable device (or other communicatively coupled electronic device).

[0407] FIG. **14**B shows block diagrams of a computing system **8040** of the HIPD **8000**, in accordance with some embodiments. The HIPD **8000**, described in detail above, can include one or more components shown in HIPD computing system **8040**. The HIPD **8000** will be understood to include the components shown and described below for the HIPD computing system **8040**. In some embodiments, all, or a substantial portion of the components of the HIPD computing system **8040** are included in a single integrated circuit. Alternatively, in some embodiments, components of the HIPD computing system **8040** are included in a plurality of integrated circuits that are communicatively coupled.

[0408] The HIPD computing system **8040** can include a processor (e.g., a CPU **8077**, a GPU, and/or a CPU with integrated graphics), a controller **8075**, a peripherals interface **8050** that includes one or more sensors **8051** and other peripheral devices, a power source (e.g., a power system **8095**), and memory (e.g., a memory **8078**) that includes an operating system (e.g., an operating system **8079**), data (e.g., data **8088**), one or more applications (e.g., applications **8080**), and one or more modules (e.g., a communications interface module **8081**, a graphics module **8082**, a task and processing management module **8083**, an interoperability module **8084**, an AR processing module **8085**, and/or a data management module **8086**). The HIPD computing system **8040** further includes a power system **8095** that includes a charger input and output **8096**, a PMIC **8097**, and a battery **8098**, all of which are defined above.

[0409] In some embodiments, the peripherals interface **8050** can include one or more sensors **8051**. The sensors **8051** can include analogous sensors to those described above in reference to FIG. **12**B. For example, the sensors **8051** can include imaging sensors **8054**, (optional) EMG sensors **8056**, IMU sensors **8058**, and capacitive sensors **8060**. In some embodiments, the sensors **8051** can include one or more pressure sensor **8052** for sensing pressure data, an altimeter **8053** for sensing an altitude of the HIPD **8000**, a magnetometer **8055** for sensing a magnetic field, a depth sensor **8057** (or a time-of flight sensor) for determining a difference between the camera and the subject of an image, a position sensor **8059** (e.g., a flexible position sensor) for sensing a relative displacement or position change of a portion of the HIPD **8000**, a force sensor **8061** for sensing a force applied to a portion of the HIPD **8000**, and a light sensor **8062** (e.g., an ambient light sensor) for detecting an amount of lighting. The sensors **8051** can include one or more sensors not shown in FIG. **17**B.

[0410] Analogous to the peripherals described above in reference to FIGS. **12**B, the peripherals interface **8050** can also include an NFC component **8063**, a GPS component **8064**, an LTE component **8065**, a Wi-Fi and/or Bluetooth communication component **8066**, a speaker **8069**, a haptic device **8071**, and a microphone **8073**. As described above in reference to FIG. **17**A, the HIPD **8000** can optionally include a display **8068** and/or one or more buttons **8067**. The peripherals interface **8050** can further include one or more cameras **8070**, touch surfaces **8072**, and/or one or more light emitters **8074**. The multi-touch input surface **8002** described above in reference to FIG. **17**A is an example of touch surface **8072**. The light emitters **8074** can be one or more LEDs, lasers, etcetera, and can be used to project or present information to a user. For example, the light emitters **8074** can include light indicators **8012** and **8026** described above in reference to FIG. **17**A. The cameras **8070** (e.g., cameras **8014** and **8022** described above in FIG. **17**A) can include one or more wide angle cameras, fish-eye cameras, spherical cameras, compound eye cameras (e.g., stereo and multi cameras), depth cameras, RGB cameras, ToF cameras, RGB-D cameras (depth and ToF cameras), and/or other available cameras. Cameras **8070** can be used for SLAM; 6 DoF ray casting, gaming, object manipulation, and/or other rendering; facial recognition and facial expression recognition, etc.

[0411] Similar to the watch body computing system **6060** and the watch band computing system **6030** described above in reference to FIG. **12**B, the HIPD computing system **8040** can include one or more haptic controllers **8076** and associated componentry (e.g., haptic devices **8071**) for providing haptic events at the HIPD **8000**.

[0412] Memory **8078** can include high-speed random-access memory and/or non-volatile memory, such as one or more magnetic disk storage devices, flash memory devices, or other non-volatile solid-state memory devices. Access to the memory **8078** by other components of the HIPD **8000**, such as the one or more processors and the peripherals interface **8050**, can be controlled by a memory controller of the controllers **8075**.

[0413] In some embodiments, software components stored in the memory **8078** include one or more operating systems **8079**, one or more applications **8080**, one or more communication interface modules **8081**, one or more graphics modules **8082**, one or more data management modules **8086**,

which are analogous to the software components described above in reference to FIG. **12**B.

[0414] In some embodiments, software components stored in the memory **8078** include a task and processing management module **8083** for identifying one or more front-end and back-end tasks associated with an operation performed by the user, performing one or more front-end and/or back-end tasks, and/or providing instructions to one or more communicatively coupled devices that cause performance of the one or more front-end and/or back-end tasks. In some embodiments, the task and processing management module **8083** uses data **8088** (e.g., device data **8090**) to distribute the one or more front-end and/or back-end tasks based on communicatively coupled devices' computing resources, available power, thermal headroom, ongoing operations, and/or other factors. For example, the task and processing management module **8083** can cause the performance of one or more back-end tasks (of an operation performed at communicatively coupled AR system **7000**) at the HIPD **8000** in accordance with a determination that the operation is utilizing a predetermined amount (e.g., at least 70%) of computing resources available at the AR system **7000**.

[0415] In some embodiments, software components stored in the memory **8078** include an interoperability module **8084** for exchanging and utilizing information received and/or provided to distinct communicatively coupled devices. The interoperability module **8084** allows for different systems, devices, and/or applications to connect and communicate in a coordinated way without user input. In some embodiments, software components stored in the memory **8078** include an AR module **8085** that is configured to process signals based at least on sensor data for use in an AR and/or VR environment. For example, the AR module **8085** can be used for 3D object manipulation, gesture recognition, facial and facial expression, and/or recognition.

[0416] The memory **8078** can also include data **8088**, including structured data. In some embodiments, the data **8088** includes profile data **8089**, device data **8090** (including device data of one or more devices communicatively coupled with the HIPD **8000**, such as device type, hardware, software, and/or configurations), sensor data **8091**, media content data **8092**, and application data **8093**.

[0417] It should be appreciated that the HIPD computing system **8040** is an example of a computing system within the HIPD **8000**, and that the HIPD **8000** can have more or fewer components than shown in the HIPD computing system **8040**, combine two or more components, and/or have a different configuration and/or arrangement of the components. The various components shown in HIPD computing system **8040** are implemented in hardware, software, firmware, or a combination thereof, including one or more signal processing and/or application-specific integrated circuits.

[0418] The techniques described above in FIG. **17**A-**17**B can be used with any device used as a human-machine interface controller. In some embodiments, an HIPD **8000** can be used in conjunction with one or more wearable device such as a head-wearable device (e.g., AR system **7000** and VR system **7010**) and/or a wrist-wearable device **6000** (or components thereof). In some embodiments, an HIPD **8000** is used in conjunction with a wearable garment, such as the wearable gloves of FIGS. **15**A-**15**C. Having thus described example HIPD **8000**, attention will now be turned to example feedback devices, such as device **9000**.

Example Feedback Devices

[0419] FIGS. **15**A and **15**B show example haptic feedback systems (e.g., hand-wearable devices) for providing feedback to a user regarding the user's interactions with a computing system (e.g., an artificial-reality environment presented by the AR system **7000** or the VR system **7010**). In some embodiments, a computing system (e.g., the AR system **5000***d*) may also provide feedback to one or more users based on an action that was performed within the computing system and/or an interaction provided by the AR system (e.g., which may be based on instructions that are executed in conjunction with performing operations of an application of the computing system). Such feedback may include visual and/or audio feedback and may also include haptic feedback provided by a haptic assembly, such as one or more haptic assemblies **9062** of the device **9000** (e.g., haptic assemblies **9062-1**, **9062-2**, and **9062-3**). For example, the haptic feedback may prevent (or, at a minimum, hinder/resist movement of) one or more fingers of a user from bending past a certain point to simulate the sensation of touching a solid coffee mug. In actuating such haptic effects, the device **9000** can change (either directly or indirectly) a pressurized state of one or more of the haptic assemblies **9062**.

[0420] Each of the haptic assemblies **9062** includes a mechanism that, at a minimum, provides resistance when the respective haptic assembly **9062** is transitioned from a first pressurized state (e.g., atmospheric pressure or deflated) to a second pressurized state (e.g., inflated to a threshold pressure). Structures of haptic assemblies **9062** can be integrated into various devices configured to be in contact or proximity to a user's skin, including, but not limited to devices such as glove worn devices, body worn clothing device, and headset devices.

[0421] As noted above, the haptic assemblies **9062** described herein can be configured to transition between a first pressurized state and a second pressurized state to provide haptic feedback to the user. Due to the ever-changing nature of artificial reality, the haptic assemblies **9062** may be required to transition between the two states hundreds, or perhaps thousands of times, during a single use. Thus, the haptic assemblies **9062** described herein are durable and designed to quickly transition from state to state. To provide some context, in the first pressurized state, the haptic assemblies **9062** do not impede free movement of a portion of the wearer's body. For example, one or more haptic assemblies **9062** incorporated into a glove are made from flexible materials that do not impede free movement of the wearer's hand and fingers (e.g., an electrostatic-zipping actuator). The haptic assemblies **9062** are configured to conform to a shape of the portion of the wearer's body when in the first pressurized state. However, once in the second pressurized state, the haptic assemblies **9062** can be configured to restrict and/or impede free movement of the portion of the wearer's body (e.g., appendages of the user's hand). For example, the respective haptic assembly **9062** (or multiple respective haptic assemblies) can restrict movement of a wearer's finger (e.g., prevent the finger from curling or extending) when the haptic assembly **9062** is in the second pressurized state. Moreover, once in the second pressurized state, the haptic assemblies **9062** may take different shapes, with some haptic assemblies **9062** configured to take a

planar, rigid shape (e.g., flat and rigid), while some other haptic assemblies **9062** are configured to curve or bend, at least partially.

[0422] As a non-limiting example, the device **9000** includes a plurality of haptic devices (e.g., a pair of haptic gloves, and a haptics component of a wrist-wearable device (e.g., any of the wrist-wearable devices described with respect to FIGS. **12**A-**12**B. Each of which can include a garment component (e.g., a garment **9004**) and one or more haptic assemblies coupled (e.g., physically coupled) to the garment component. For example, each of the haptic assemblies **9062-1**, **9062-2**, **9062-3**, . . . **9062**-N are physically coupled to the garment **9004** are configured to contact respective phalanges of a user's thumb and fingers. As explained above, the haptic assemblies **9062** are configured to provide haptic simulations to a wearer of the device **9000**. The garment **9004** of each device **9000** can be one of various articles of clothing (e.g., gloves, socks, shirts, or pants). Thus, a user may wear multiple devices **9000** that are each configured to provide haptic stimulations to respective parts of the body where the devices **9000** are being worn.

[0423] FIG. **15**C shows block diagrams of a computing system **9040** of the device **9000**, in accordance with some embodiments. The computing system **9040** can include one or more peripheral interfaces **9050**, one or more power systems **9095**, one or more controllers **9075** (including one or more haptic controllers **9076**), one or more processors **9077** (as defined above, including any of the examples provided), and memory **9078**, which can all be in electronic communication with each other. For example, the one or more processors **9077** can be configured to execute instructions stored in the memory **9078**, which can cause a controller of the one or more controllers **9075** to cause operations to be performed at one or more peripheral devices of the peripherals interface **9050**. In some embodiments, each operation described can occur based on electrical power provided by the power system **9095**. The power system **9095** includes a charger input **9096**, a PMIC **9097**, and a battery **9098**.

[0424] In some embodiments, the peripherals interface **9050** can include one or more devices configured to be part of the computing system **9040**, many of which have been defined above and/or described with respect to wrist-wearable devices shown in FIGS. **12**A and **12**B. For example, the peripherals interface **9050** can include one or more sensors **9051**. Some example sensors include: one or more pressure sensors **9052**, one or more EMG sensors **9056**, one or more IMU sensors **9058**, one or more position sensors **9059**, one or more capacitive sensors **9060**, one or more force sensors **9061**; and/or any other types of sensors defined above or described with respect to any other embodiments discussed herein.

[0425] In some embodiments, the peripherals interface can include one or more additional peripheral devices, including one or more Wi-Fi and/or Bluetooth devices **9068**; one or more haptic assemblies **9062**; one or more support structures **9063** (which can include one or more bladders **9064**; one or more manifolds **9065**; one or more pressure-changing devices **9067**; and/or any other types of peripheral devices defined above or described with respect to any other embodiments discussed herein.

[0426] In some embodiments, each haptic assembly **9062** includes a support structure **9063**, and at least one bladder **9064**. The bladder **9064** (e.g., a membrane) is a sealed, inflatable pocket made from a durable and puncture resistance material, such as thermoplastic polyurethane (TPU), a flexible polymer, or the like. The bladder **9064** contains a medium (e.g., a fluid such as air, inert gas, or even a liquid) that can be added to or removed from the bladder **9064** to change a pressure (e.g., fluid pressure) inside the bladder **9064**. The support structure **9063** is made from a material that is stronger and stiffer than the material of the bladder **9064**. A respective support structure **9063** coupled to a respective bladder **9064** is configured to reinforce the respective bladder **9064** as the respective bladder changes shape and size due to changes in pressure (e.g., fluid pressure) inside the bladder.

[0427] The device **9000** also includes a haptic controller **9076** and a pressure-changing device **9067**. In some embodiments, the haptic controller **9076** is part of the computer system **9040** (e.g., in electronic communication with one or more processors **9077** of the computer system **9040**). The haptic controller **9076** is configured to control operation of the pressure-changing device **9067**, and in turn operation of the device **9000**. For example, the controller **9076** sends one or more signals to the pressure-changing device **9067** to activate the pressure-changing device **9067** (e.g., turn it on and off). The one or more signals may specify a desired pressure (e.g., pounds-per-square inch) to be output by the pressure-changing device **9067**. Generation of the one or more signals, and in turn the pressure output by the pressure-changing device **9067**, may be based on information collected by the sensors in FIGS. **11**A and **11**B. For example, the one or more signals may cause the pressure-changing device **9067** to increase the pressure (e.g., fluid pressure) inside a haptic assembly **9062** at a first time, based on the information collected by the sensors in FIGS. **11**A and **11**B (e.g., the user makes contact with an artificial coffee mug). Then, the controller may send one or more additional signals to the pressure-changing device **9067** that cause the pressure-changing device **9067** to further increase the pressure inside the haptic assembly **9062** at a second time after the first time, based on additional information collected by the sensors **9051**. Further, the one or more signals may cause the pressure-changing device **9067** to inflate one or more bladders **9064** in a device **9000**-A, while one or more bladders **9064** in a device **9000**-B remain unchanged. Additionally, the one or more signals may cause the pressure-changing device **9067** to inflate one or more bladders **9064** in a device **9000**-A to a first pressure and inflate one or more other bladders **9064** in the device **9000**-A to a second pressure different from the first pressure. Depending on the number of devices **9000** serviced by the pressure-changing device **9067**, and the number of bladders therein, many different inflation configurations can be achieved through the one or more signals and the examples above are not meant to be limiting.

[0428] The device **9000** may include an optional manifold **9065** between the pressure-changing device **9067** and the devices **9000**. The manifold **9065** may include one or more valves (not shown) that pneumatically couple each of the haptic assemblies **9062** with the pressure-changing device **9067** via tubing. In some embodiments, the manifold **9065** is in communication with the controller **9075**, and the controller **9075** controls the one or more valves of the manifold **9065** (e.g., the controller generates one or more control signals). The manifold **9065** is configured to switchably couple the pressure-changing device **9067** with one

or more haptic assemblies **9062** of the same or different devices **9000** based on one or more control signals from the controller **9075**. In some embodiments, instead of using the manifold **9065** to pneumatically couple the pressure-changing device **9067** with the haptic assemblies **9062**, the device **9000** may include multiple pressure-changing devices **9067**, where each pressure-changing device **9067** is pneumatically coupled directly with a single (or multiple) haptic assembly **9062**. In some embodiments, the pressure-changing device **9067** and the optional manifold **9065** are configured as part of one or more of the devices **9000** (not illustrated) while, in other embodiments, the pressure-changing device **9067** and the optional manifold **9065** are configured as external to the device **9000**. A single pressure-changing device **9067** may be shared by multiple devices **9000**.

[0429] In some embodiments, the pressure-changing device **9067** is a pneumatic device, hydraulic device, a pneudraulic device, or some other device capable of adding and removing a medium (e.g., fluid, liquid, gas) from the one or more haptic assemblies **9062**.

[0430] The devices shown in FIGS. **15**A to **15**C may be coupled via a wired connection (e.g., via busing). Alternatively, one or more of the devices shown in FIGS. **15**A to **15**C may be wirelessly connected (e.g., via short-range communication signals).

[0431] The memory **9078** includes instructions and data, some or all of which may be stored as non-transitory computer-readable storage media within the memory **9078**. For example, the memory **9078** can include one or more operating systems **9079**; one or more communication interface applications **9081**; one or more interoperability modules **9084**; one or more AR processing applications **9085**; one or more data management modules **9086**; and/or any other types of data defined above or described with respect to any other embodiments discussed herein.

[0432] The memory **9078** also includes data **9088** which can be used in conjunction with one or more of the applications discussed above. The data **9088** can include: device data **9090**; sensor data **9091**; and/or any other types of data defined above or described with respect to any other embodiments discussed herein.

[0433] Having thus described system-block diagrams and then example devices, attention will now be directed to certain example embodiments.

Example Embodiments-Gesture Detection

[0434] Turning now to some example embodiments of the methods, devices, systems, and computer-readable storage media described earlier. In short, the descriptions below proceed by first discussing the paragraphs beginning with an A symbol, which are related to an aspect in which wrist movements are used to control a user interface; following that is a discussion of paragraphs beginning with a B symbol, which relate to an aspect in which in-air hand gestures are used to move and snap a point of focus.

[0435] (A1) In one aspect, some embodiments include a method (e.g., the method **1000**) of using wrist movements to control a user-interface. In some embodiments, the method is performed at a wearable device (e.g., the wrist-wearable device **120**) having memory (e.g., memory **1160**) and one or more processors (e.g., the processor(s) **6079**). The method includes: (i) receiving, via one or more neuromuscular-signal sensors of a wrist-wearable device worn by a user, data generated during performance of an in-air wrist movement by the user; (ii) moving a point of focus on the user interface in accordance with the in-air wrist movement (e.g., as illustrated in FIG. **1**G); (iii) receiving, via the one or more neuromuscular-signal sensors, additional data generated during performance of an in-air gesture by the user; (iv) determining that the in-air gesture is an execution gesture; and (v) executing a command corresponding to the execution gesture (e.g., as illustrated in FIG. **1**H). For example, after moving a cursor via wrist rotations, the user taps the thumb (or other phalange) to execute a command for a user interface element selected by the cursor. In some situations, snapping to a closest element helps reduce frustration with noisy input signals. In some embodiments, the point of focus is moved in accordance with a gesture distance from an initial position (e.g., as described in FIGS. **7**S-**7**U).

[0436] In some embodiments, a priming gesture is required before wrist rotation by the user is accepted as a control input for a point of focus. For example, a user is required to maintain a first or pinch gesture while rotating their wrist in order for the wrist rotation to move the point of focus (e.g., as illustrated in FIGS. **1**A-**1**G). In this way, inadvertent wrist movements won't cause the point of focus to move when undesired by the user.

[0437] In some embodiments, the data generated corresponds to muscle movement during the performance of the wrist movement. For example, moving a cursor around using wrist angle information, where a wrist-wearable watch can sense the angle of the user's wrist (e.g., using an EMG and/or IMU sensor). In this way, a user can use minute wrist movements to navigate a user interface.

[0438] In some embodiments, the wearable device is a wrist-wearable device, such as a smartwatch (e.g., the wrist-wearable device **120**). In some embodiments, the wearable device includes an inertial measuring unit (IMU). In some embodiments, the wearable device is a head-wearable wearable device, such as smart glasses (e.g., the head-wearable device **402**). The methods described herein, in addition to being performed at a wearable device, can also be performed at an artificial-reality system (e.g., the AR system **5000**) that includes both a wrist-wearable device and a head-wearable wearable device, among other hardware accessories or components.

[0439] In some embodiments, by using the data from the one or more neuromuscular-signal sensors, an in-air hand gesture described herein is detected before its performance has been completed by the user, such as detecting an intention to perform the in-air hand gesture followed by completion of the in-air hand gesture, which can either be separately detected or determined based on the user's intention to perform the in-air hand gesture.

[0440] In some embodiments, the in-air hand gestures described herein include movement of a user's wrist, elbow, and shoulder (e.g., an arm lift or wave gesture). In some embodiments, the in-air gesture is a gesture that does not contact the wearable device.

[0441] (A2) In some embodiments of A1, the method further includes, prior to moving the point of focus, identifying the in-air wrist movement as being part of a navigation gesture, where the point of focus is moved in accordance with the identification. For example, the

system forgoes moving the point of focus for wrist movements that are not intended as navigation gestures.

[0442] In some embodiments, the system activates a user interface in accordance with identifying a navigation, priming, or control gesture. In some embodiments, activating the user interface includes giving focus to a first user interface element of the user interface. In some embodiments, activating the user interface includes causing a plurality of user interface elements to be displayed. In some embodiments, activating the user interface includes presenting a user interface element that was not presented prior to activating the user interface. For example, activating commands for the user interface, where the commands correspond to the additional gestures. In some embodiments, activating the user interface further includes activating one or more sensors of a wearable device. In some embodiments, activating the user interface includes enabling display of the user interface. In some embodiments, activating the user interface includes updating display of the user interface (e.g., to display a menu that wasn't previously displayed).

[0443] (A3) In some embodiments of A1 or A2: (i) the in-air wrist movement includes the wrist of the user rotating from an initial position to a rotated position, and where the wrist of the user is maintained in the rotated position for an amount of time; and (ii) the method further includes, while the wrist of the user is maintained in the rotated position for the amount of time, scrolling the point of focus through a plurality of selectable user interface elements. For example, while the user maintains the downward wrist rotation shown in FIG. **1**G, the point of focus **105** moves downward through the emojis in the emoji menu.

[0444] (A4) In some embodiments of any of A1-A3, the movement (e.g., rotation) of the wrist causes the movement of the point of focus. In some embodiments, the (relative) position of the wrist causes the movement. In some embodiments, the movement of the point of focus is based on both the movement and position of the user's wrist. In some embodiments, a type of navigation is selected based on the movement and/or position of the wrist (e.g., as illustrated in FIG. **5**A-**5**E).

[0445] (A5) In some embodiments of A4, the method further includes, in accordance with a determination that the in-air wrist movement comprises the wrist of the user returning to the initial position (e.g., the user's wrist returning to the origin point on the scale **510** as illustrated in FIG. **5**B), ceasing to scroll the point of focus and selecting a nearest user interface element to the point of focus. In some embodiments, in accordance with the determination that the in-air wrist movement comprises the wrist of the user returning to the initial position, the scroll of the point of focus ceases without selecting the nearest user interface element.

[0446] (A6) In some embodiments of A5, the nearest user interface element is not selected unless the point of focus is overlaid with the nearest user interface element (or within a snapping threshold (e.g., the snapping boundary **412**) of the nearest user interface element).

[0447] (A7) In some embodiments of any of A1-A6, the method further includes, prior to moving the point of focus, identifying an initial position of the wrist of the user, where the point of focus is moved in accordance with movement of the wrist of the user from the initial position (e.g., as described previously with respect to FIGS. **5**A-**5**E). For example, whatever angle the user's wrist is at initially (e.g., at the time when the user performs an associated priming gesture) becomes the origin point [0,0,0] in a reference plane for the gesture.

[0448] (A8) In some embodiments of any of A1-A7, the point of focus is moved at a speed that corresponds to a wrist angle of the wrist of the user. In some embodiments, if the wrist angle is greater than a first threshold but less than a second threshold the point of focus moves at a first speed, and if the wrist angle is greater than the second threshold the point of focus moves at a second speed greater than the first speed. In some embodiments, a type of navigation is selected based on the movement and/or position of the wrist with respect to one or more thresholds (e.g., as illustrated in FIG. **5**A-**5**E).

[0449] (A9) In some embodiments of any of A1-A8, the point of focus is moved at a speed that corresponds to a speed of the in-air wrist movement. In some embodiments, if the wrist movement speed is greater than a first threshold but less than a second threshold the point of focus moves at a first speed, and if the wrist movement speed is greater than the second threshold the point of focus moves at a second speed greater than the first speed (e.g., a gentle rotation vs. a flick rotation).

[0450] (A10) In some embodiments of any of A1-A9, the method further includes, in accordance with a determination that the point of focus is within a threshold distance of a selectable user interface element, selecting the user interface element by snapping the point of focus to the selectable user interface element. For example, FIGS. **4**C and **4**D illustrate the point of focus **408** moving within the snapping boundary **412** and snapping to the user interface element **414**.

[0451] (A11) In some embodiments of A10, the method further includes: (i) after selecting the user interface element, detecting a user-interface control gesture; and (ii) in accordance with a determination that movement of the user-interface control gesture would cause the point of focus to move beyond a second threshold distance of the selected user interface element, deselecting the user interface element. For example, FIGS. **4**E and **4**F illustrate the point of focus **408** moving beyond the snapping boundary **412** and deselection of the user interface element **414**. In some embodiments the snapping threshold and un-snapping thresholds are different. In some embodiments, the point of focus is displayed separately from the selection and when the point of focus moves beyond the second threshold distance the user interface element is deselected. In some embodiments, in accordance with the point of focus moving to a position that is closer to another selectable object (as compared to the selected user interface element), the user interface element is deselected, and the other selectable object is selected. In some embodiments, the point of focus is moved by different gestures that can deselect one element, and select another. In some embodiments, a single gesture causes selection and subsequent deselection of the user interface element (e.g., a long swipe gesture causes the point of focus to move past the user interface element). In some embodiments, point of focus unsnaps and does

not re-snap until it's within a threshold distance of another selectable user interface element. For example, in accordance with some embodiments, while the point of focus is greater than a threshold distance from every selectable user interface element, no user interface element is selected.

[0452] (A12) In some embodiments of A11, the method further includes, in accordance with deselecting the user interface element, selecting a different selectable user interface element by snapping the point of focus to the different selectable user interface element. In some embodiments, at least one user interface element is always selected. For example, the point of focus is overlaid with a first element and the first element is selected. In this example, as the point of focus moves away from the first element, the first element continues to be selected until the point of focus overlays a second element, at which time the select element becomes selected and the first element is deselected. In some embodiments, when a user interface element has been deselected, another is immediately selected. In some embodiments, another UI element is not selected if the threshold distance is not met.

[0453] (A13) In some embodiments of any of A1-A12, the point of focus is presented as a cursor. In some embodiments, the user can use their wrist movements as a cursor, and the point of focus is displayed using that cursor.

[0454] (A14) In some embodiments of any of A1-A13, the method further includes: (i) receiving, via the one or more neuromuscular-signal sensors, more data generated from performance of an additional in-air gesture by the user; (ii) determining that the additional in-air gesture is a navigation gesture; and (iii) snapping the point of focus to a selectable user interface element in accordance with the navigation gesture. For example, the additional in-air gesture is a pinch gesture (e.g., a gesture in which the user's pointer finger touches the user's thumb). As an example, the pinch gesture causes a point of focus to scroll to the next item such as a next photo in a photo gallery. In some embodiments, a user-interface control gesture is performed by a user making a pinch gesture using a first phalange (pointer finger) with another phalange (thumb) resulting in selecting the next item in a list.

[0455] (A15) In some embodiments of any of A1-A14: (i) the user interface includes a plurality of selectable user interface elements organized in a grid; and (ii) the method further includes: (a) receiving, via the one or more neuromuscular-signal sensors, data generated from performance of an additional navigation gesture; (b) in accordance with the additional navigation gesture having a first directionality, snapping the point of focus to a next user interface element in the grid; and (c) in accordance with the additional navigation gesture having a second directionality, snapping the point of focus to a previous user interface element in the grid. In some embodiments, the grid is a one-dimensional grid (e.g., a single row or column) also sometimes referred to as a list. In some embodiments, the additional navigation gesture includes the user's thumb moving in a directional pad (d-pad) manner (e.g., moving along a virtual d-pad).

[0456] (A16) In some embodiments of any of A1-A15, the user interface is displayed via a head-wearable device worn by the user. For example, the user interface could be on a smart watch, glasses, phone, monitor, or the like. In some embodiments, the user interface is part of an augmented-reality or virtual-reality environment.

[0457] (B1) In another aspect, some embodiments include a method (e.g., the method **800**) using in-air gestures to control a point of focus in a user-interface. In some embodiments, the method is performed at a wearable device (e.g., the wrist-wearable device **120**) having memory (e.g., memory **6050** and/or **6080**) and one or more processors (e.g., the processor(s) **6049** and/or **6079**). The method includes: (i) receiving, via one or more sensors of a wrist-wearable device worn by a user, data generated during performance of an in-air hand gesture by the user; (ii) determining, based on the sensor data, that the in-air hand gesture is a user-interface control gesture; (iii) moving a point of focus on the user interface in accordance with the user-interface control gesture; and (iv) in accordance with a determination that the point of focus is within a threshold distance of a selectable user interface element, selecting the user interface element by snapping the point of focus to the selectable user interface element. In some embodiments, the data generated corresponds to muscle movement during the performance of the in-air hand gesture. In some embodiments, the point of focus is moved in accordance with a gesture distance from an initial position (e.g., as described in FIGS. **7**S-**7**U).

[0458] (B2) In some embodiments of B1, the method further includes: (i) after selecting the user interface element, detecting a second user-interface control gesture; and (ii) in accordance with a determination that movement of the second user-interface control gesture would cause the point of focus to move beyond a second threshold distance of the selected user interface element, deselecting the user interface element (e.g., as described previously with respect to A11).

[0459] (B3) In some embodiments of B2, the method further includes, in accordance with deselecting the user interface element, selecting a different selectable user interface element by snapping the point of focus to the different selectable user interface element (e.g., as described previously with respect to A12).

[0460] (B4) In some embodiments of any of B1-B3, the in-air hand gesture includes one or more wrist movements, and the point of focus moves in accordance with wrist angle information corresponding to the one or more wrist movements (e.g., as described previously with respect to A1).

[0461] (B5) In some embodiments of any of B1-B4, the point of focus is presented as a cursor. In some embodiments, the point of focus is presented as a cursor in some situations (e.g., when between selectable user interface elements) and not presented as a cursor in other situations (e.g., when overlaid with a selectable user interface element).

[0462] (B6) In some embodiments of any of B1-B5, the method further includes: (i) receiving, via the one or more sensors, data generated from performance of an additional in-air hand gesture by the user; (ii) determining that the additional in-air hand gesture is an

execution gesture; and (iii) in accordance with the execution gesture, executing a command corresponding to the execution gesture and the selected user interface element. For example, the additional in-air gesture comprises the user tapping the thumb (phalange) against the index finger to execute a command associated with the selected user interface element.

[0463] (B7) In some embodiments of any of B1-B6, the method further includes: (i) receiving, via the one or more sensors, data generated from performance of an additional in-air hand gesture by the user; (ii) determining that the additional in-air hand gesture is a navigation gesture; and (iii) in accordance with the navigation gesture, snapping the point of focus to an adjacent selectable user interface element. As an example, the pinch gesture causes a point of focus to scroll to the next item such as a next photo in a photo gallery. In some embodiments, a user-interface control gesture is performed by a user making a pinch gesture using a first phalange (pointer finger) with another phalange (thumb) resulting in selecting the next item in a list.

[0464] (B8) In some embodiments of any of B1-B7: (i) the user interface includes a plurality of selectable user interface elements organized in a grid; and (ii) the method further includes: (a) receiving, via the one or more neuromuscular-signal sensors, data generated from performance of an additional navigation gesture; (b) in accordance with the additional navigation gesture having a first directionality, snapping the point of focus to a next user interface element in the grid; and (c) in accordance with the additional navigation gesture having a second directionality, snapping the point of focus to a previous user interface element in the grid (e.g., as described previously with respect to A15). In some embodiments, a user-interface control gesture is performed by a user making a pinch gesture using a second phalange (middle finger) with another phalange (thumb) resulting in selecting the previous item in the list.

[0465] (B9) In some embodiments of any of B1-B8: (i) the user-interface control gesture is maintained for an amount of time; and (ii) the method further includes, while the user-interface control gesture is maintained for the amount of time, scrolling the point of focus through a plurality of selectable user interface elements (e.g., as described previously with respect to A3). For example, FIGS. **2**D and **2**E show the user interface **206** scrolling photos in accordance with a held pinch gesture. In some embodiments, the system starts the scrolling after the gesture is held for at least a preset amount of time (e.g., 0.5, 1, or 2 seconds).

[0466] (B10) In some embodiments of B9, the method further includes, in accordance with a determination that the user-interface control gesture is released, ceasing to scroll the point of focus, and selecting a nearest user interface element to the point of focus. For example, the user makes a pinch gesture with two phalanges and holds it, resulting in continuously scrolling until the user releases the gesture.

[0467] (B11) In some embodiments of any of B1-B10, the user interface is displayed via a head-wearable device worn by the user. For example, the user interface could be on a smart watch, glasses, phone, monitor, or the like. In some embodiments, the user interface is part of an augmented-reality or virtual-reality environment.

[0468] (B12) In some embodiments of any of B1-B11, the one or more sensors of the wrist-wearable device include one or more of an electromyography (EMG) sensor, and an inertial measurement unit (IMU) sensor. In some embodiments, gestures are detected using one or more of: an IMU sensor and an EMG sensor.

[0469] (C1) In another aspect, some embodiments include a method of presenting at a head-wearable device (e.g., the head-wearable device **202**), a user interface that includes a first quick-action user interface element associated with a first direction (e.g., the quick-action user interface elements **602** in FIG. **6**A). For example, the user interface can be a home-screen/landing page user interface with which users navigate through an augmented-reality environment to access applications, functions, and the like.

[0470] The method includes: (i) receiving, from a wrist-wearable device (e.g., the wrist-wearable device **120**), an indication of performance of a first in-air directional-pad ("d-pad") gesture in which a user's thumb moves in the first direction (e.g., the upward direction shown in FIG. **6**B); (ii) in response to receiving the indication of the performance of the first in-air d-pad gesture in which the user's thumb moves in the first direction (e.g., across a top of the user's index finger and substantially without moving other fingers or the user's hand as a whole): (a) ceasing to display the user interface; and (b) presenting, via the head-wearable device, information associated with the first quick-action user interface element (e.g., FIG. **7**B shows activation of a messaging application corresponding to quick-action user interface element **602***a*), and a return user interface element (e.g., quick-action user interface element **704**) associated with a second direction, substantially opposite to the first direction; (iii) receiving, from the wrist-wearable device, an indication of performance of a second in-air d-pad gesture in which the user's thumb moves in the second direction (e.g., as shown in FIG. **7**L); (iv) in response to receiving the indication of the performance of the second in-air hand d-pad gesture in which the user's thumb moves in the second direction: (a) ceasing to present the information associated with the first quick-action user interface element; and (b) presenting, via the head-wearable device, the user interface that includes the first quick-action user interface element associated with the first direction (e.g., as shown in FIG. **7**L). In some embodiments, a home screen quick-action user interface element (e.g., a quick-action icon) is displayed on each screen to allow a user to do a d-pad gesture to return back to the home screen.

[0471] (C2) In some embodiments of C1, the user interface that includes the first quick-action user interface element associated with the first direction also includes a second quick-action user interface element associated with the second direction (e.g., the notifications application quick-action user interface element **602***c* in FIG. **6**A). The method further includes: (i) while presenting the user interface that includes the first quick-action user interface element and the second quick-action user interface element, receiving, from the wrist-wearable device, an indication of performance of a third in-air d-pad gesture in which the user's thumb moves in the second direction (e.g., across a top of the user's index finger and substantially without moving

other fingers or the user's hand as a whole); and (ii) in response to receiving the indication of the performance of the third in-air d-pad gesture in which the user's thumb moves in the second direction: (a) ceasing to display the user interface; and (b) presenting, via the head-wearable device, information associated with the second quick-action user interface element and the return user interface element associated with the second direction.

[0472] (C3) In some embodiments of C2, the user interface that includes the first quick-action user interface element associated with the first direction and the second quick-action user interface element associated with the second direction also includes a third quick-action user interface element (e.g., the quick-action user interface element **602***b*) associated with a third direction (e.g., substantially perpendicular (within +/−5 degrees of perpendicular) to the first and second directions), and the method further includes: (i) while presenting the user interface that includes the first quick-action user interface element, the second quick-action user interface element, and the third quick-action user interface element, receiving, from the wrist-wearable device, an indication of performance of a fourth in-air directional-pad ("d-pad") gesture in which the user's thumb moves in the third direction; and (ii) in response to receiving the indication of the performance of the fourth in-air d-pad gesture in which the user's thumb moves in the third direction: (a) ceasing to display the user interface; and (b) presenting, via the head-wearable device, information associated with the third quick-action user interface element, and the return user interface element associated with the second direction (e.g., the music user interface displayed in FIG. **7**M in response to activation of the music application quick-action user interface element **602***b* in FIG. **7**L).

[0473] (C4) In some embodiments of C3, wherein the user interface that includes the first quick-action user interface element associated with the first direction, the second quick-action user interface element associated with the second direction, and the third quick-action user interface element associated with a third direction also includes a fourth quick-action user interface element associated with a fourth direction (e.g., substantially perpendicular (within +/−5 degrees of perpendicular) to the first and second directions), and the method further includes: (i) while presenting the user interface that includes the first quick-action user interface element, the second quick-action user interface element, the third quick-action user interface element, and the fourth quick-action user interface, receiving, from the wrist-wearable device, an indication of performance of a fifth in-air directional-pad ("d-pad") gesture in which the user's thumb moves in the third direction; and (ii) in response to receiving the indication of the performance of the fifth in-air d-pad gesture in which the user's thumb moves in the fourth direction: (a) ceasing to display the user interface; and (b) presenting, via the head-wearable device, information associated with the fourth quick-action user interface element, and the return user interface element associated with the second direction.

[0474] (C5) In some embodiments of C4, the performance of the first, second, third, fourth, and/or fifth in-air d-pad gestures are detected using a plurality of neuromuscular-signal sensors of the wrist-wearable device (e.g., sensor channels **6014***a* and **6014***b* and/or electrodes **6013***a*-**6013***d* of FIG. **12**A).

[0475] (C6) In some embodiments of any of C1-C5, the user interface is caused to be presented via the head-wearable device in response to a quick-action gesture (e.g., a wake gesture) detected via a low-power gesture detector on the wrist-wearable device. For example, prior to presenting the user interface, the wrist-wearable device is operating in a low power mode in which it is responsive to one or more wake gesture (e.g., but not responsive to other types of gestures). In some embodiments, the wrist-wearable device includes a low-power detector (e.g., a microcontroller) and a high-power detector (e.g., a CPU and/or DSP). In some embodiments, while operating in the low-power mode, the wrist-wearable device detects, identifies, and/or responds to quick-action gestures using a low-power detector and not the high-power detector. For example, the wrist-wearable device detects, identifies, and/or responds to quick-action gestures while maintaining the high-power detector in an inactive state.

[0476] (C7) In some embodiments of any of C1-C6, the head-wearable device is a pair of augmented-reality smart glasses (e.g., the AR system **7000**) in which user interfaces are viewable in conjunction with pass-through views of physical objects in the real-world (e.g., as illustrated in FIG. **6**E).

[0477] (C8) In some embodiments of any of C1-C7, the information associated with the first quick-action user interface element is application content associated with a messaging application (e.g., the messages shown in FIG. **7**C).

[0478] (C9) In some embodiments of any of C2-C8, the information associated with the second quick-action user interface element is application content associated with a music application (e.g., the music user interface shown in FIG. **7**M).

[0479] (C10) In some embodiments of C9, the method further includes detecting a gating in-air hand gesture (e.g., the pinch gesture shown in FIG. **7**N) that is maintained while a wrist-roll gesture is performed (e.g., the wrist-roll gesture shown in FIG. **7**O) to manipulate a volume level associated with the music application (e.g., a volume level corresponding to the volume indicator **732**).

[0480] (C11) In some embodiments of any of C3-C10, the information associated with the third quick action user interface element is application content associated with an application that is distinct from respective applications associated with the first and second quick-action user interface elements (e.g., information associated with the notifications application quick-action user interface element **602***c* or the camera application quick-action user interface element **602***d* in FIG. **6**A).

[0481] (C12) In some embodiments of any of C3-C11, the information associated with the fourth quick-action user interface element is application content associated with an application that is distinct from respective applications associated with the first, second, and third quick-action user interface elements.

[0482] In some embodiments, one or more of the gestures described above (e.g., with respect to A1-A16, B1-B12,

and/or C1-C12) are detected with an optical sensor (e.g., a camera) or sensors associated with an inertial measurement unit (IMU) rather than (or in addition to, via fusing the sensor inputs to detect the various in-air hand gestures described herein) the one or more neuromuscular-signal sensors. In some embodiments, the one or more gestures described above (e.g., with respect to A1-A16, B1-B12, and/or C1-C12) are replaced with gestures performed by other parts of the user's body (e.g., head gestures, leg gestures, or torso gestures). As one example, an in-air priming gesture can be detected using one or more of neuromuscular-signal sensors, data from an IMU, and cameras; as another example, a control gesture can be a shaking of the user's head (as if the user is indicating "No") or a nodding of the user's head (as if the user is indicating "Yes").

[0483] In some embodiments, the wearable device detects neuromuscular signals travelling through the user's neck or back, which can be done using neuromuscular-signal sensors coupled with the VR goggles or the AR glasses in some example embodiments. In some embodiments, the one or more gestures described above (e.g., with respect to A1-A16, B1-B12, and/or C1-C12) are replaced with (or performed using) in-air hand gestures on a controller (e.g., a handheld controller or foot pedal controller). In some embodiments, the one or more in-air hand gestures described above (e.g., with respect to A1-A16, B1-B12, and/or C1-C12) are replaced with audio commands (e.g., spoken word commands or non-word commands such as a tongue click).

[0484] In another aspect, some embodiments include a computing system including one or more processors and memory coupled to the one or more processors, the memory storing one or more programs configured to be executed by the one or more processors, the one or more programs including instructions for performing any of the methods described herein (e.g., methods **800**, **900**, and **1000** and A1-A16, B1-B12, and C1-C12 above).

[0485] In yet another aspect, some embodiments include a non-transitory computer-readable storage medium storing one or more programs for execution by one or more processors of a computing system, the one or more programs including instructions for performing any of the methods described herein (e.g., methods **800**, **900**, and **1000** and A1-A16, B1-B12, and C1-C12 above).

Example Embodiments—Multi-Stage Gesture Detection

[0486] Turning now to some additional example embodiments of the methods, devices, systems, and computer-readable storage media described earlier.

[0487] (D1) In one aspect, some embodiments include a method (e.g., the method **2800**) of using a multi-stage in-air hand gesture to activate user-interface interactions. In some embodiments, the method is performed at a wearable device (e.g., the wrist-wearable device **120**) having memory (e.g., memory **6080**) and one or more processors (e.g., the processor(s) **6079**). The method includes: (i) receiving, via one or more sensors (e.g., the sensors **6021**) of a wrist-wearable device worn by a user (e.g., the user **115**), data generated from performance of a multi-stage in-air hand gesture by the user (e.g., the sensor data **6089**A); (ii) in accordance with a determination that a first stage of the multi-stage in-air hand gesture is a priming gesture (e.g., the pinch gesture in FIG. **16**B), activating a user interface (e.g., presenting the radial menu **2131**); and (iii) in accordance with a determination that a last stage of the multi-stage in-air hand gesture is a control gesture (e.g., the tap gesture of FIG. **16**D) received within a predefined threshold amount of time of the priming gesture, executing a command for the user interface that corresponds to the control gesture.

[0488] In some embodiments, the wearable device is a wrist-wearable device, such as a smartwatch (e.g., the wrist-wearable device **120**). In some embodiments, the wearable device includes an inertial measuring unit (IMU). In some embodiments, the wearable device is a head-wearable wearable device, such as smart glasses (e.g., the head-wearable device **202**). The methods described herein, in addition to being performed at a wearable device, can also be performed at an artificial-reality system (e.g., the system **5000***a*) that includes both a wrist-wearable device and a head-wearable wearable device, among other hardware accessories or components.

[0489] In some embodiments, by using the data from the one or more neuromuscular-signal sensors, an in-air hand gesture described herein is detected before its performance has been completed by the user, such as detecting an intention to perform the in-air hand gesture followed by completion of the in-air hand gesture, which can either be separately detected or determined based on the user's intention to perform the in-air hand gesture.

[0490] In some embodiments, the in-air hand gestures described herein include movement of a user's wrist, elbow, and shoulder (e.g., an arm lift or wave gesture). In some embodiments, the in-air gesture is a gesture that does not contact the wearable device.

[0491] In some situations, the requirement for both a priming gesture and a control gesture reduces false positives (e.g., from the user inadvertently performing a gesture). In some embodiments, the priming gesture and the control gesture are identified from data collected by one or more EMG sensors. In some embodiments, the priming gesture is identified from data collected by an IMU sensor and in response an EMG sensor is activated (e.g., to detect a subsequent control gesture). In some embodiments, each stage of the multi-stage gesture is detected by an EMG sensor, and IMU sensor, or a combination of both sensors. In some embodiments, other types of sensors are used to detect at least one stage of the multi-stage gesture (e.g., a stage of the gesture is detected via optical and EMG sensors).

[0492] (D2) In some embodiments of D1: (i) the priming gesture includes maintaining a pinch-and-hold gesture in which at least two phalanges of the user's hand remain in contact for at least a preset amount of time; and (ii) activating the user interface includes displaying a plurality of selectable user interface elements within the user interface while the pinch-and-hold gesture is maintained (e.g., as illustrated in FIGS. **16**B-**1**D). In some embodiments, the pinch-and-hold gesture uses two phalanges (e.g., a middle finger and thumb). In some embodiments, each stage of a multi-stage gesture has a corresponding gesture force (e.g., that is detected via an EMG sensor), where the gesture type for each stage is based on the corresponding amount of gesture force.

[0493] In some embodiments, gestures that are unlikely to be performed by the user inadvertently are designated as priming gestures. For example, a middle finger and thumb pinch gesture is designated as a priming gesture, whereas an index finger and thumb pinch gesture is not designated as a priming gesture.

[0494] (D3) In some embodiments of D2, the method further includes ceasing to display the plurality of selectable user interface elements in accordance with a determination, based on data from the one or more sensors of the wrist-wearable device, that the pinch-and-hold gesture is no longer maintained. In some embodiments, activating the user interface further includes ceasing to display the plurality of selectable user interface elements in accordance with the pinch-and-hold gesture being released. For example, in FIG. **16**E the user **115** has released the pinch gesture shown in FIG. **16**D and the radial menu **2131** is no longer displayed.

[0495] (D4) In some embodiments of D2 or D3, the pinch-and-hold gesture is performed with a finger and thumb on a hand of the user wearing the wrist-wearable device (e.g., a middle finger and thumb pinch).

[0496] (D5) In some embodiments of any of D2-D4: (i) the multi-stage in-air hand gesture further includes a navigation stage; (ii) the navigation stage includes a rotation of a wrist of the user to navigate through a plurality of user interface elements in the user interface and select a selected user interface element from the plurality of user interface elements (e.g., FIG. **16**C shows the user navigating the radial menu **2131** via rotation of the wrist); and (iii) the control gesture comprises a release of the pinch-and-hold gesture to execute a command for the selected user interface element (e.g., as illustrated in FIG. **16**E).

[0497] (D6) In some embodiments of any of D2-D4: (i) the multi-stage in-air hand gesture further includes a navigation stage; and (ii) the navigation stage includes a sliding movement of a first phalange of the at least two phalanges across a surface of a second phalange of the at least two phalanges, the first and second phalanges being located on different fingers of the hand of the user. For example, the priming stage includes a pinch gesture, the navigation stage includes sliding movement of one phalange in the pinch across the surface of the phalange in the pinch gesture, and the control stage includes a deep pinch where the force of the pinch exceeds a preset threshold.

[0498] (D7) In some embodiments of any of D2-D4 or D6: (i) the pinch-and-hold gesture is maintained via a pressing force between the at least two phalanges of the user's hand, the pressing force not meeting a preset activation criterion; (ii) the control gesture comprises an increase in the pressing force between the at least two phalanges of the user's hand, such that the pressing force becomes an increased pressing force; and (iii) the command is executed in accordance with the increased pressing force meeting the preset activation criterion. In some embodiments, (i) the pinch-and-hold gesture has a corresponding force between the fingers, the corresponding force not meeting a preset activation criterion; (ii) the control gesture comprises an increase in the force between the fingers; and (iii) the command is executed in accordance with the force meeting the preset activation criterion (e.g., as described previously with respect to FIGS. **16**D and **16**F).

[0499] In some embodiments, there are multiple thresholds for force of a gesture. For example, a priming gesture comprises a pinch with a force below a first threshold; a first control gesture comprises a pinch with a force above the first threshold, but below a second threshold; and a second control gesture comprises a pinch with a force above the second threshold. In this example, the priming gesture may cause a menu to be displayed, the first control gesture may update the menu to include one or more elements not initially displayed in response to the priming gesture, and the second control gesture may select (activate) a highlighted element in the menu.

[0500] (D8) In some embodiments of any of D1-D7, the method further comprises identifying the command for the user interface based on a combination of the priming gesture and the control gesture. For example, the user interface is responsive to multiple priming gestures for priming different types of commands. In this example, for each priming gesture there are multiple command gestures to identify the command from among multiple commands of the particular type. In this way, the specific command to be executed is identified based on both the priming gesture and the control gesture.

[0501] (D9) In some embodiments of any of D1-D8, activating the user interface includes presenting a user interface element that was not presented prior to activating the user interface. For example, activating commands for the user interface, where the commands correspond to the additional gestures. In some embodiments, activating the user interface further includes activating one or more sensors of the wrist-wearable device. In some embodiments, activating the user interface includes enabling display of the user interface. In some embodiments, activating the user interface includes updating display of the user interface (e.g., to display a menu that was not previously displayed).

[0502] (D10) In some embodiments of any of D1-D9, the method further comprises activating a display of the wrist-wearable device in response to the priming gesture. In some embodiments, activating the display includes increasing power supplied to the display and/or increasing illumination of the display. In some embodiments, the wrist-wearable device does not include a display and, in response to the priming gesture, the wrist-wearable device transitions to a state that is response to control gestures (e.g., by powering on additional sensors and/or additional sensor logic). In some embodiments, the wrist-wearable device includes a display, and activating the user interface includes supplying power to the display of the wrist-wearable device. In some embodiments, the priming gesture activates a display separate from the wrist-wearable device (e.g., a display of a head-wearable device, a television, or a monitor). In some embodiments, activating the display comprises sending instructions to a remote display to cause it to activate. For example, the wrist-wearable device sends an instruction to a head-wearable device instructing the head-wearable device to activate its display.

[0503] (D11) In some embodiments of any of D1-D10, the method further comprises activating a display of a

head-wearable device in response to the priming gesture. In some embodiments, activating the display includes increasing power supplied to the display and/or increasing illumination of the display.

[0504] (D12) In some embodiments of any of D1-D11, the method further comprises: (i) receiving data generated from performance of a second multi-stage in-air hand gesture by the user; (ii) in accordance with a determination that a first portion of the second in-air hand gesture is the priming gesture, activating the user interface; and (iii) in accordance with a determination that the control gesture is not detected within a predetermined amount of time of the priming gesture, deactivating the user interface (e.g., as described above with respect to FIGS. **20**A-**20**D).

[0505] In some situations, the priming gesture could be a false positive and thus if no control gestures are performed within a short time afterwards the user interface is deactivated to prevent execution of undesirable commands. Additionally, if a second in-air hand gesture is performed but that it is not a control gesture that corresponds to the priming gesture, the user interface may be deactivated (e.g., if the user interface is specific to the priming gesture). In some embodiments, the user interface is deactivated in accordance with executing the command. In some embodiments, the user interface is deactivated after a set amount of time (e.g., a set amount of time from executing the command or a set amount of time from activation).

[0506] (D13) In some embodiments of any of D1-D3, D5, or D7-D12, the control gesture includes a rotational movement of a wrist on which the wrist-wearable device is worn. For example, wrist rotation is used to confirm which UI element the user desires to activate. As an example, when sending a message to a remote user, the send action is gated by a wrist roll to confirm. In some embodiments, rotation of the user's wrist is detected using a type of sensor (e.g., an IMU sensor) that can be distinct from a type of sensor used to detect the priming gesture (e.g., a neuromuscular-signal sensor). In this way, data from an EMG sensor can be used to prime EMG-controlled actions, which can help to reduce false positives as the IMU wrist-roll gesture may be erroneously performed during daily use but priming it with an intentional EMG gesture helps to ensure the IMU gesture is correctly detected with a lower false positive rate (e.g., rate of false positives reduced to less than 5%). The rotational movement can be a rotational movement within a roll axis of the wrist-wearable device (e.g., an axis extending circumferentially around the user's wrist).

[0507] (D14) In some embodiments of any of D1-D13, activating the user interface includes causing a plurality of user interface elements to be displayed within the user interface. In some embodiments, the menu displayed is a radial menu or a grid menu. In some embodiments, the plurality of user interface elements are displayed within a menu, a window, or an application interface.

[0508] (D15) In some embodiments of D14, activating the user interface includes causing the plurality of user interface elements to be displayed for a preset amount of time, and the plurality of user interface elements cease to be displayed automatically, without further instructions from the user, when a control gesture is not detected within the predefined threshold amount of time. In some embodiments, activating the user interface includes causing the plurality of user interface elements to be displayed for a preset amount of time, and the plurality of user interface elements cease to be displayed automatically when a control gesture is not detected within the predetermined amount of time.

[0509] In some embodiments: (i) a second in-air hand gesture is detected at the wrist-wearable device; (ii) in accordance with a determination that the second in-air hand gesture is a priming gesture, a menu is caused to be displayed; and (iii) in accordance with a determination that the second in-air hand gesture does not include a control gesture, ceasing to display the menu. In some embodiments, the menu is displayed for a preset amount of time after ceasing to detect the priming gesture.

[0510] (D16) In some embodiments of D14 or D15, the method further comprises, in accordance with (or in conjunction with) executing the command, deactivating the user interface including ceasing to display the plurality of user interface elements. In some embodiments, the user interface is closed (or deactivated), but the display is not in accordance with executing the command. In some embodiments, the display and the user interface are deactivated in accordance with executing the command. In some embodiments, whether the display and/or the user interface are deactivated depends on the type of command activated.

[0511] (D17) In some embodiments of any of D1 or D8-D16: (i) the priming gesture comprises a double tap gesture in which at least one digit of the user's hand contacts at least a part of the user's hand twice in succession; (ii) the control gesture comprises a snapping gesture in which at least two digits of the user's hand touch and slide against one another; and (iii) the command, which is identified based on the priming gesture and the control gesture, comprises capturing a video with an imaging device communicatively coupled to the wrist-wearable device. A double tap gesture in which at least one digit of the user's hand contacts at least a part of the user's hand twice in succession comprises two taps being detected within a preset time threshold of one another (e.g., the two taps are detected within 10, 20, or 30 milliseconds of one another). In some embodiments, the double tap gesture is performed using the pointer finger on top of a middle finger. However, the double tap gesture can be performed using other fingers. In some embodiments, the imaging device is a component of a smartphone, a head-wearable device, or a wrist-wearable device.

[0512] (D18) In some embodiments of D17, the method further comprises: (i) receiving data generated from performance of a second multi-stage in-air hand gesture by the user, where: (a) a priming gesture of the second multi-stage in-air hand gesture comprises a single tap gesture; (b) a control gesture of the second multi-stage in-air hand gesture comprises the snapping gesture; and (ii) in accordance with the priming and control gestures of the second multi-stage in-air hand gesture, executing a new command, distinct from the command, the new command including capturing an image with the imaging device. In some embodiments, the image comprises a static image. In some embodiments, multiple images are captured (e.g., at multiple exposures) and are fused

to create a finished image. For example, capturing the image comprises capturing a high dynamic range (HDR) image.

[0513] (D19) In some embodiments of any of D1-D18, activating the user interface includes causing one or more options to be presented to the user, the one or more options corresponding to available control gestures, including the control gesture that is the last stage of the multi-stage in-air hand gesture. In some embodiments, activating the user interface includes causing one or more options to be presented to the user, the one or more options corresponding to available control gestures (e.g., the options **2606** shown in FIG. **21**C).

[0514] (D20) In some embodiments of any of D1-D19, the method further includes, after determining that the last stage of the multi-stage in-air hand gesture is the control gesture and prior to executing the command, causing a confirmation to be presented to the user, the confirmation requesting that the user confirm that execution of the command is intended by the user, wherein the command is executed in response to the user confirming that execution of the command is intended. For example, in response to a multi-stage gesture being detected, the wearable device causes a notification to be display to the user, the notification indicating the command to be executed in response to the multi-stage gesture and providing the user with an option to confirm or deny the execution of the command. In some embodiments, the method further comprises, after determining that the last stage of the multi-stage in-air hand gesture is the control gesture and prior to executing the command, causing a confirmation to be presented to the user, the confirmation requesting that the user confirm that execution of the command is intended by the user, where the command is executed in response to the user confirming that execution of the command is intended.

[0515] (D21) In some embodiments of any of D1-D20: (i) the priming gesture is performed while a first user interface element is in focus within the user interface, and (ii) the method further includes: (a) in conjunction with activating the user interface, causing display of a plurality of options for interacting with the first user interface element, each of the plurality of options associated with a respective command for the user interface; and (b) in accordance with a determination that a second stage of the multi-stage in-air hand gesture, detected before the last stage of the multi-stage in-air hand gesture, is a navigation gesture, navigating through the plurality of options for interacting with the first user interface element until a respective option of the plurality of options is in focus within the user interface, the respective option of the plurality of options associated with the command, and (iii) where the control gesture is performed while the respective option remains in focus within the user interface, thereby causing the executing of the command that is associated with the respective option. In some embodiments, (i) activating the user interface includes giving focus to a first user interface element of the user interface; and (ii) the method further includes: (a) in accordance with giving focus to the first user interface element, causing display of a first plurality of options for interacting with the first user interface element; (b) in accordance with a determination that a second stage of the multi-stage in-air hand gesture is a navigation gesture, moving the focus to a second user interface element of the user interface; and (c) in accordance with moving the focus to the second user interface element, causing display of a second plurality of options for interacting with the second user interface element, where the second plurality of options is different than the first plurality of options.

[0516] For example, which element is currently in focus can also cause changes to the radial menu of options. If focus is at a first UI object when the priming gesture is detected, then the plurality of user interface elements is a first plurality of user interface elements associated with the first UI object. If focus is at a second UI object, distinct from the first UI object, when the priming gesture is detected, then the plurality of user interface elements is a second plurality of user interface elements associated with the second UI object. For example, the available commands and corresponding control gestures is based on which user interface element has focus.

[0517] (D22) In some embodiments of any of D1-D21, the one or more sensors of the wrist-wearable device include one or more of an inertial measurement unit (IMU) sensor and an electromyography sensor.

[0518] (E1) In another aspect, some embodiments include a method for gating adjustment gestures. The method includes: (i) while a gating in-air hand gesture is maintained (e.g., the pinch gesture in FIG. **22**B), receiving a first indication of performance of an adjustment in-air hand gesture (e.g., a wrist-roll gesture, such as shown in FIG. **22**D) of a first magnitude (e.g., a velocity and/or distance travelled by the wrist during the wrist-roll gesture), the adjustment in-air hand gesture of the first magnitude being directed to a user interface object (e.g., the menu **2704** in FIG. **22**D) presented via a head-wearable device (e.g., the head-wearable device **202**), the user interface object associated with a plurality of values (e.g., corresponding to user interface elements **2706**); (ii) in response to receiving the first indication of the performance of the adjustment in-air hand gesture of the first magnitude, adjusting the user interface object to have a first state after moving through some of the plurality of values based on the first magnitude (e.g., scrolling the menu **2704** as illustrated in FIG. **22**D); (iii) after receiving an indication of a release of the gating in-air hand gesture, in response to receiving a second indication of performance of the adjustment in-air hand gesture, forgoing adjusting the user interface object such that the user interface object continues to have the first state; (iv) while the gating in-air hand gesture is again maintained, receiving a third indication of performance of the adjustment in-air hand gesture of a second magnitude, distinct from the first magnitude, the adjustment in-air hand gesture of the second magnitude being directed to the user interface object while it has the first state; and (v) in response to receiving the third indication of the performance of the adjustment in-air hand gesture of the second magnitude, adjusting the user interface object to move through more of the plurality of values based on the second magnitude such that the user interface object has a second state, distinct from

the first state (e.g., scrolling the menu **2704** to the user interface element **2706-4** as shown in FIG. **22**E).

[0519] As an example, once the gating gesture is released, the user can return their wrist to its original position, then perform the gating gesture again with the adjustment in-air hand gesture to cause a continuous navigation/adjustment to the user interface element. In some embodiments, the first state is the state in which the UI object appears after the adjustment (and it is different from the state of that UI object before the adjustment occurred).

[0520] In some embodiments, the first indication includes data regarding performance of the adjustment in-air hand gesture from a different device, such as a wrist-wearable device that includes neuromuscular-signal sensors. In some embodiments, the plurality of values correspond to selectable options of a menu, positions within an application such as a photo application or messaging application, volume levels for a volume slider bar, or the like.

[0521] (E2) In some embodiments of E1, the gating in-air hand gesture is an in-air pinch gesture in which a user's finger contacts a thumb of the user for at least a predetermined threshold amount of time (e.g., for at least 500 ms, 1 second, or 1.5 seconds).

[0522] (E3) In some embodiments of E2, the method further includes, after receiving an indication of a release of the gating in-air hand gesture while the user interface object has the second state, causing a selection of an option from within the user interface object in response to receiving an indication that the gating in-air hand gesture includes contact between the user's finger and the thumb of the user that lasts for less than the predetermined threshold amount of time. For example, the gating gesture, e.g., a thumb-to-index finger pinch, can be recognized as a gating gesture if it is maintained for at least the predetermined threshold amount of time, but is instead recognized as a selection gesture if it is lasts for a shorter period of time. For example, FIG. **22**G shows the pinch gesture **2729** causing selection of the user interface element **2706-4** (shown in FIG. **22**F).

[0523] (E4) In some embodiments of any of E1-E3: (i) the adjustment in-air hand gesture of the first magnitude is an in-air wrist roll gesture in which a wrist of the user is rotated in a rotational direction substantially around a center point (e.g., within 5, 10, or 15 degrees of the center point), and (ii) the adjusting of the user interface object to have the first state is also based on moving through the some of the plurality of values in accordance with the rotational direction (e.g., the pinch-and-roll gesture shown in FIG. **22**H). For example, if the menu is a vertical menu, then rotational direction to the left can cause the vertical menu to scroll up, and vice versa. For example, if the menu is a horizontal menu, then rotational direction to the left can cause moving through the horizontal menu in a leftward direction, and vice versa. The same behavior/relationship may be used for UI objects with a slide scale of values (e.g., a volume slider bar).

[0524] (E5) In some embodiments of any of E1-E3, the adjustment in-air hand gesture is a translation movement of a hand of the user in which the user's hand moves a distance between distinct first and second spatial positions (e.g., the translation gesture shown in FIG. **22**K).

[0525] (E6) In some embodiments of any of E1-E5, the user interface object is a volume slider, and the plurality of values correspond to respective volume levels of the volume slider.

[0526] (E7) In some embodiments of any of E1-E5, the user interface object is a chat thread having messages displayed in a vertical direction, and each of the plurality of values corresponds to a respective vertical position within the chat thread (e.g., the messages **2732** shown in FIG. **22**H and/or the messages **2774** shown in FIG. **22**O).

[0527] (E8) In some embodiments of any of E1-E5, the user interface object is a menu that includes a plurality of selectable options, and each of the plurality of values corresponds to a respective selectable option of the plurality of selectable options (e.g., the menu **2704** in FIG. **22**A and/or the menu **2778** in FIG. **22**P).

[0528] (E9) In some embodiments of E8, the menu is associated with a messaging application, and the plurality of selectable options include emojis and quick-response messages (e.g., the menu **2778** in FIG. **22**P).

[0529] (E10) In some embodiments of any of E1-E9: (i) the first magnitude of the adjustment in-air hand gesture corresponds to one or both of a velocity and a distance associated with the performance of the adjustment of the in-air hand gesture of the first magnitude, and (ii) the second magnitude of the adjustment in-air hand gesture corresponds to one or both of a velocity and a distance associated with the performance of the adjustment of the in-air hand gesture of the second magnitude (e.g., the first magnitude is indicated in FIG. **22**B by the arrow **2714** and the second magnitude is indicated in FIG. **22**D by the arrow **2724**).

[0530] (E11) In some embodiments of any of E1-E10, the performance of the adjustment in-air hand gesture of the first magnitude, the gating in-air hand gesture, the release of the gating in-air hand gesture, and the performance of the adjustment in-air hand gesture of the second magnitude are all detected using one or more sensors of a wrist-wearable device (e.g., the wrist-wearable device **120**) is in communication with the head-wearable device (e.g., the head-wearable device **202**). For example, an intermediary device (e.g., the HIPD **8000**) can be used to assist with processing the sensor signals (e.g., EMG signals) to help with detecting the gestures. As another example, data from the wrist-wearable device and/or an intermediary device can be communicated to the head-wearable device to allow it to make appropriate UI adjustments.

[0531] (E12) In some embodiments of E11, the one or more sensors of the wrist-wearable device include a plurality of neuromuscular-signal sensors (e.g., the sensors **6013** in FIG. **12**A).

[0532] (E13) In some embodiments of E11 or E12, the wrist-wearable device does not include a display (e.g., the wrist-wearable device **6000**). For example, the wrist-wearable device is used as a gesture-detection device for EMG and/or IMU (and/or other sensor signals) based gestures used with the head-wearable device, and the wrist-wearable device does not have its own display.

[0533] (E14) In some embodiments of any of E1-E13, the method further includes: (i) determining, based on one or more sensors the head-wearable device (e.g.,

gaze-tracking sensors and/or an IMU tracking head position), that a user's focus has shifted from the user interface object to a new user interface object presented via the head-wearable device; and (ii) while the user's focus remains on the new user interface object, performance of the gating in-air hand gesture that is maintained while the adjustment in-air hand gesture is performed causes an adjustment to the new user interface object and not to the user interface object.

[0534] (E15) In some embodiments of E14, the adjustment to the new user interface object is distinct from the adjusting the user interface object to have the first state. For example, different UI adjustments are available/activated for different types of UI elements (e.g., scrolling through menus as opposed to adjusting values for a slide bar).

[0535] (F1) In one aspect, some embodiments include a method of using a multi-stage in-air hand gesture for user-interface interactions. In some embodiments, the method is performed at a wearable device (e.g., the wrist-wearable device **120**) having memory (e.g., memory **6080**) and one or more processors (e.g., the processor(s) **6079**). In some embodiments, the method is performed at a computing system (e.g., composed of a plurality of devices, such as wearable devices and intermediary devices). The method includes: (i) receiving, via one or more sensors of a wrist-wearable device worn by a user, data generated from performance of a multi-stage in-air hand gesture by the user, (ii) in accordance with a determination that a first stage of the multi-stage in-air hand gesture is a priming gesture, identifying an initial position of a body part of the user, and (iii) in accordance with a determination that a second stage of the multi-stage in-air hand gesture is a navigation gesture, navigating through a user interface based on a change in position of the body part from the initial position during performance of the navigation gesture, wherein a navigation speed is based on the change in position of the body part. For example, in response to detecting a rotation of a wrist of the user **115** in a first direction (e.g., clockwise), the system causes a navigation toward the right (e.g., a focus moves to the right within the user interface and/or user interface elements move to the left). FIG. **25**B shows a clockwise wrist rotation gesture and a corresponding navigation to the right within the user interface **1220**. To continue the example, in response to detecting a rotation of a wrist of the user **115** in a second direction (e.g., counter-clockwise), the system causes a navigation toward the left (e.g., a focus moves to the left within the user interface and/or user interface elements move to the right). FIG. **25**H shows a counter-clockwise wrist rotation gesture and a corresponding navigation to the left within the user interface **1220**. In some embodiments, a speed of the navigation is based on a speed and/or distance of movement of the body part during performance of the navigation gesture (e.g., in accordance with the graphs shown in FIGS. **26**A-**26**C). For example, the navigation is based on a speed and/or amount of wrist rotation, lateral arm movement, and/or other body part movement.

[0536] (F2) In some embodiments of F1, the method further includes, in accordance with the determination that the first stage of the multi-stage in-air hand gesture is a priming gesture, displaying a plurality of selectable user interface elements within the user interface and/or providing feedback to the user indicating the user can perform additional gestures. In some embodiments, the priming gesture causes the user interface to become responsive to additional gestures from the user (e.g., while the priming gesture is maintained and/or for a set amount of time after the priming gesture is released).

[0537] (F3) In some embodiments of F1 or F2, navigating through the user interface based on the change in the position of the body part includes navigating in a first manner (e.g., navigating pages and/or chapters of a document). In some embodiments, the method further includes, in accordance with a determination that a third stage of the multi-stage in-air hand gesture is another navigation gesture, navigating through the user interface in a second manner (e.g., navigating sentences of a document) based on a change in position of the body part from the initial position during performance of the another navigation gesture. In some embodiments, the multi-stage in-air gesture includes a first navigation gesture (e.g., while maintaining the priming gesture) and a second navigation gesture (e.g., another type of navigation gesture) subsequent to the first navigation gesture (e.g., as described previously with respect to FIGS. **27**A-**27**D). For example, the user can perform a translation from one location to another to scroll through a plurality of user interface elements, stop the translation and then rotate their wrist to further scroll through the plurality of user interface elements.

[0538] (F4) In some embodiments of F3, the method further includes, in accordance with a determination that a fourth stage of the multi-stage in-air hand gesture is a control gesture, executing a command for the user interface that corresponds to the control gesture. In some embodiments, the control gesture causes activation of a function associated with the user interface element that has focus when the control gesture is detected.

[0539] (F5) In some embodiments of F3 or F4, the navigation gesture is distinct from the another navigation gesture. In some embodiments, the navigation gesture is a hand translation gesture (e.g., as described previously with respect to FIGS. **25**B-**25**H) and the another navigation gesture is a wrist rotation gesture (e.g., as described previously with respect to FIGS. **24**B-**24**E). In some embodiments, the navigation gesture and the another navigation gesture are a same type of navigation gesture (e.g., two instances of a rotational gesture or a translational gesture).

[0540] (F6) In some embodiments of any of F1-F5, the priming gesture is a maintained gesture and the method further includes: (i) in response to the priming gesture, activating a user interface and (ii) in accordance with a determination that a third stage of the multi-stage in-air hand gesture includes a release of the maintained gesture, deactivating the user interface. For example, the user interface is only activated while a priming gesture is maintained (and optionally a preset amount of time after it is released). In some embodiments, when the user releases the priming gesture (e.g., as described previously with respect to FIG. **24**D), the user interface is deactivated and the multi-stage in-air hand gesture is also ended (e.g., ending the navigation

gesture associated with the second stage of the multi-stage in-air hand gesture). In some embodiments, the release of a maintained gesture is interpreted by the system as a control gesture followed by an end of the multi-stage gesture.

[0541] (F7) In some embodiments of any of F1-F6, the method further includes: (i) receiving via the one or more sensors of the wrist-wearable device, data generated from performance of a second multi-stage in-air hand gesture, (ii) in accordance with a determination a first stage of the second multi-stage in-air hand gesture is another priming gesture, determining a second initial position of the body part of the user and activating the user interface, and (iii) in accordance with a determination that a second stage of the second multi-stage in-air hand gesture is another navigation gesture, navigating through the user interface based on a change in position of the body part from the second initial position during performance of the navigation gesture, where a navigation speed for the another navigation gesture is based on the change in position of the body part from the second initial position. In some embodiments, the priming gesture and the another priming gesture are instances of a same gesture (e.g., a pinch gesture). In some embodiments, the priming gesture and the another priming gesture are instances of different gestures (e.g., one is a pinch gesture and the other is a first clench gesture). In some embodiments, the navigation gesture and the another navigation gesture are instances of a same gesture (e.g., a wrist-roll gesture). In some embodiments the navigation gesture and the another navigation gesture are instances of different gestures (e.g., one is a wrist-roll gesture and the other is a hand-translation gesture, as described previously with respect to FIGS. **27**A-**27**D).

[0542] (F8) In some embodiments of any of F1-F7, the navigation gesture includes translation of a hand of the user from the initial position to a second position. For example, while the user is maintaining the priming gesture (e.g., a pinch-and-hold gesture) the user moves their hand across a plane to navigate through one or more user interface elements (e.g., as described previously with respect to FIGS. **24**C-**24**E). In some embodiments, the speed of navigation is based on the distance between the initial position and the second position.

[0543] (F9) In some embodiments of F8, a navigation speed through the user interface is proportional to a speed and/or distance in which the user translates their hand from the initial position to the second position. For example, the more quickly the user moves their hand, the faster the system navigates through user interface elements in the user interface (e.g., as described previously with respect to FIGS. **24**B-**24**E). For example, if the user is attempting to select a calendar date, the user can have precision selection abilities while moving their hand slowly. In this example, if they want to skip through multiple dates, they can move their hand more quickly to scroll through more dates while moving a same distance. For example, the farther the user slides their hand, a larger range of numbers is available, and the faster the user slides their hand for a similar distance, more numbers will be scrolled through.

[0544] (F10) In some embodiments of any of F1-F9, the navigation gesture includes a rotation of a wrist of the user in a first or second direction. For example, the user rotates their wrist to navigate through a plurality of user interface elements (e.g., as described previously with respect to FIGS. **25**A-**25**H).

[0545] (F11) In some embodiments of F10, the navigation speed is proportional to a rotation angle of the wrist of the user. For example, if the user rotates their wrist slightly, navigation through the user interface elements is slower (e.g., more controlled), and if the user rotates their wrist more dramatically, navigation through the user interface elements is faster (e.g., to move through the items more quickly).

[0546] (F12) In some embodiments of any of F1-F11, the navigation speed is based on a cubic function of the change in position of the body part. In some embodiments, different curves (e.g., linear (FIG. **26**A), step function (FIG. **26**B), and cubic (FIG. **26**C)) are used to determine how fast to navigate through user interface elements. In some embodiments, different curves are selected depending on the active application and/or what type of element has focus.

[0547] (F13) In some embodiments of any of F1-F11, the navigation speed is based on a step function of the change in position of the body part. For example, FIGS. **25**B-**25**H illustrate examples of navigating in accordance with a step function.

[0548] (F14) In some embodiments of any of F1-F11, the navigation speed is based on a linear function of the change in position of the body part. For example, FIGS. **24**B-**24**E illustrate examples of navigating in accordance with a linear function.

[0549] (F15) In some embodiments of any of F1-F14, navigating through the user interface includes, while detecting the navigation gesture: (i) forgoing navigating through the user interface in accordance with the change in position of the body part being less than a first threshold and (ii) navigating through the user interface in accordance with the change in position of the body part being greater than the first threshold. In some embodiments, the speed of navigation is zero below the first threshold (e.g., there is a deadzone as illustrated by the graph in FIG. **25**B). In some embodiments, the speed of navigation is proportional to the change in position of the body part while beyond the first threshold (e.g., as illustrated in FIGS. **27**B-**12**E). In some embodiments, the speed is based on a step function, a linear function, a cubic function, and/or another function while the change in position is beyond the first threshold.

[0550] (F16) In some embodiments of F15, navigating through the user interface further includes: (i) in accordance with a determination that the change in position of the body part is greater than the first threshold and less than a second threshold, navigating through the user interface at a first speed, and (ii) in accordance with a determination that the change in position of the body part is greater than the second threshold, navigating through the user interface at a second speed greater than the first speed. For example, when a user rotates their wrist past the initial position, the user navigates through the user interface at a first speed (e.g., as illustrated in FIG. **25**D). For example, the first

speed slowly and individually scrolls through numbers at a pace so that the user has very fine control over which number they intend to select. To continue the example, when the user rotates their wrist past a first threshold, the user navigates through the user interface at a second speed, distinct from the first speed. For example, in a scenario where a user is rotating through several numbers and wants to skip from **1** to **20**, they can scroll through at a greater speed in order to skip additional numbers.

[0551] In some embodiments, a dead zone is defined between the initial position and the first threshold. For example, in the dead zone the user can rotate their wrist without navigating in the user interface. In some embodiments, once the user rotates their wrist past the first threshold (the dead zone) the user navigates through the user interface on a cubic scale (e.g., as illustrated by FIG. **26**C).

[0552] (F17) In some embodiments of any of F1-F16, the method further includes, in accordance with a determination that the second stage of the multi-stage in-air hand gesture is the navigation gesture, causing display of a navigation indicator (e.g., user interface element **1326**) in the user interface, where the navigation indicator indicates the navigation speed. For example, a navigation indicator provides the user with information about a navigation speed, a rotation angle, a navigation distance, and/or a navigation direction. For example, when the user rotates their wrist past an initial position after performing a priming gesture, an indicator indicating how far the user has rotated their wrist in reference to the initial position is displayed. Therefore, as the user rotates their wrist to navigate through user interface items, the user has a visual cue as to how they are currently navigating. The navigation indicator can improve clarity and efficiency by helping to ensure that users understand how their gestures affects the user interface.

[0553] (F18) In some embodiments of any of F1-F17, the method further includes, in accordance with a determination that the change in position of the body part meets one or more criteria, ceasing to increase the navigation speed and providing feedback (e.g., the user interface element **1332**) to the user indicating that the navigation speed is at an upper limit. In some embodiments, feedback is provided to the user via the user interface (e.g., as an indicator and/or icon). In some embodiments, the feedback is provided to the user via haptic feedback (e.g., at the wrist-wearable device and/or the head-wearable device). In some embodiments, providing feedback includes providing audio feedback, haptic feedback, and/or visual feedback. Providing feedback that the navigation speed is at an upper limit notifies the user that they can stop moving the body part as further movement would not increase speed. As an example, as a user is navigating through user interface items, once the change in position of the body part meets the one or more criteria (e.g., a maximum distance threshold), the navigation speed is capped, and the corresponding navigation is at the maximum speed. For example, if the user continues to move the body part past the distance threshold, the speed is maintained at the maximum navigation speed. In some embodiments, the maximum speed is independent of the direction of navigation. For example, the maximum speed when navigating in a first direction (e.g., scrolling right) is the same as the maximum speed when navigating in a second direction (e.g., scrolling left).

[0554] (F19) In some embodiments of any of F1-F18, the priming gesture is a maintained gesture performed by at least two phalanges of the user. In some embodiments, the priming gesture is a maintained pinch gesture performed by the user. For example, the user interface is activated while the priming gesture is being maintained and deactivated when the priming gesture is released.

[0555] (F20) In some embodiments of any of F1-F18, the method further includes, in accordance with a determination that the first stage of the multi-stage in-air hand gesture is the priming gesture, starting a predetermined window of time (e.g., 1 second, 2 seconds, 5 seconds, or 10 seconds) for detecting one or more subsequent multi-stage gestures. For example, the system is responsive to subsequent navigation/control gestures detected within the predetermined window of time, but is not responsive to subsequent navigation/control gestures performed after the predetermined window of time has elapsed (unless proceeded by a separate priming gesture). In some embodiments, the priming gesture is not maintained, but rather starts a predefined window for detecting subsequent multi-stage in-air gestures.

[0556] In some embodiments, one or more of the gestures described above (e.g., with respect to D1-D22, E1-E15, and F1-F20) are detected with an optical sensor (e.g., a camera) or sensors associated with an inertial measurement unit (IMU) rather than (or in addition to, via fusing the sensor inputs to detect the various in-air hand gestures described herein) the one or more neuromuscular-signal sensors. In some embodiments, the one or more gestures described above (e.g., with respect to D1-D22, E1-E15, and F1-F20) are replaced with gestures performed by other parts of the user's body (e.g., head gestures, leg gestures, or torso gestures). As one example, an in-air priming gesture can be detected using one or more of neuromuscular-signal sensors, data from an IMU, and cameras; as another example, a control gesture can be a shaking of the user's head (as if the user is indicating "No") or a nodding of the user's head (as if the user is indicating "Yes").

[0557] In some embodiments, the wearable device detects neuromuscular signals travelling through the user's neck or back, which can be done using neuromuscular-signal sensors coupled with the VR goggles or the AR glasses in some example embodiments. In some embodiments, the one or more gestures described above (e.g., with respect to D1-D22, E1-E15, F1-F20) are replaced with (or performed using) in-air hand gestures on a controller (e.g., a handheld controller or foot pedal controller). In some embodiments, the one or more in-air hand gestures described above (e.g., with respect to D1-D22, E1-E15, F1-F20) are replaced with audio commands (e.g., spoken word commands or non-word commands such as a tongue click).

[0558] In another aspect, some embodiments include a computing system including one or more processors and memory coupled to the one or more processors, the memory storing one or more programs configured to be executed by the one or more processors, the one or more programs including instructions for performing any of the methods

described herein (e.g., methods **2800**, **2850**, **1600** and D1-D22, E1-E15, F1-F20 above).

[0559] In yet another aspect, some embodiments include a non-transitory computer-readable storage medium storing one or more programs for execution by one or more processors of a computing system, the one or more programs including instructions for performing any of the methods described herein (e.g., methods **2800**, **2850**, **1600** and D1-D22, E1-E15, F1-F20 above).

[0560] It will be understood that, although the terms "first," "second," etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another.

[0561] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the claims. As used in the description of the embodiments and the appended claims, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will also be understood that the term "and/or" as used herein refers to and encompasses any and all possible combinations of one or more of the associated listed items. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0562] As used herein, the term "if" can be construed to mean "when" or "upon" or "in response to determining" or "in accordance with a determination" or "in response to detecting," that a stated condition precedent is true, depending on the context. Similarly, the phrase "if it is determined [that a stated condition precedent is true]" or "if [a stated condition precedent is true]" or "when [a stated condition precedent is true]" can be construed to mean "upon determining" or "in response to determining" or "in accordance with a determination" or "upon detecting" or "in response to detecting" that the stated condition precedent is true, depending on the context.

[0563] The foregoing description, for purpose of explanation, has been described with reference to specific embodiments. However, the illustrative discussions above are not intended to be exhaustive or to limit the claims to the precise forms disclosed. Many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain principles of operation and practical applications, to thereby enable others skilled in the art.

What is claimed is:

1. A method comprising:

causing display, at a display of a pair of smart glasses, of a user interface for an application;

receiving, from one or more sensors of a wrist-wearable device worn by a user of the pair of smart glasses, data generated from performance of a multi-stage in-air hand gesture;

in response to receiving the data and in accordance with a determination that a first stage of the multi-stage in-air hand gesture is a pinch gesture in which a thumb and index finger of the user maintain contact for a threshold amount of time:

in accordance with a determination that a second stage of the multi-stage in-air hand gesture is a wrist-rotation gesture in a first rotational direction while the pinch gesture is maintained, increasing a volume for speaker output at the pair of smart glasses;

receiving, from the one or more sensors of the wrist-wearable device worn by the user of the pair of smart glasses, additional data generated from performance of an additional pinch gesture in which the thumb and index finger of the user maintain contact for less than the threshold amount of time; and

in response to receiving the additional data generated from performance of the additional pinch gesture, causing performance of an operation at the user interface for the application while maintaining the increased volume for speaker output at the pair of smart glasses.

2. The method of claim **1**, further comprising:

receiving, from one or more sensors of the wrist-wearable device worn by the user of the pair of smart glasses, data generated from performance of another multi-stage in-air hand gesture;

in response to receiving the data and in accordance with a determination that a first stage of the other multi-stage in-air hand gesture is a third pinch gesture in which a thumb and index finger of the user maintain contact for the threshold amount of time:

in accordance with a determination that a second stage of the other multi-stage in-air hand gesture is a wrist-rotation gesture in a second rotational direction while the third pinch gesture is maintained, wherein the second rotational direction is an opposite direction from the first rotational direction, decreasing the volume for speaker output at the pair of smart glasses.

3. The method of claim **1**, further comprising:

receiving, from one or more sensors of the wrist-wearable device worn by the user of the pair of smart glasses, data generated from performance of another multi-stage in-air hand gesture;

in response to receiving the data and in accordance with a determination that a first stage of the other multi-stage in-air hand gesture is a third pinch gesture in which a thumb and index finger of the user maintain contact for the threshold amount of time:

in accordance with a determination that a wrist-rotation gesture is not detected while the thumb and index finger of the user maintain contact for a second threshold amount of time, forgoing any adjustments to the volume for speaker output at the pair of smart glasses.

4. The method of claim **1**, further comprising:

while the display of the pair of smart glasses is in a sleep state:

receiving, from one or more sensors of the wrist-wearable device worn by the user of the pair of smart glasses, data generated from performance of a gesture in which a middle finger of the user twice touches the thumb of the user within a threshold amount of time; and

in response to receiving the data generated from performance of the gesture in which the middle finger of the user twice touches the thumb of the user within the threshold amount of time, causing the display of the pair of smart glasses to exit the sleep state.

5. The method of claim **1**, further comprising:

in accordance with a determination that the user performs a third pinch gesture in which a thumb of the user and a middle finger of the user maintain contact for a second threshold amount of time:

ceasing to display the user interface for the application on the display of the pair of smart glasses; and

causing presentation of a home screen user interface for the pair of smart glasses.

6. The method of claim **5**, further comprising:

in accordance with a determination that the user performs a fourth pinch gesture in which the thumb of the user and the middle finger of the user make contact for less than the second threshold amount of time:

ceasing to cause presentation of the home screen user interface for the pair of smart glasses; and

causing display of the user interface for the application on the display of the pair of smart glasses.

7. The method of claim **1**, wherein increasing the volume for speaker output at the pair of smart glasses is performed in accordance with an additional determination that an audio output is being provided at the pair of smart glasses when the multi-stage in-air hand gesture is performed.

8. The method of claim **1**, wherein the user interface for the application does not include image data, and the method further comprises:

while a representation of image data from a camera of the pair of smart glasses is displayed via the display:

receiving, from one or more sensors of a wrist-wearable device worn by the user of the pair of smart glasses, data generated from performance of another multi-stage in-air hand gesture;

in response to receiving the data and in accordance with a determination that a first stage of the other multi-stage in-air hand gesture is a third pinch gesture in which a thumb and index finger of the user maintain contact for the threshold amount of time, activating a zoom interface associated with the image data; and

in accordance with a determination that a second stage of the other multi-stage in-air hand gesture is a wrist-rotation gesture in a first rotational direction while the third pinch gesture is maintained, adjusting the zoom interface to reflect an increased zoom level for the image data.

9. The method of claim **1**, further comprising:

while a plurality of selectable user interface elements is being displayed on the display of the pair of smart glasses:

receiving, from the wrist-wearable device, data generated from performance of another multi-stage in-air hand gesture;

in response to receiving the data and in accordance with a determination that a first stage of the other multi-stage in-air hand gesture is a thumb swipe gesture in which a thumb of the user moves in a direction across a part of the index finger of the user, scrolling through the plurality of selectable user interface elements in a scroll direction that corresponds to the direction in which the thumb of the user moves; and

in accordance with a determination that a second stage of the other multi-stage in-air hand gesture is a press gesture in which the thumb of the user presses against the index finger of the user for less than a second threshold amount of time:

selecting a selectable user interface element from among the plurality of selectable user interface elements.

10. A non-transitory, computer-readable storage medium storing instructions that, when executed by one or more processors, cause the one or more processors to:

cause display, at a display of a pair of smart glasses, of a user interface for an application;

receive, from one or more sensors of a wrist-wearable device worn by a user of the pair of smart glasses, data generated from performance of a multi-stage in-air hand gesture;

in response to receiving the data and in accordance with a determination that a first stage of the multi-stage in-air hand gesture is a pinch gesture in which a thumb and index finger of the user maintain contact for a threshold amount of time:

in accordance with a determination that a second stage of the multi-stage in-air hand gesture is a wrist-rotation gesture in a first rotational direction while the pinch gesture is maintained, increase a volume for speaker output at the pair of smart glasses;

receive, from the one or more sensors of the wrist-wearable device worn by the user of the pair of smart glasses, additional data generated from performance of an additional pinch gesture in which the thumb and index finger of the user maintain contact for less than the threshold amount of time; and

in response to receiving the additional data generated from performance of the additional pinch gesture, cause performance of an operation at the user interface for the application while maintaining the increased volume for speaker output at the pair of smart glasses.

11. The non-transitory, computer-readable storage medium of claim **10**, wherein the instructions further cause the one or more processors to:

receive, from one or more sensors of the wrist-wearable device worn by the user of the pair of smart glasses, data generated from performance of another multi-stage in-air hand gesture;

in response to receiving the data and in accordance with a determination that a first stage of the other multi-stage in-air hand gesture is a third pinch gesture in which a thumb and index finger of the user maintain contact for the threshold amount of time:

in accordance with a determination that a second stage of the other multi-stage in-air hand gesture is a wrist-rotation gesture in a second rotational direction while the third pinch gesture is maintained, wherein the second rotational direction is an opposite direction from the first rotational direction, decrease the volume for speaker output at the pair of smart glasses.

12. The non-transitory, computer-readable storage medium of claim **10**, wherein the instructions further cause the one or more processors to:

receive, from one or more sensors of the wrist-wearable device worn by the user of the pair of smart glasses, data generated from performance of another multi-stage in-air hand gesture;

in response to receiving the data and in accordance with a determination that a first stage of the other multi-stage in-air hand gesture is a third pinch gesture in which a

thumb and index finger of the user maintain contact for the threshold amount of time:

in accordance with a determination that a wrist-rotation gesture is not detected while the thumb and index finger of the user maintain contact for a second threshold amount of time, forgo any adjustments to the volume for speaker output at the pair of smart glasses.

13. The non-transitory, computer-readable storage medium of claim **10**, wherein the instructions further cause the one or more processors to:

while the display of the pair of smart glasses is in a sleep state:

receive, from one or more sensors of the wrist-wearable device worn by the user of the pair of smart glasses, data generated from performance of a gesture in which a middle finger of the user twice touches the thumb of the user within a threshold amount of time; and

in response to receiving the data generated from performance of the gesture in which the middle finger of the user twice touches the thumb of the user within the threshold amount of time, cause the display of the pair of smart glasses to exit the sleep state.

14. The non-transitory, computer-readable storage medium of claim **10**, wherein the instructions further cause the one or more processors to:

in accordance with a determination that the user performs a third pinch gesture in which a thumb of the user and a middle finger of the user maintain contact for a second threshold amount of time:

cease to display the user interface for the application on the display of the pair of smart glasses; and

cause presentation of a home screen user interface for the pair of smart glasses.

15. The non-transitory, computer-readable storage medium of claim **14**, wherein the instructions further cause the one or more processors to:

in accordance with a determination that the user performs a fourth pinch gesture in which the thumb of the user and the middle finger of the user make contact for less than the second threshold amount of time:

cease to cause presentation of the home screen user interface for the pair of smart glasses; and

cause display of the user interface for the application on the display of the pair of smart glasses.

16. The non-transitory, computer-readable storage medium of claim **15**, wherein increasing the volume for speaker output at the pair of smart glasses is performed in accordance with an additional determination that an audio output is being provided at the pair of smart glasses when the multi-stage in-air hand gesture is performed.

17. The non-transitory, computer-readable storage medium of claim **14**, wherein the instructions further cause the one or more processors to:

while a representation of image data from a camera of the pair of smart glasses is displayed via the display:

receive, from one or more sensors of a wrist-wearable device worn by the user of the pair of smart glasses, data generated from performance of another multi-stage in-air hand gesture;

in response to receiving the data and in accordance with a determination that a first stage of the other multi-stage in-air hand gesture is a third pinch gesture in which a thumb and index finger of the user maintain contact for the threshold amount of time, activate a zoom interface associated with the image data; and

in accordance with a determination that a second stage of the other multi-stage in-air hand gesture is a wrist-rotation gesture in a first rotational direction while the third pinch gesture is maintained, adjust the zoom interface to reflect an increased zoom level for the image data.

18. The non-transitory, computer-readable storage medium of claim **10**, wherein the instructions further cause the one or more processors to:

while a plurality of selectable user interface elements is being displayed on the display of the pair of smart glasses:

receive, from the wrist-wearable device, data generated from performance of another multi-stage in-air hand gesture;

in response to receiving the data and in accordance with a determination that a first stage of the other multi-stage in-air hand gesture is a thumb swipe gesture in which a thumb of the user moves in a direction across a part of the index finger of the user, scroll through the plurality of selectable user interface elements in a scroll direction that corresponds to the direction in which the thumb of the user moves; and

in accordance with a determination that a second stage of the multi-stage in-air hand gesture is a press gesture in which the thumb of the user presses against the index finger of the user for less than a second threshold amount of time:

select a selectable user interface element from among the plurality of selectable user interface elements.

19. A pair of smart glasses, comprising:

a display;

one or more processors for:

causing display, at the display of the pair of smart glasses, of a user interface for an application;

receiving, from one or more sensors of a wrist-wearable device worn by a user of the pair of smart glasses, data generated from performance of a multi-stage in-air hand gesture;

in response to receiving the data and in accordance with a determination that a first stage of the multi-stage in-air hand gesture is a pinch gesture in which a thumb and index finger of the user maintain contact for a threshold amount of time:

in accordance with a determination that a second stage of the multi-stage in-air hand gesture is a wrist-rotation gesture in a first rotational direction while the pinch gesture is maintained, increasing a volume for speaker output at the pair of smart glasses;

receiving, from the one or more sensors of the wrist-wearable device worn by the user of the pair of smart glasses, additional data generated from performance of an additional pinch gesture in which the thumb and index finger of the user maintain contact for less than the threshold amount of time; and

in response to receiving the additional data generated from performance of the additional pinch gesture, causing performance of an operation at the user interface for

the application while maintaining the increased volume for speaker output at the pair of smart glasses.

20. The smart glasses of claim **19**, wherein the one or more processors are further for:

receiving, from one or more sensors of the wrist-wearable device worn by the user of the pair of smart glasses, data generated from performance of another multi-stage in-air hand gesture;

in response to receiving the data and in accordance with a determination that a first stage of the other multi-stage in-air hand gesture is a third pinch gesture in which a thumb and index finger of the user maintain contact for the threshold amount of time:

in accordance with a determination that a second stage of the other multi-stage in-air hand gesture is a wrist-rotation gesture in a second rotational direction while the third pinch gesture is maintained, wherein the second rotational direction is an opposite direction from the first rotational direction, decreasing the volume for speaker output at the pair of smart glasses.

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