US009710144B2

(12) **United States Patent**
Jubner et al.

(10) **Patent No.: US 9,710,144 B2**
(45) **Date of Patent: *Jul. 18, 2017**

(54) **USER INTERFACE FOR CURVED INPUT DEVICE**

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(72) Inventors: **Alexander Jubner**, Stockholm (SE); **Thomas Eriksson**, Stockholm (SE); **Gunnar Martin Fröjdh**, Dalarö (SE); **Simon Fellin**, Sigtuna (SE); **Stefan Holmgren**, Sollentuna (SE)

(73) Assignee: **Neonode Inc.**, San Jose, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/805,445**

(22) Filed: **Jul. 21, 2015**

(65) **Prior Publication Data**

US 2015/0324111 A1 Nov. 12, 2015

Related U.S. Application Data

(63) Continuation of application No. 14/590,010, filed on Jan. 6, 2015, now Pat. No. 9,092,093, which is a (Continued)

(51) **Int. Cl.**

G06F 7/00	(2006.01)
G06F 3/0484	(2013.01)
G06F 3/042	(2006.01)
G06F 3/01	(2006.01)
G06F 3/041	(2006.01)
G06F 3/0488	(2013.01)
B62D 1/04	(2006.01)
B60K 37/06	(2006.01)
G06F 3/033	(2013.01)
G06F 3/0487	(2013.01)

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

CPC .... ***G06F 3/04847*** (2013.01); ***B60K 37/06*** (2013.01); ***B62D 1/04*** (2013.01); (Continued)

(58) **Field of Classification Search**

CPC ...... B60K 2350/928; B60K 2350/1012; B60K 2350/1036; B60K 37/06; B62D 1/046 (Continued)

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Primary Examiner — Gertrude Arthur Jeanglaud
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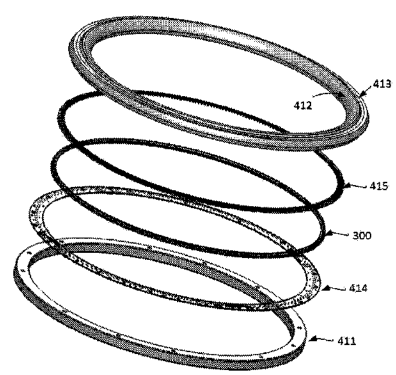
(57) **ABSTRACT**

A computer readable medium storing instructions which cause a processor to generate data structures for an object moving along the perimeter of a curved touch-sensitive user input device, each data structure corresponding to a gesture and including a time stamp, polar angles at which the object starts and ends, a middle polar angle of the object, and an assigned state being one of the group RECOGNIZED, UPDATED and ENDED, wherein the instructions cause the processor to assign the RECOGNIZED state to the data structure when the moving object is initially detected on the perimeter of the device, to assign the UPDATED state to the data structure when the moving object is further detected on the perimeter of the device after the initial detection, and to assign the ENDED state to the data structure when the moving object ceases to be detected on the perimeter of the device.

15 Claims, 19 Drawing Sheets



Related U.S. Application Data

continuation-in-part of application No. 14/551,096, filed on Nov. 24, 2014, now Pat. No. 9,389,710, and a continuation-in-part of application No. 14/555,731, filed on Nov. 28, 2014, said application No. 14/551, 096 is a continuation of application No. 14/312,711, filed on Jun. 24, 2014, now Pat. No. 8,918,252, which is a continuation of application No. 14/088,458, filed on Nov. 25, 2013, now Pat. No. 8,775,023, said application No. 14/455,731 is a continuation-in-part of application No. 14/312,787, filed on Jun. 24, 2014, now Pat. No. 9,164,625, and a continuation-in-part of application No. 14/311,366, filed on Jun. 23, 2014, now Pat. No. 9,063,614, and a continuation-in-part of application No. 14/140,635, filed on Dec. 26, 2013, now Pat. No. 9,001,087, said application No. 14/312, 787 is a continuation of application No. PCT/US2014/040112, filed on May 30, 2014, said application No. 14/311,366 is a continuation of application No. PCT/US2014/040579, filed on Jun. 3, 2014.

(60) Provisional application No. 61/730,139, filed on Nov. 27, 2012, provisional application No. 61/828,713, filed on May 30, 2013, provisional application No. 61/838,296, filed on Jun. 23, 2013, provisional application No. 61/846,089, filed on Jul. 15, 2013, provisional application No. 61/929,992, filed on Jan. 22, 2014, provisional application No. 61/972,435, filed on Mar. 31, 2014, provisional application No. 61/986,341, filed on Apr. 30, 2014, provisional application No. 61/830,671, filed on Jun. 4, 2013, provisional application No. 61/833,161, filed on Jun. 10, 2013, provisional application No. 61/911,915, filed on Dec. 4, 2013, provisional application No. 61/919,759, filed on Dec. 22, 2013, provisional application No. 61/923,775, filed on Jan. 6, 2014, provisional application No. 61/950,868, filed on Mar. 11, 2014.

(52) **U.S. Cl.**
CPC ***B62D 1/046*** (2013.01); ***G06F 3/017*** (2013.01); ***G06F 3/0416*** (2013.01); ***G06F 3/0421*** (2013.01); ***G06F 3/0488*** (2013.01); ***G06F 3/04842*** (2013.01); *B60K 2350/1012* (2013.01); *B60K 2350/1036* (2013.01); *B60K 2350/928* (2013.01); *G06F 3/033* (2013.01); *G06F 3/0487* (2013.01); *G06F 2203/0339* (2013.01); *H04M 2250/22* (2013.01)

(58) **Field of Classification Search**
USPC 701/36, 41, 418; 345/175
See application file for complete search history.

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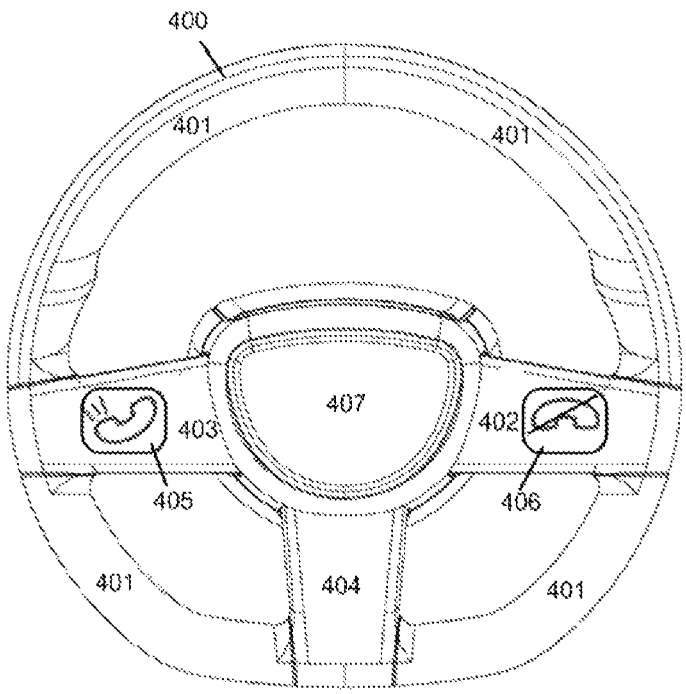

FIG. 1
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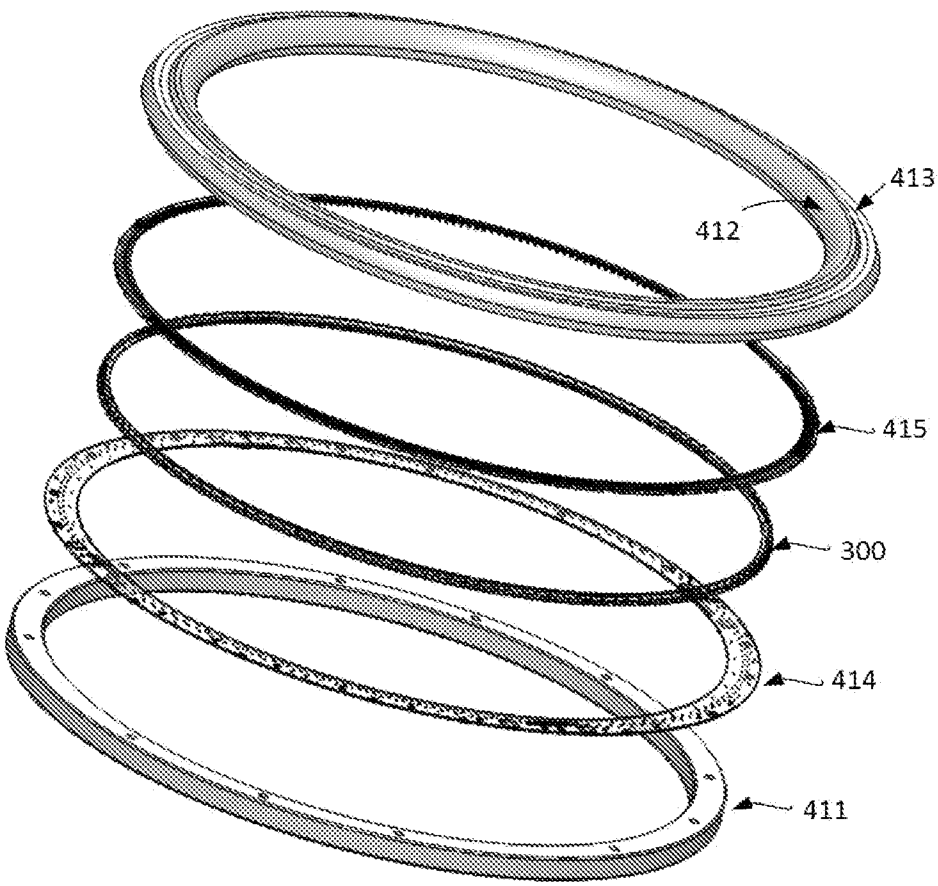


FIG. 2

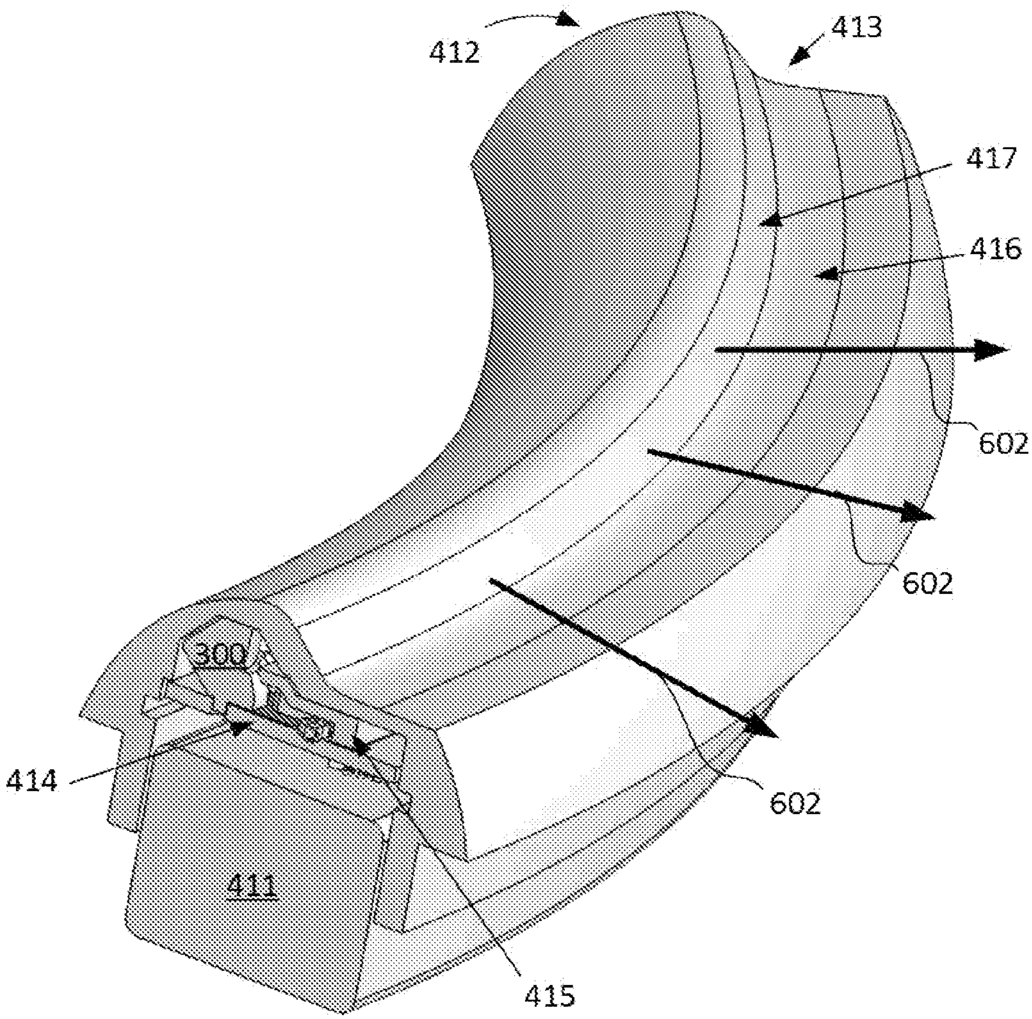


FIG. 3

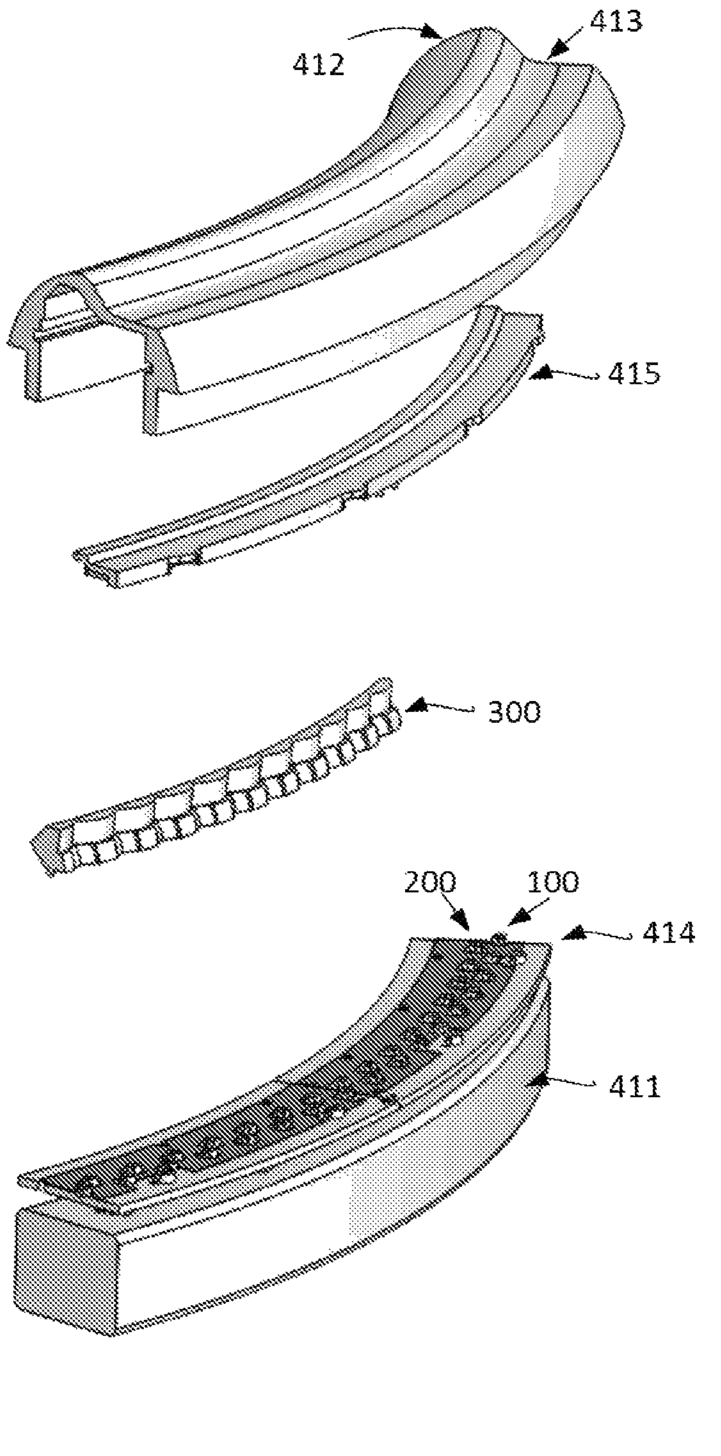


FIG. 4

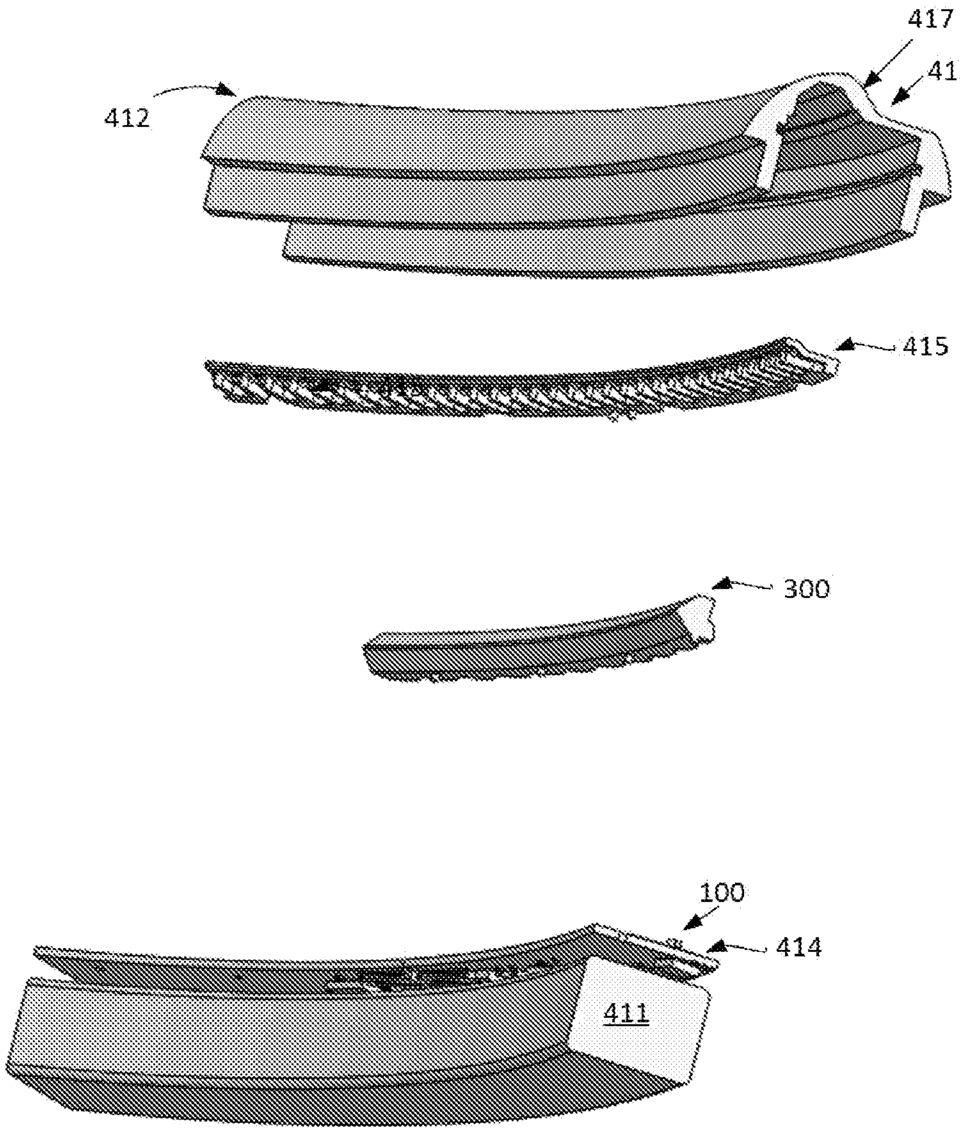


FIG. 5

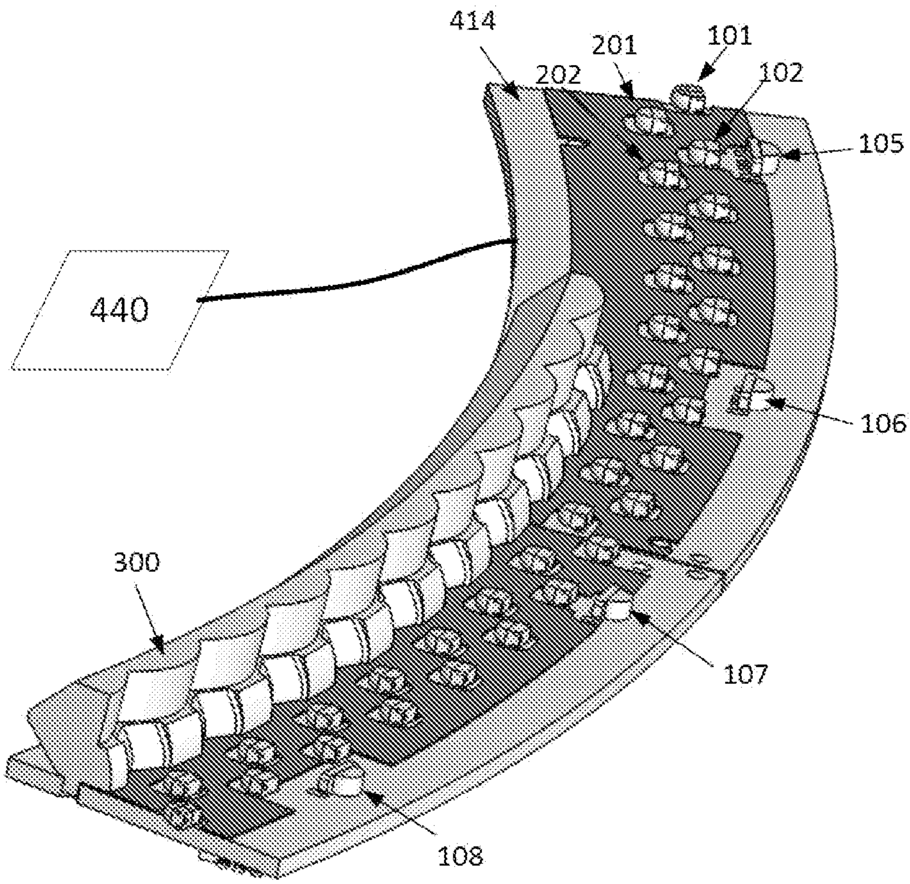


FIG. 6

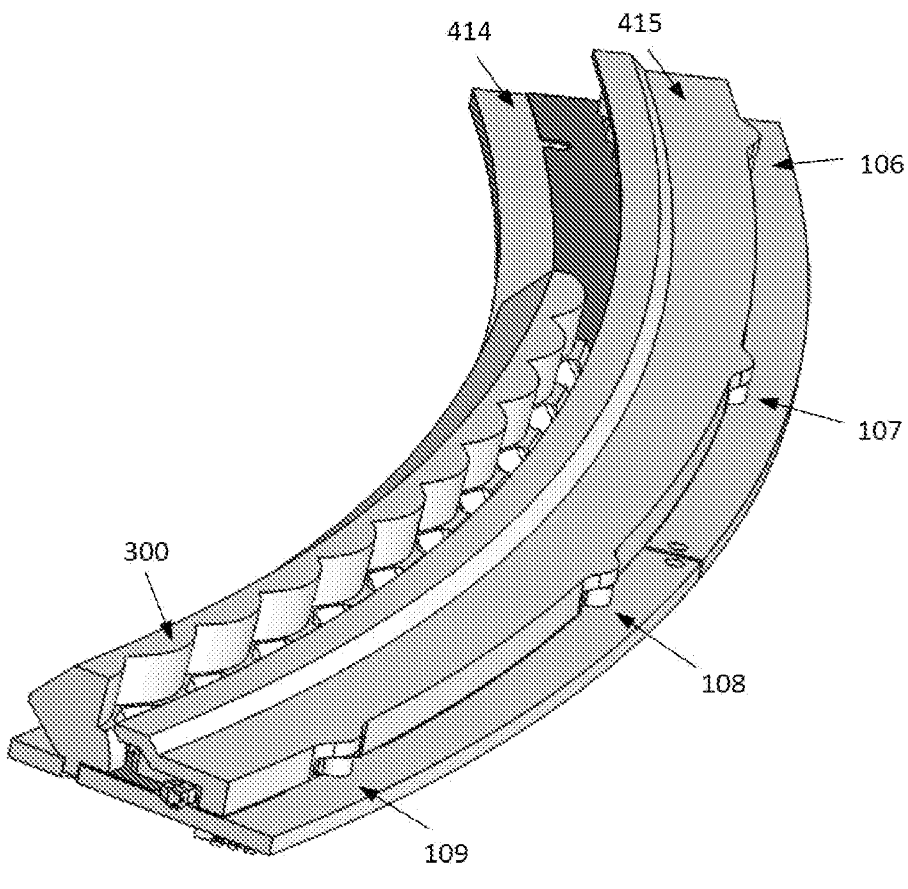


FIG. 7

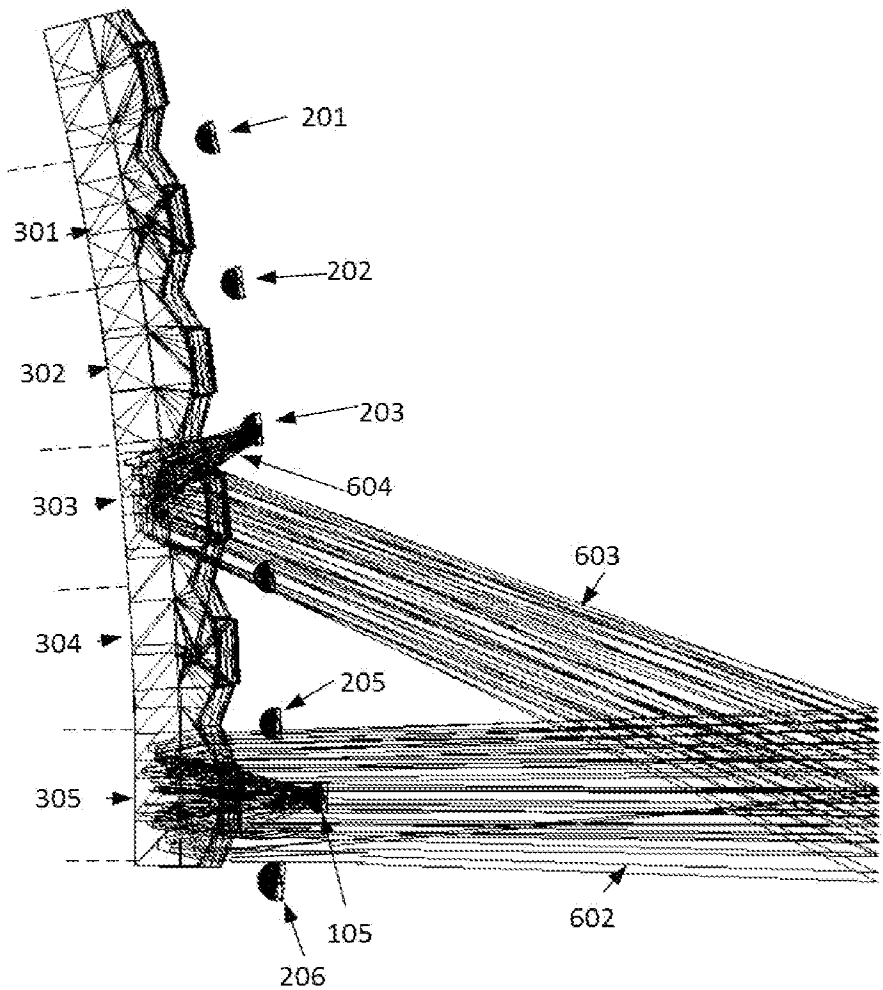


FIG. 8

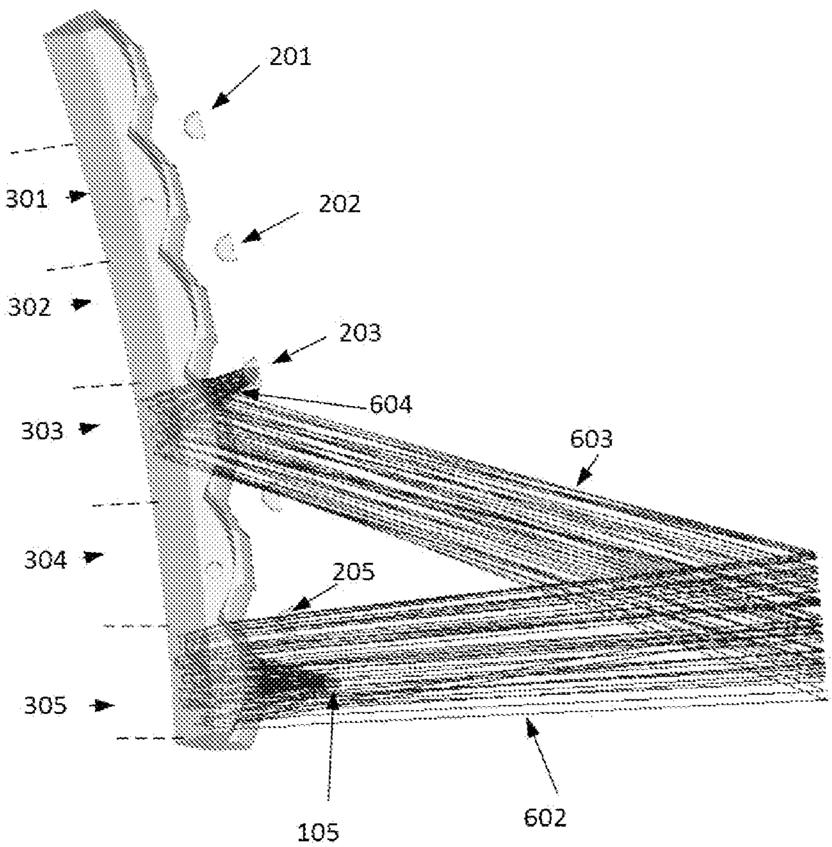


FIG. 9

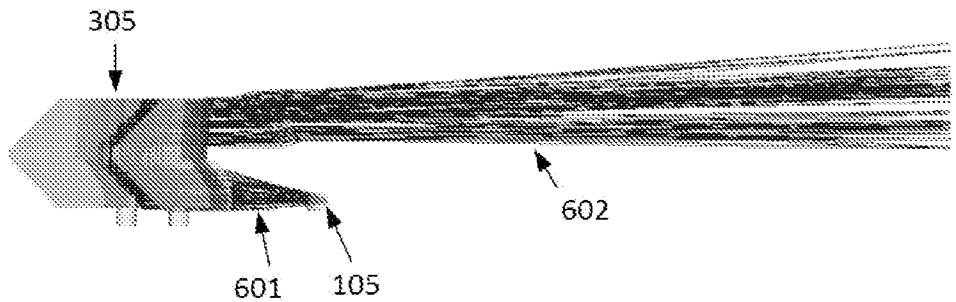


FIG. 10

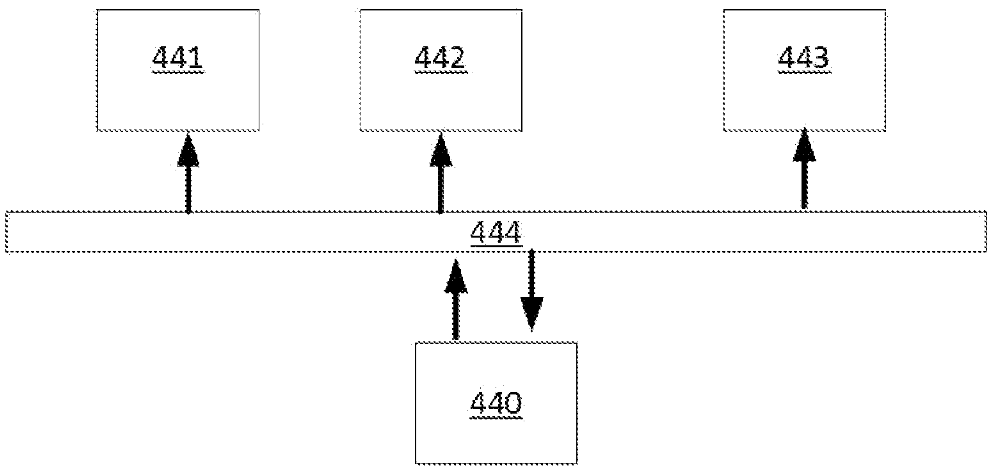
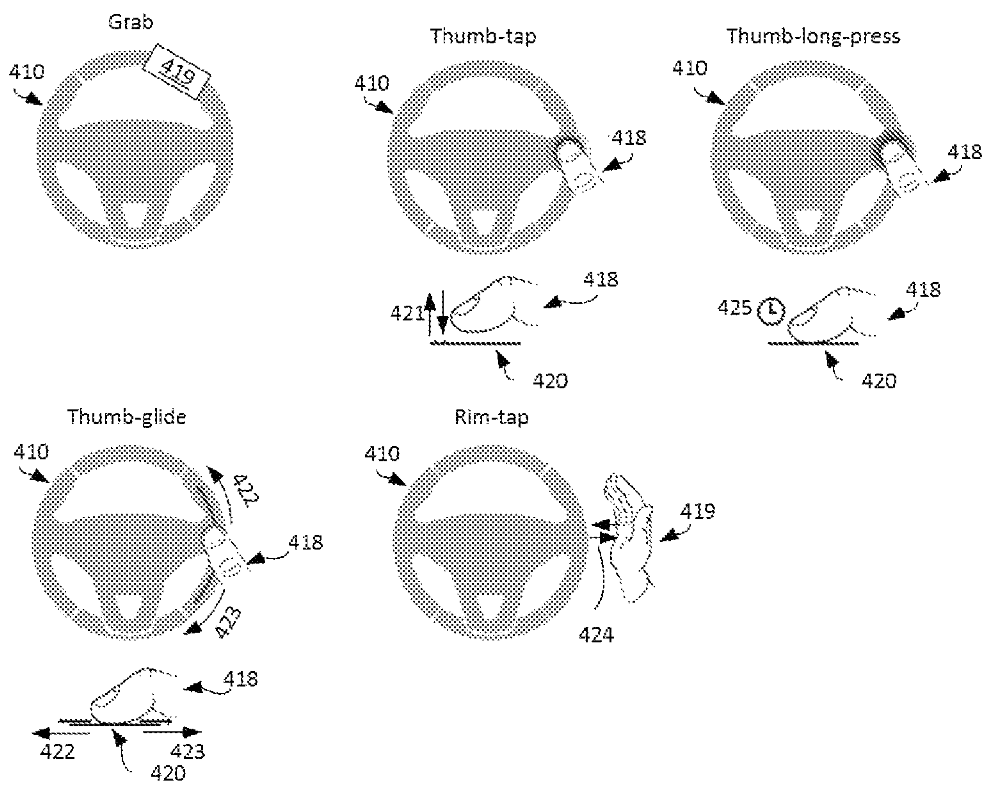


FIG. 11



Grab
410
419
Thumb-tap
410
418
421
418
420
Thumb-long-press
410
418
425
418
420
Thumb-glide
410
422
418
423
418
422
423
420
Rim-tap
410
419
424

FIG. 12

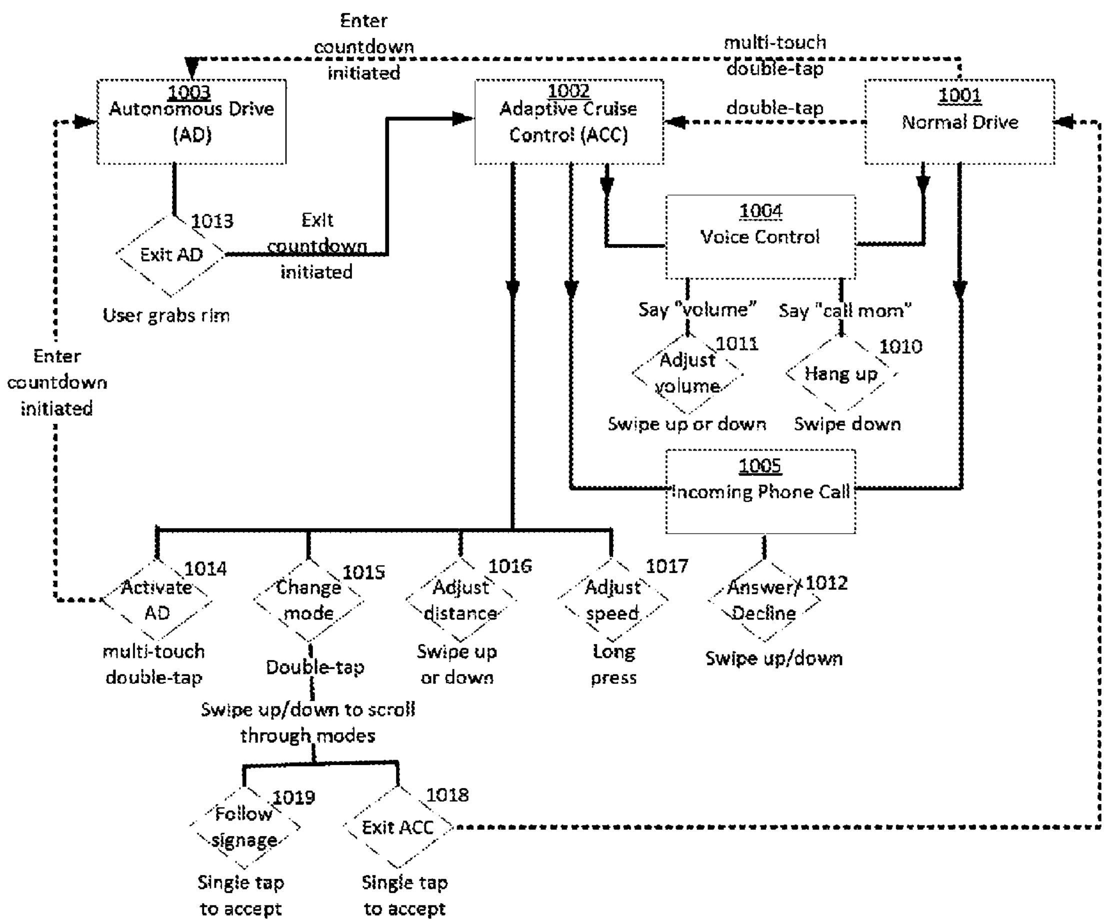

Enter
countdown
initiated
multi-touch
double-tap
1003
Autonomous Drive
(AD)
1002
Adaptive Cruise
Control (ACC)
double-tap
1001
Normal Drive
1013
Exit AD
User grabs rim
Exit
countdown
initiated
1004
Voice Control
Say "volume"
Say "call mom"
Adjust
volume
1011
Hang up
1010
Swipe up or down
Swipe down
Enter
countdown
initiated
1005
Incoming Phone Call
Activate
AD
1014
multi-touch
double-tap
Change
mode
1015
Double-tap
Swipe up/down to scroll
through modes
Adjust
distance
1016
Swipe up
or down
Adjust
speed
1017
Long
press
Answer/
Decline
1012
Swipe up/down
Follow
signage
1019
Single tap
to accept
Exit ACC
1018
Single tap
to accept

FIG. 13

Adaptive Cruise Control User Interface

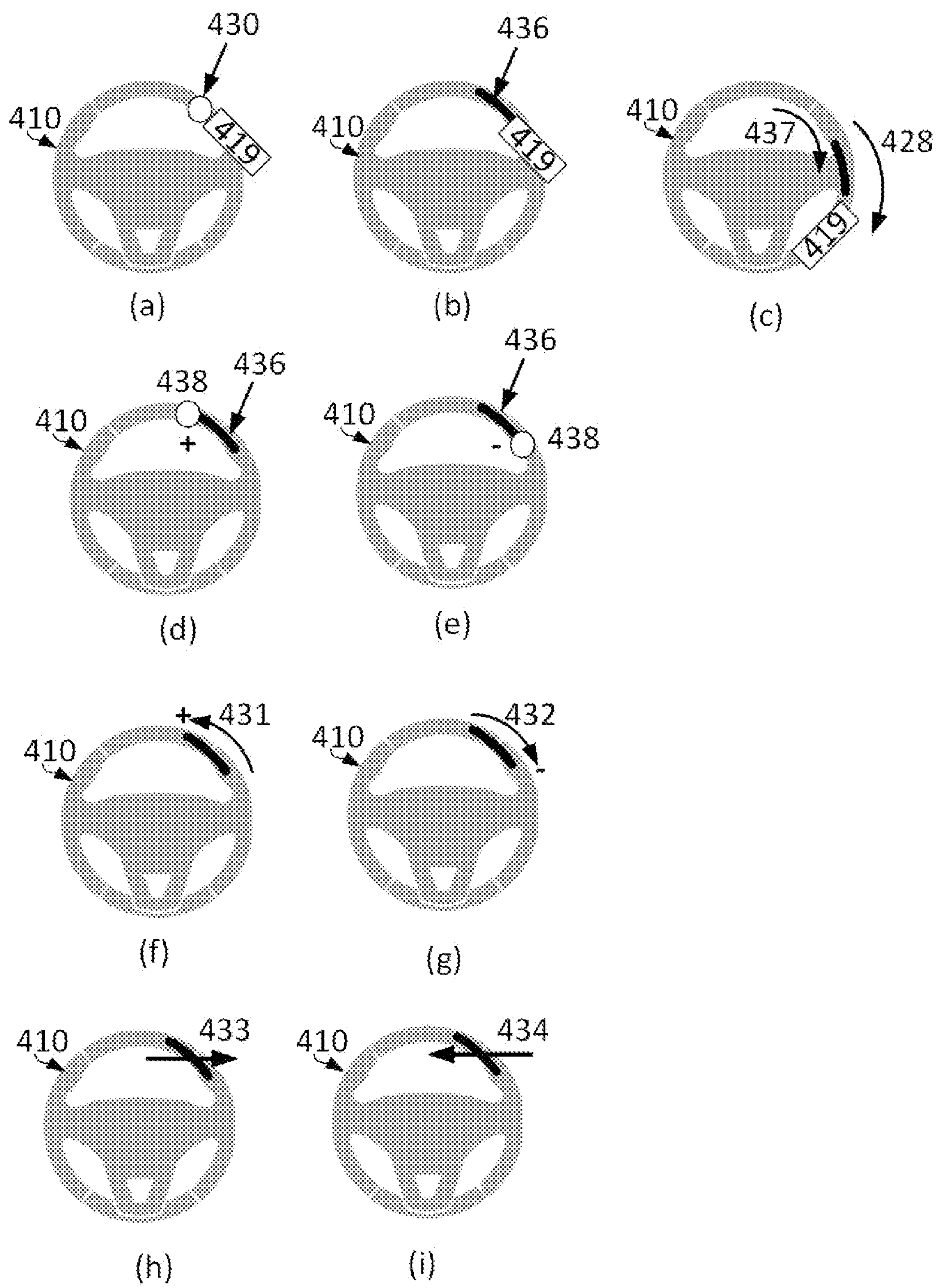
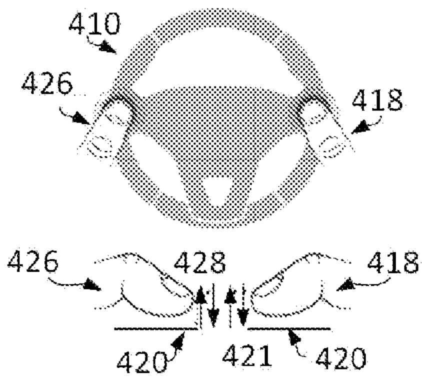
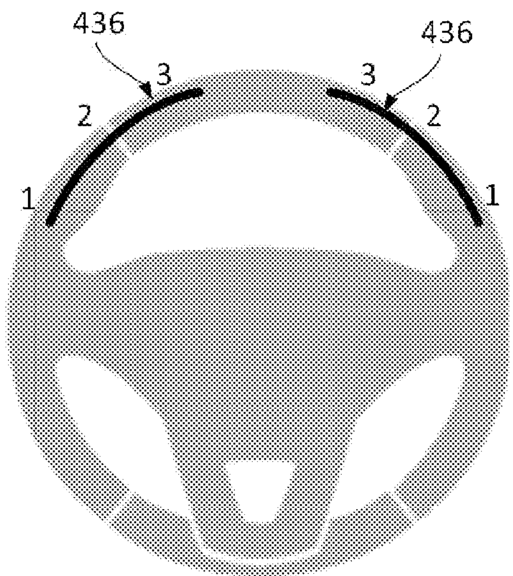


FIG. 14

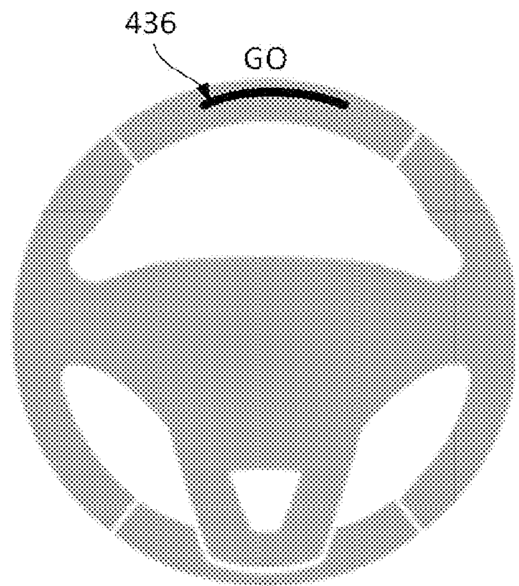
Autonomous Drive User Interface

(a)





(b)



(c)

FIG. 15

Exit Autonomous Drive Mode

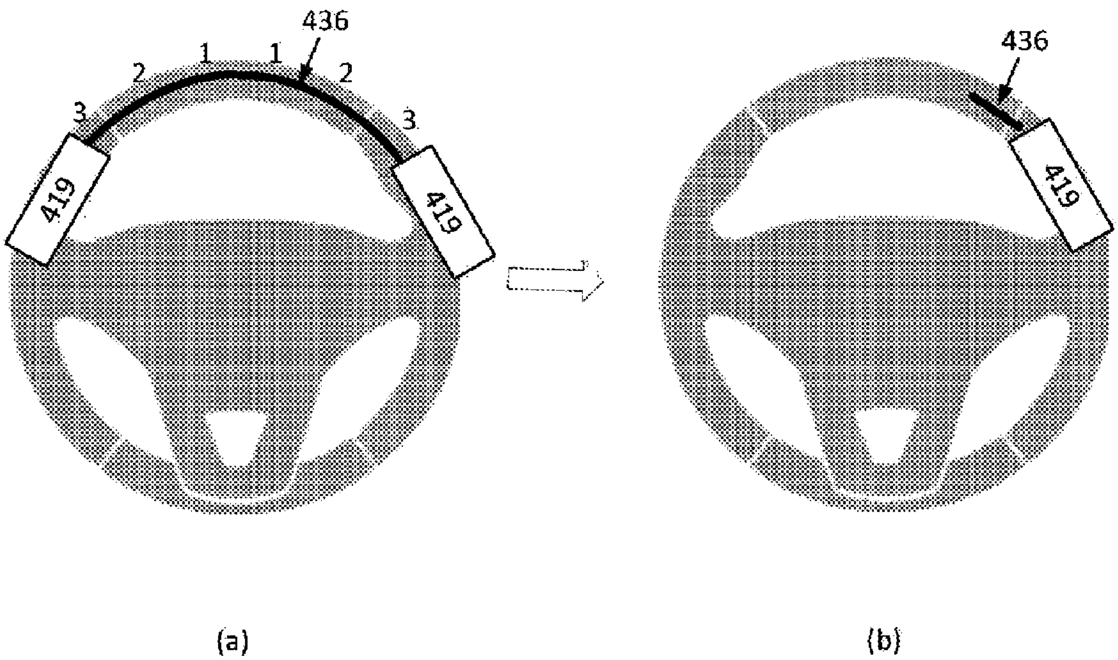


FIG. 16

Incoming Call User Interface

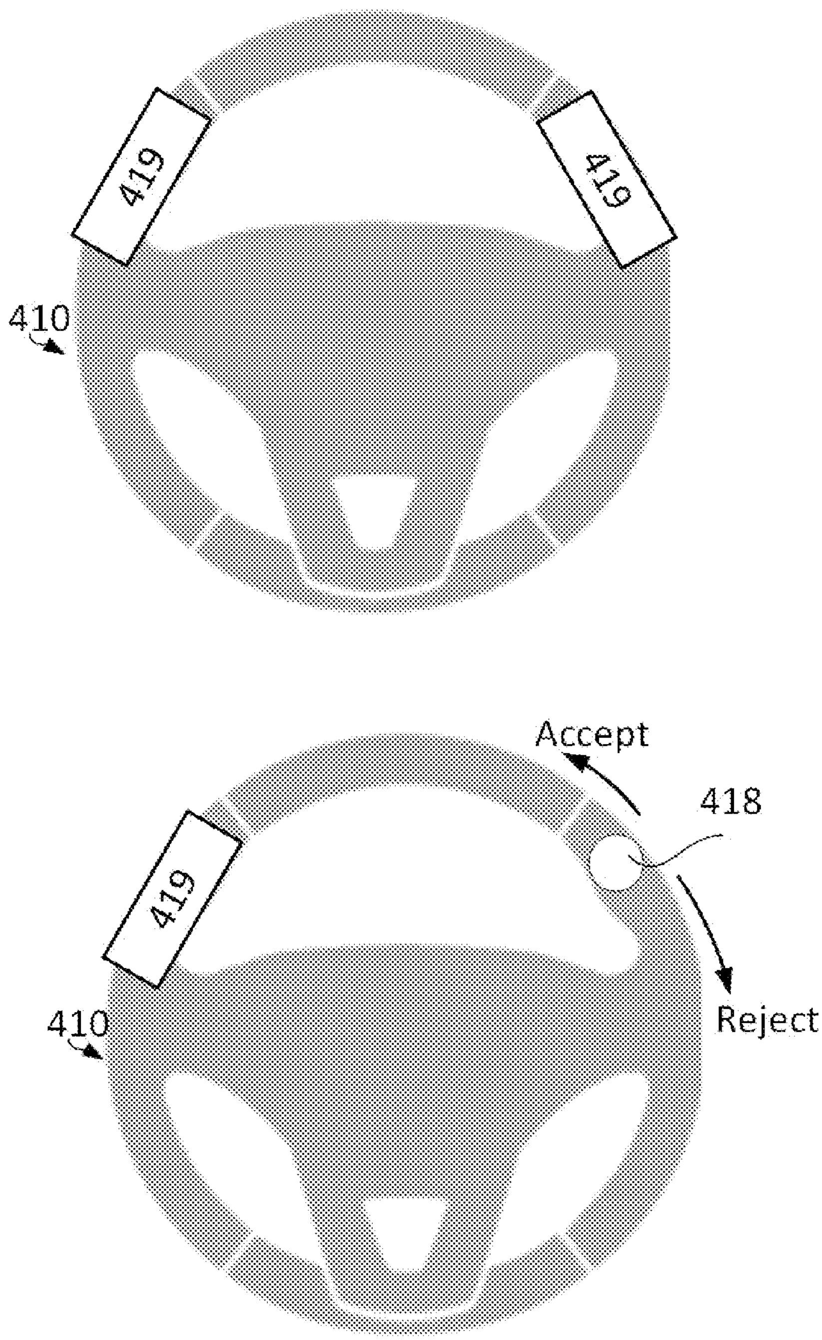


FIG. 17

Phone Call User Interface

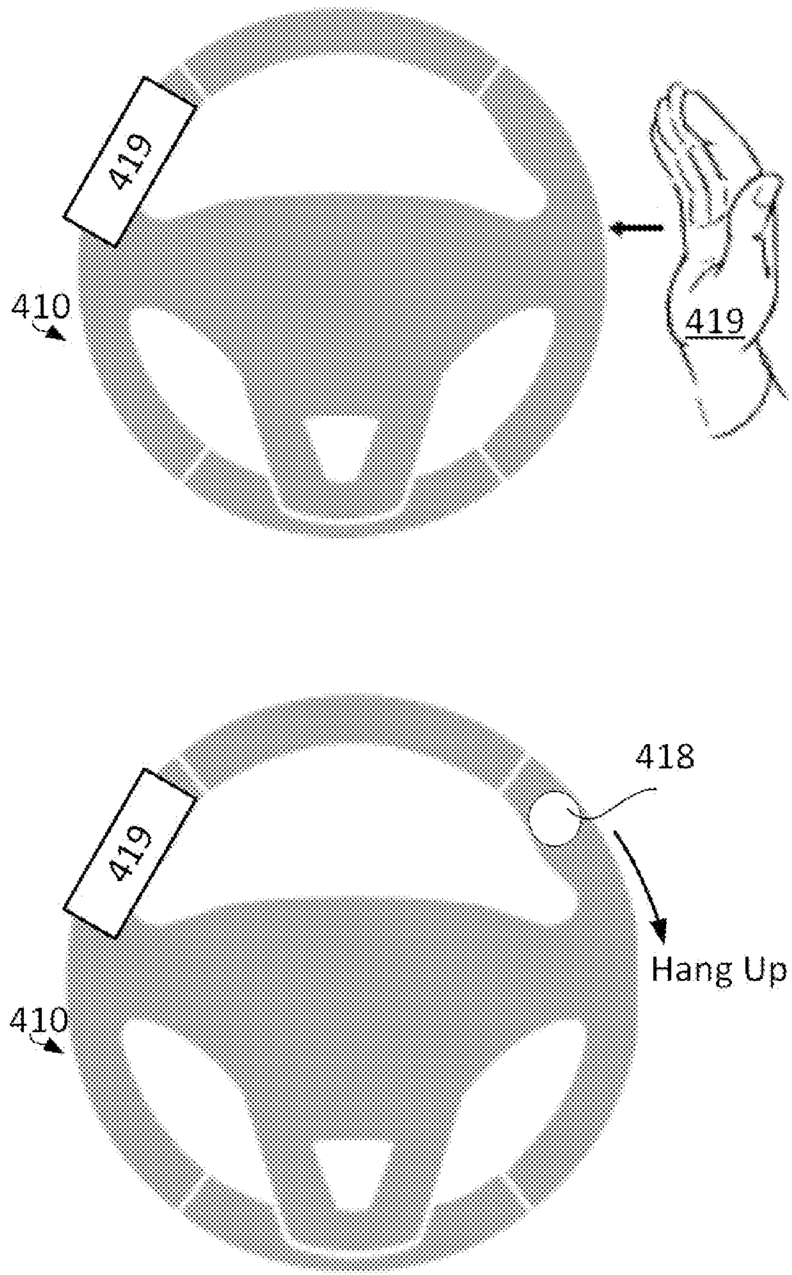
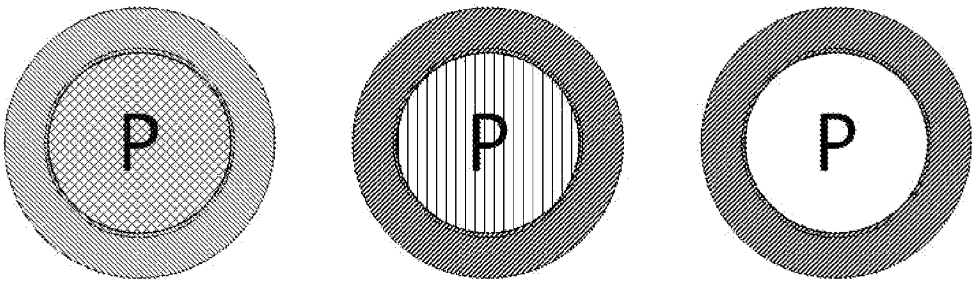
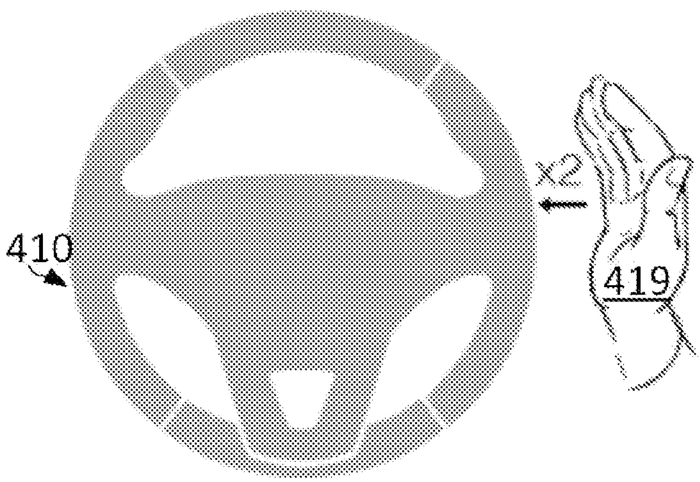


FIG. 18

Park Assist User Interface



(a) (b) (c)



(d)

FIG. 19

USER INTERFACE FOR CURVED INPUT DEVICE

CROSS REFERENCES TO RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 14/510,090, now U.S. Pat. No. 9,092,093, entitled STEERING WHEEL USER INTERFACE and filed on Jan. 6, 2015 by inventors Alexander Jubner, Thomas Eriksson, Gunnar Martin Fröjdh, Simon Fellin and Stefan Holmgren. U.S. application Ser. No. 14/510,090 is a continuation-in-part of U.S. application Ser. No. 14/551,096, now U.S. Pat. No. 9,389,710, entitled LIGHT-BASED CONTROLS IN A TOROIDAL STEERING WHEEL and filed on Nov. 24, 2014, by inventors Gunnar Martin Fröjdh, Simon Fellin, Thomas Eriksson, John Karlsson, Maria Hedin and Richard Berglind, the contents of which are hereby incorporated herein in their entirety.

U.S. application Ser. No. 14/510,090 is a continuation-in-part of U.S. application Ser. No. 14/555,731 entitled DOOR HANDLE WITH OPTICAL PROXIMITY SENSORS and filed on Nov. 28, 2014, by inventors Sairam Iyer, Stefan Holmgren and Per Rosengren, the contents of which are hereby incorporated herein in their entirety.

U.S. application Ser. No. 14/551,096 is a continuation of U.S. application Ser. No. 14/312,711, now U.S. Pat. No. 8,918,252, entitled LIGHT-BASED TOUCH CONTROLS ON A STEERING WHEEL and filed on Jun. 24, 2014 by inventors Gunnar Martin Fröjdh, Simon Fellin, Thomas Eriksson, John Karlsson, Maria Hedin and Richard Berglind, the contents of which are hereby incorporated herein in their entirety.

U.S. application Ser. No. 14/312,711 is a continuation of U.S. application Ser. No. 14/088,458, now U.S. Pat. No. 8,775,023, entitled LIGHT-BASED TOUCH CONTROLS ON A STEERING WHEEL AND DASHBOARD and filed on Nov. 25, 2013 by inventors Gunnar Martin Fröjdh, Simon Fellin, Thomas Eriksson, John Karlsson, Maria Hedin and Richard Berglind, the contents of which are hereby incorporated herein in their entirety.

U.S. application Ser. No. 14/088,458 is a non-provisional of U.S. Provisional Application No. 61/730,139 entitled LIGHT-BASED TOUCH CONTROLS ON A STEERING WHEEL AND DASHBOARD and filed on Nov. 27, 2012 by inventors Gunnar Martin Fröjdh, Thomas Eriksson, John Karlsson, Maria Hedin and Richard Berglind, the contents of which are hereby incorporated herein in their entirety.

U.S. application Ser. No. 14/555,731 is a continuation-in-part of U.S. application Ser. No. 14/312,787, now U.S. Pat. No. 9,164,625, entitled OPTICAL PROXIMITY SENSORS and filed on Jun. 24, 2014 by inventors Stefan Holmgren, Sairam Iyer, Richard Berglind, Karl Erik Patrik Nordström, Lars Sparf, Per Rosengren, Erik Rosengren, John Karlsson, Thomas Eriksson, Alexander Jubner, Remo Behdasht, Simon Fellin, Robin Åman and Joseph Shain, the contents of which are hereby incorporated herein in their entirety.

U.S. application Ser. No. 14/555,731 is a continuation-in-part of U.S. application Ser. No. 14/311,366, now U.S. Pat. No. 9,063,614, entitled OPTICAL TOUCH SCREENS and filed on Jun. 23, 2014 by inventors Robert Pettersson, Per Rosengren, Erik Rosengren, Stefan Holmgren, Lars Sparf, Richard Berglind, Thomas Eriksson, Karl Erik Patrik Nordström, Gunnar Martin Fröjdh, Xiatao Wang and Remo Behdasht, the contents of which are hereby incorporated herein in their entirety.

U.S. application Ser. No. 14/555,731 is a continuation-in-part of U.S. application Ser. No. 14/140,635, now U.S. Pat. No. 9,001,087, entitled LIGHT-BASED PROXIMITY DETECTION SYSTEM AND USER INTERFACE and filed on Dec. 26, 2013 by inventors Thomas Eriksson and Stefan Holmgren, the contents of which are hereby incorporated herein in their entirety.

U.S. application Ser. No. 14/312,787 is a continuation of International Application No. PCT/US14/40112 entitled OPTICAL PROXIMITY SENSORS and filed on May 30, 2014 by inventors Stefan Holmgren, Sairam Iyer, Richard Berglind, Karl Erik Patrik Nordström, Lars Sparf, Per Rosengren, Erik Rosengren, John Karlsson, Thomas Eriksson, Alexander Jubner, Remo Behdasht, Simon Fellin, Robin Åman and Joseph Shain, the contents of which are hereby incorporated herein in their entirety.

International Application No. PCT/US14/40112 claims priority benefit of U.S. Provisional Application No. 61/828,713 entitled OPTICAL TOUCH SCREEN SYSTEMS USING REFLECTED LIGHT and filed on May 30, 2013 by inventors Per Rosengren, Lars Sparf, Erik Rosengren and Thomas Eriksson; of U.S. Provisional Application No. 61/838,296 entitled OPTICAL GAME ACCESSORIES USING REFLECTED LIGHT and filed on Jun. 23, 2013 by inventors Per Rosengren, Lars Sparf, Erik Rosengren, Thomas Eriksson, Joseph Shain, Stefan Holmgren, John Karlsson and Remo Behdasht; of U.S. Provisional Application No. 61/846,089 entitled PROXIMITY SENSOR FOR LAPTOP COMPUTER AND ASSOCIATED USER INTERFACE and filed on Jul. 15, 2013 by inventors Richard Berglind, Thomas Eriksson, Simon Fellin, Per Rosengren, Lars Sparf, Erik Rosengren, Joseph Shain, Stefan Holmgren, John Karlsson and Remo Behdasht; of U.S. Provisional Application No. 61/929,992 entitled CLOUD GAMING USER INTERFACE filed on Jan. 22, 2014 by inventors Thomas Eriksson, Stefan Holmgren, John Karlsson, Remo Behdasht, Erik Rosengren, Lars Sparf and Alexander Jubner; of U.S. Provisional Application No. 61/972,435 entitled OPTICAL TOUCH SCREEN SYSTEMS and filed on Mar. 31, 2014 by inventors Sairam Iyer, Karl Erik Patrik Nordström, Lars Sparf, Per Rosengren, Erik Rosengren, Thomas Eriksson, Alexander Jubner and Joseph Shain; and of U.S. Provisional Application No. 61/986,341 entitled OPTICAL TOUCH SCREEN SYSTEMS and filed on Apr. 30, 2014 by inventors Sairam Iyer, Karl Erik Patrik Nordström, Lars Sparf, Per Rosengren, Erik Rosengren, Thomas Eriksson, Alexander Jubner and Joseph Shain, the contents of which are hereby incorporated herein in their entirety.

U.S. application Ser. No. 14/311,366 is a continuation of International Application No. PCT/US14/40579 entitled OPTICAL TOUCH SCREENS and filed on Jun. 3, 2014 by inventors Robert Pettersson, Per Rosengren, Erik Rosengren, Stefan Holmgren, Lars Sparf, Richard Berglind, Thomas Eriksson, Karl Erik Patrik Nordström, Gunnar Martin Fröjdh, Xiatao Wang and Remo Behdasht, the contents of which are hereby incorporated herein in their entirety.

International Application No. PCT/US14/40579 claims priority benefit of U.S. Provisional Application No. 61/830,671 entitled MULTI-TOUCH OPTICAL TOUCH SCREENS WITHOUT GHOST POINTS and filed on Jun. 4, 2013 by inventors Erik Rosengren, Robert Pettersson, Lars Sparf and Thomas Eriksson; of U.S. Provisional Application No. 61/833,161 entitled CIRCULAR MULTI-TOUCH OPTICAL TOUCH SCREENS and filed on Jun. 10, 2013 by inventors Richard Berglind, Erik Rosengren, Robert Pettersson, Lars Sparf, Thomas Eriksson, Gunnar

Martin Fröjdh and Xiatao Wang; of U.S. Provisional Application No. 61/911,915 entitled CIRCULAR MULTI-TOUCH OPTICAL TOUCH SCREENS and filed on Dec. 4, 2013 by inventors Richard Berglind, Erik Rosengren, Robert Pettersson, Lars Sparf, Thomas Eriksson, Gunnar Martin Fröjdh and Xiatao Wang; of U.S. Provisional Application No. 61/919,759 entitled OPTICAL TOUCH SCREENS WITH TOUCH-SENSITIVE BORDERS and filed on Dec. 22, 2013 by inventors Remo Behdasht, Erik Rosengren, Robert Pettersson, Lars Sparf and Thomas Eriksson; of U.S. Provisional Application No. 61/923,775 entitled MULTI-TOUCH OPTICAL TOUCH SCREENS WITHOUT GHOST POINTS and filed on Jan. 6, 2014 by inventors Per Rosengren, Stefan Holmgren, Erik Rosengren, Robert Pettersson, Lars Sparf and Thomas Eriksson; and of U.S. Provisional Application No. 61/950,868 entitled OPTICAL TOUCH SCREENS and filed on Mar. 11, 2014 by inventors Karl Erik Patrik Nordström, Per Rosengren, Stefan Holmgren, Erik Rosengren, Robert Pettersson, Lars Sparf and Thomas Eriksson, the contents of which are hereby incorporated herein in their entirety.

FIELD OF THE INVENTION

The field of the present invention is steering wheel user interfaces for vehicles.

BACKGROUND OF THE INVENTION

Reference is made to FIG. **1**, which is a simplified illustration of a prior art steering wheel. A steering wheel **400**, shown in FIG. **1**, includes a circular gripping member **401**, one or more connecting members **402**-**404** that connect the gripping member **401** to steering column **407**, and buttons **405** and **406** on connecting members **402** and **403** for controlling various devices in the vehicle. Connecting members **402**-**404**, which connect gripping member **401** to steering column **407**, are also referred to as spokes. In FIG. **1**, button **405** is used to answer an incoming phone call on the vehicle's BLUETOOTH® speaker phone and button **406** hangs up the call. BLUETOOTH is a trademark owned by the Bluetooth SIG of Kirkland, Wash., USA. Controls mounted in a steering wheel can be operated comfortably and safely since the driver is able to control and operate these controls without taking hands off the wheel or eyes off the road.

Historically, the first button added to a steering wheel was a switch to activate the car's electric horn. When cruise control systems were introduced, some automakers located the operating switches for this feature on the steering wheel as well. Today additional button controls for an audio system, a telephone and voice control system, a navigation system, a stereo system, and on board computer functions are commonly placed on the steering wheel.

U.S. Patent Publication No. 2012/0232751 A1 for PRESSURE SENSITIVE STEERING WHEEL CONTROLS describes adding pressure-sensitive controls to the circular gripping member of the steering wheel. Pressure sensors are located at various locations along the perimeter of the gripping member, and different locations correspond to different controls. A control is actuated in response to application of pressure at a sensor location, e.g., by the user tightening his grip.

Prior art user interfaces associated with steering wheels, such as the buttons and grips discussed hereinabove, associate a function with an absolute position on the steering wheel. This is conceptually analogous to a touch-sensitive screen displaying icons where the user touches the location on the screen at which the icon is located to activate the icon. The concept of absolute positioning for user input goes back even further: each key on a keyboard is positioned at an absolute position within the keyboard. Similarly, early graphical user interfaces using light pens required the user to place the light pen onto a graphic displayed on the screen in order to activate a corresponding function.

In contrast to these user interfaces based on absolute positioning, the computer mouse introduced a user interface for controlling a cursor based on relative positioning. Namely, the mouse cursor moves on the screen in a direction that the mouse moves from point A to point B, but this movement is not at all contingent on the actual coordinates—the absolute positions—of points A and B. This shift from absolute positioning to relative positioning frees the user from having to look at, or be aware of, the location of the mouse on the table. The user only has to control the direction in which the mouse moves on the table, which he can do without looking at the mouse. One of the objectives of the present invention is to provide a user interface for a driver based on the relative positioning user interface model.

SUMMARY

The present disclosure relates to user interfaces for on board vehicle systems, and teaches a user interface that does not require the user to be aware of the location at which he is touching the steering wheel in order to activate a function. The present disclosure teaches a robust vocabulary of user gestures that can be mapped to a wide variety of applications. The user gestures of the present disclosure are performed with absolute confidence by a user, without the user looking at the surface on which the gestures are performed. In certain embodiments of the invention the gestures are performed on the rim of a steering wheel. The nature of these gestures and the underlying hardware provided for detecting these gestures enables each user interface gesture to be performed by the user without any need for looking at the steering wheel. Furthermore these gestures are entirely independent of how the steering wheel is rotated at the time the gestures are performed.

There is thus provided in accordance with an embodiment of the present invention a steering wheel that identifies gestures performed on its surface, including a circular gripping element including a thumb-receiving notch disposed along its circumference, an array of light-based proximity sensors, mounted in the gripping element, that projects light beams through the notch radially outward from the gripping element, and detects light beams reflected back into the gripping element by a moving object at or near the notch, and a processor, coupled with the proximity sensor array, for determining polar angles along the circumference of the gripping element occupied by the object, responsive to light beams projected by the proximity sensor array and reflected back by the object being detected by the proximity sensor array.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be more fully understood and appreciated from the following detailed description, taken in conjunction with the drawings in which:

FIG. **1** is a simplified illustration of prior art steering wheel;

FIG. **2** is an exploded view of a steering wheel, in accordance with a first embodiment of the present invention;

FIG. **3** is a cutaway view of a segment of the steering wheel of FIG. **2**, in accordance with an embodiment of the present invention;

FIGS. **4** and **5** are exploded views of the steering wheel segment illustrated in FIG. **3**, in accordance with an embodiment of the present invention;

FIG. **6** is a simplified illustration of electronic components in the steering wheel segment of FIG. **2** connected to a processor, in accordance with an embodiment of the present invention;

FIG. **7** is a simplified illustration of a structure of light baffles placed upon the electronic components in FIG. **6**, in accordance with an embodiment of the present invention;

FIGS. **8** and **9** are simplified illustrations of light beams detecting an object, in accordance with an embodiment of the present invention;

FIG. **10** is simplified side view illustration of light beams projected radially outward from a steering wheel, in accordance with an embodiment of the present invention;

FIG. **11** is a simplified illustration of communication between touch detection firmware and multiple clients over a network, in accordance with an embodiment of the present invention;

FIG. **12** is a simplified illustration of five basic gesture components used in a steering wheel user interface, in accordance with an embodiment of the present invention;

FIG. **13** is a flowchart of an exemplary vehicle user interface, in accordance with an embodiment of the present invention;

FIG. **14** is a simplified illustration of user interface gestures performed on a steering wheel for an exemplary adaptive cruise control function, in accordance with an embodiment of the present invention;

FIG. **15** is a simplified illustration of a multi-touch double-tap gesture and an exemplary user interface to activate an autonomous drive mode, in accordance with an embodiment of the present invention;

FIG. **16** is a simplified illustration of a gesture and an exemplary user interface for exiting the autonomous drive mode, in accordance with an embodiment of the present invention;

FIG. **17** is a simplified illustration showing how an incoming call is received, in accordance with an embodiment of the present invention;

FIG. **18** is a simplified illustration showing how to hang up a call, in accordance with an embodiment of the present invention; and

FIG. **19** is a simplified illustration of a user interface for a park assist function, in accordance with an embodiment of the present invention.

In the disclosure and figures, the following numbering scheme is used. Light transmitters are numbered in the 100's, light detectors are numbered in the 200's, light guides and lenses are numbered in the 300's, miscellaneous items are numbered in the 400's, light beams are numbered in the 600's, and flow chart elements are numbered 1000-1100. Like numbered elements are similar but not necessarily identical.

The following tables catalog the numbered elements and list the figures in which each numbered element appears.

Light Transmitters	
Element	FIGS.
100	4, 5
101	6
102	6
105	8-10
106	6, 7
107	6, 7
108	6, 7
109	6, 7

Light Detectors	
Element	FIGS.
200	4
201	6, 8, 9
202	6, 8, 9
203	8, 9
205	8, 9
206	8

Light Guides and Lenses	
Element	FIGS.
300	2-7
301	8, 9
302	8, 9
303	8, 9
304	8, 9
305	8-10

Miscellaneous Items		
Element	FIGS.	Description
400	1	steering wheel
401	1	grip
402	1	right spoke
403	1	left spoke
404	1	bottom spoke
405	1	answer button
406	1	reject button
410	12, 14-19	steering wheel
411	2-5	steering wheel frame
412	2-5	top cover
413	2-5	thumb notch
414	2-7	PCB
415	2-5, 7	light baffle
416	3, 5	transparent cover section
417	3, 5	transparent cover section
418	12, 14, 15, 17, 18	finger
419	12, 14, 16-19	hand
420	12, 15	steering wheel surface
421-424, 428, 431-434	12, 15	hand/finger movement directions
425	12	clock icon
426	12	finger
430	14	double-tap gesture
436	14-16	Illumination

-continued

Miscellaneous Items		
Element	FIGS.	Description
437	14	movement of illumination
438	14, 17	tap gesture
440	6, 11	Processor
441-443	11	network client
444	11	message bus

Light Beams		
Element	FIGS.	Description
601	10	light beam
602	3, 8-10	light beam
603	8, 9	light beam
604	8, 9	light beam

Flow Chart Stages		
Element	FIGS.	Description
1001-1005	13	vehicle application state
1010-1019	13	vehicle application action

DETAILED DESCRIPTION

Aspects of the present disclosure relate to light-based touch controls that allow a driver to keep his hands on a steering element while operating peripheral electronic devices and automated features in a vehicle.

According to a first embodiment of the invention, a steering wheel is provided with a touch sensitive strip disposed along the entire circumference of the steering wheel. In order to facilitate locating the strip, it is disposed in a thumb receiving notch or groove that is etched or otherwise formed along the circumference of the steering wheel. In addition to a touch sensor, there is also a visible-light illuminator behind or around the touch sensitive strip that is used to indicate the state of the user interface to the user, and also indicate where certain tap gestures should be performed.

A user interface for this steering wheel is designed to be independent of the rotation of the steering wheel. Sweep gestures are clockwise and counter-clockwise so that they are independent of rotation of the wheel. A function is activated in response to a gesture, such as a double-tap, performed anywhere along the circumference of the wheel. The activation of some functions places the user interface into a state in which one or more additional functions can be selectively activated. In order to activate these additional functions, the touch location at which the initial gesture was performed is illuminated and subsequent gestures are performed in relation to the illuminated portion of the wheel. When a portion of the wheel is thus illuminated, and the driver slides his hand along the steering wheel grip, the illuminated portion of the steering wheel follows the hand so that the hand is always next to the location for performing subsequent gestures. Similarly, when the user switches hands gripping the steering wheel, the illumination jumps to the newly gripped part of the wheel.

Reference is made to FIG. **2**, which is an exploded view of a steering wheel, in accordance with a first embodiment of the present invention. Elements of this steering wheel include steering wheel frame **411**, PCB **414**, an array of lenses **300**, a light baffle structure **415**, and a steering wheel top cover **412**. A thumb-receiving notch **413** is disposed within steering wheel cover **412**.

Reference is made to FIG. **3**, which is a cutaway view of a segment of the steering wheel of FIG. **2**, in accordance with an embodiment of the present invention. Thumb-receiving notch **413** is illustrated in FIG. **3**. Two light transmissive portions of cover **412** are also shown in FIG. **3**. A first light transmissive portion **417** forms the side wall of thumb-receiving notch **413**. Light beams traveling into and out of this portion provide touch detection and proximity detection, as explained below. Three touch detection light beams **602** are shown directed radially outward from the steering wheel gripping element. The second light transmissive portion **416** forms a floor of thumb-receiving notch **413**, and is used for visible illumination indicating a state of the user interface to the driver, and at which location the driver should perform additional user interface gestures.

Reference is made to FIGS. **4** and **5**, which are exploded views of the steering wheel segment illustrated in FIG. **3**, in accordance with an embodiment of the present invention. As shown in FIG. **4**, two concentric rows of elements are mounted on PCB **414**. Namely, an inner row of light detectors **200** and an outer row of light emitters **100**. Light from the emitters enters lenses **300** through which it is re-directed out of the steering wheel through light transmissive portion **417** as light beams **602**, illustrated in FIGS. **3** and **8-10**. An object such as a thumb placed in notch **413** reflects the light back through portion **417** and lenses **300** onto one or more of the light detectors **200**, thereby providing touch detection, as illustrated in FIGS. **8** and **9**. Similarly, an object such as a user's hand placed along the outer rim of the steering wheel outside notch **413** and opposite light transmissive portion **417** also reflects the light back through portion **417** and lenses **300** onto one or more of the light detectors **200**, thereby providing proximity detection.

FIG. **5** shows an exploded view from below of the steering wheel segment illustrated in FIG. **3**, in accordance with an embodiment of the present invention.

Reference is made to FIG. **6**, which is a simplified illustration of electronic components in the steering wheel segment of FIG. **2** connected to a processor, in accordance with an embodiment of the present invention. FIG. **6** shows processor **440** connected to PCB **414** on which three concentric arrangements of light elements are mounted, namely, an inner circular arrangement of inward facing light detectors, including detectors **201** and **202**; a middle circular arrangement of inward facing light emitters, including emitters **101** and **102**; and an outer circular arrangement of outward facing light emitters **105-108**. The inward facing light emitters are used for touch and proximity detection and typically emit light in the near infrared range. Processor **440** controls activation of the emitters and detectors, and detects gestures performed on the steering wheel based on these activations and based on the outputs of the detectors.

The outward facing light emitters are used to provide visual indications to the user by illuminating light transmissive portion **416** of the steering wheel cover, and emit light in the visible range. Lenses **300** are described in assignee's co-pending application U.S. Ser. No. 14/555,731, entitled DOOR HANDLE WITH OPTICAL PROXIMITY SENSORS, the contents of which are incorporated herein in their entirety by reference.

Reference is made to FIG. **7**, which is a simplified illustration of a structure of light baffles placed upon the electronic components in FIG. **6**, in accordance with an embodiment of the present invention. FIG. **7** shows PCB **414** and lenses **300** of FIG. **6**, but with baffle structure **415** placed above the mounted light elements.

Reference is made to FIGS. **8** and **9**, which are simplified illustrations of light beams detecting an object, in accordance with an embodiment of the present invention. FIGS. **8** and **9** show a light path used to detect an object. Shown in FIGS. **8** and **9** are individual lens structures **301-305**. Each lens structure serves a respective opposite emitter and two detectors, one to the left of the emitter and one to the right of the emitter. Thus, for example, lens structure **305** serves emitter **105** and detectors **205** and **206**. In addition each detector is served by two lens structures; e.g., detector **205** receives reflected light from lens structures **304** and **305**. In the example shown in FIGS. **8** and **9**, light from emitter **105** is reflected by an object (not shown) into lens structure **303** and onto detector **203**. Three segments of the detected light are indicated in FIGS. **8** and **9**; namely, light beam **602** projected outward from lens structure **305** and radially outward of the steering wheel, light beam **603** reflected by the object into lens structure **303**, and light beam **604** directed by lens structure **303** onto detector **203**.

Reference is made to FIG. **10**, which is simplified side view illustration of light beams projected radially outward from a steering wheel, in accordance with an embodiment of the present invention. FIG. **10** shows a cutaway side view of the light path illustrated in FIGS. **8** and **9**. FIG. **10** shows light beam **601** from emitter **105** entering lens structure **305**, where it is redirected outward as light beam **602**.

Methods for determining two-dimensional coordinates of an object detected by the disclosed proximity sensor array are described in assignee's co-pending application Ser. No. 14/312,787, entitled OPTICAL PROXIMITY SENSORS, and U.S. Ser. No. 14/555,731, entitled DOOR HANDLE WITH OPTICAL PROXIMITY SENSORS, both incorporated herein in their entireties by reference. Because the present application is for a steering wheel and the proximity sensor array is arranged along an arc-shaped grip of the steering wheel, the determined coordinates are polar coordinates, including a polar angle and a radial coordinate. The polar angle corresponds to a coordinate along the proximity sensor array, which in application Ser. Nos. 14/312,787 and 14/555,731 is described as an x-axis coordinate. The radial coordinate corresponds to a distance from the proximity sensor array, which in application Ser. Nos. 14/312,787 and 14/555,731 is described as a y-axis coordinate.

Discussion now turns to the firmware and software used to detect and interpret user gestures. There are five basic gesture components that are detected by the hardware and low level drivers: (i) Thumb-Tap, (ii) Thumb-Glide, (iii) Thumb-Long-Press, (iv) Grab and (v) Rim-Tap. These components are emitted on the network as they are detected, and are used by higher level software to assemble more complex gestures such as double-taps. Application software interprets these gestures as input commands. In some embodiments of the invention multiple client applications are connected via a network to the detector firmware. The firmware sends information for each detected gesture component over the network, and a client application translates that information into commands and/or constructs compound gestures from multiple gesture components.

Reference is made to FIG. **11**, which is a simplified illustration of communication between touch detection firmware and multiple clients over a network, in accordance with an embodiment of the present invention. FIG. **11** shows an exemplary network architecture in which processor **440** sends detected gesture components over message bus **444**, e.g., using the Message Queue Telemetry Transport (MQTT) messaging protocol on top of the TCP/IP protocol, to connected clients **441-443**.

The five basic gesture components are categorized according to whether they are performed by a large object (hand) or small object (thumb), and whether the nature of the gesture component is discrete or continuous, as presented in the table below.

Component	Description	Object	Type
Thumb-Tap	Tap thumb on steering wheel rim	Small	Discrete
Thumb-Glide	Glide thumb along steering wheel rim	Small	Continuous
Thumb-Long-Press	Hold thumb on steering wheel rim	Small	Continuous
Grab	Grab hold of steering wheel rim	Large	Continuous
Rim-Tap	Tap hand on steering wheel rim	Large	Discrete

These gesture components are alternatively referred to as follows.

Component	Alternative Name
Thumb-Tap	small-object tap
Thumb-Glide	small-object glide
Thumb-Long-Press	small-object touch-and-hold
Grab	large-object grab
Rim-Tap	large-object tap

The parameters are the same for all gesture components; namely, time stamp, start angle (min_angle), end angle (max_angle), center angle (angle) and state.

The angle parameters refer to a polar angle along the steering wheel at which the object is detected. Because of the object's size, there is a first polar angle at which the object begins (start angle) and a last polar angle at which the object ends (end angle). The midpoint between the start and end angles (center angle) is used as the object's polar angle. The start and end angles are useful for determining the size of a detected object.

The state parameter takes on three values: RECOGNIZED, UPDATED and ENDED. The ENDED state is applied to all discrete gesture components, and also when a continuous gesture component ends. The RECOGNIZED and UPDATED states are only applied to continuous gesture components. The RECOGNIZED state is applied when a continuous gesture component is first detected. The UPDATED state is applied during the course of a continuous gesture component.

The discrete gesture components, Thumb-Tap and Rim-Tap, are emitted to the clients after they happen, and then only one message is sent for the gesture component. They are only sent with the state ENDED.

The continuous gesture components, Thumb-Glide, Thumb-Long-Press and Grab, are emitted to the clients intermittently from the instant that they are recognized until they end when the hand or finger leaves the rim. When they are first recognized, they are sent to the network with the state RECOGNIZED. With a configurable interval, the gesture component is reported to the network with new parameters and the state UPDATED. When the gesture component ends, the gesture component is sent with the state ENDED.

Reference is made to FIG. **12**, which is a simplified illustration of five basic gesture components used in a steering wheel user interface, in accordance with an embodiment of the present invention. FIG. **12** shows the five gesture components performed by thumb **418** and hand **419** on steering wheel **410**. Some gesture components are illustrated both from above and from the side. When illustrated from the side, thumb **418** is shown interacting with steering wheel surface **420**.

A Thumb-Tap gesture component is generated when a small object touches the rim (or gets very close) and then is lifted from the rim within a short period. This period is configurable, but typically it is 100-200 ms. FIG. **12** shows the Thumb-Tap gesture component from above and from the side, and illustrates the movement of thumb **418** by arrows **421**.

A Rim-Tap gesture component is the same as a Thumb-Tap, but for a large object such as a hand. FIG. **12** shows the Rim-Tap gesture component from the side and illustrates the movement of hand **419** by arrows **424**.

A Thumb-Glide gesture component is generated when a small object touches the rim and moves at least a certain threshold distance along the rim. That distance is configurable. When it continues to move, UPDATE messages are sent when the object has moved a certain distance, also configurable. FIG. **12** shows the Thumb-Glide gesture component from above and from the side, and illustrates the movement of thumb **418** by arrows **422** and **423**.

A Grab gesture component is the same as a Thumb-Glide gesture component, but for a large object touching the rim, and with the difference that the Grab gesture component does not have to move to be reported on the network. When the hand has been on the rim for a certain time threshold, the Grab gesture component is recognized and messages are intermittently sent to the network. FIG. **12** shows the Grab gesture component from above by showing hand **419** gripping steering wheel **410**.

A Thumb-Long-Press gesture component is generated when a small object is present, and not moving, on the rim. When the small object has been present for a certain time, messages are sent intermittently to the network about the gesture component. If the object starts moving, the Thumb-Long-Press gesture component is ended and a Thumb-Glide gesture component is started instead. FIG. **12** shows the Thumb-Long-Press gesture component from above and from the side. Clock icon **425** indicates the time threshold required to distinguish this gesture component from a Thumb-Tap.

As mentioned above, gesture components are combined into compound user interface gestures. In some cases, environment conditions at the gesture location are combined with the gesture component to define a gesture. For example, a Thumb-Tap gesture performed at one end of an illuminated portion of the rim is translated into a first command, and a Thumb-Tap gesture performed at the other end of the illuminated portion of the rim is translated into a second command. The following table lists the different gestures and compound gestures in the steering wheel user interface, the gesture components that make up each gesture, additional gesture parameters, and example context and commands for each gesture.

Gesture	Gesture Components	Additional Parameters	Example Context	Example Command
Tap inside notch	Thumb-Tap	Thumb-tap performed at top or bottom of illuminated portion of illuminated segment of steering wheel	Cruise control is active	Increase or decrease cruise control speed in 5 mph increments
Tap on steering wheel outer rim	Rim-Tap		During phone call	Reactivate phone interaction, e.g., when phone call is active for set period of time. Enables hanging up the phone call with a clockwise swipe gesture
Single object double-tap inside notch	Two Thumb-Taps	Thumb-taps have different time stamps, similar center angles	Vehicle is in motion	Activate cruise control and illuminate location of double-tap
Single object double-tap on steering wheel outer rim	Two Rim-Taps	Side of steering wheel rim (left or right) at which double-tap is performed	Car is not moving, and Park Assist icon is displayed on HUD	Activate Park Assist to park on left or right side of car, based on tapped side of rim
Multi-touch double-tap inside notch	Two Thumb-Taps	Thumb-taps have similar time stamps, different center angles	Autonomous drive is not active	Activate autonomous drive
Extended touch inside notch	Thumb-Long-Press	Thumb-long-press performed at top or bottom of illuminated portion of illuminated segment of steering wheel	Cruise control is active	Increase or decrease cruise control speed in 1 mph increments

-continued

Gesture	Gesture Components	Additional Parameters	Example Context	Example Command
Grab	Grab		Autonomous drive is active	Deactivate autonomous drive, and enter cruise control mode
Swipe	Thumb-Glide	clockwise/counter-clockwise	Cruise control is active	Increase or decrease distance from forward car in cruise control mode
Radial swipe	Thumb-Glide	Thumb-glide data structures have similar center angles and different radial coordinates	Cruise control is active	Open cruise control menu on HUD
Slide	Grab	Grab data structures have different time stamps and different center angles	Portion of steering wheel is selectively illuminated	Move illumination to new hand location (follow slide movement)
Switch hands	Grab	Grab data structures have different time stamps and different center angles	Portion of steering wheel is selectively illuminated	Move illumination to new hand location (jump to other side of wheel)

Reference is made to FIG. **13**, which is a flowchart of an exemplary vehicle user interface, in accordance with an embodiment of the present invention. The flowchart illustrates the different application states, different commands within each state, and the gestures used to issue those commands. The details of the gestures are illustrated in FIGS. **14**-**19**. In some embodiments a heads-up display (HUD) is provided.

The flowchart of FIG. **13** illustrates a highway scenario that includes three driving modes: Normal Drive **1001**, Adaptive Cruise Control **1002** and Autonomous Drive **1003**. In Normal Drive mode, the driver steers the vehicle and controls its speed. In Adaptive Cruise Control mode the driver steers the vehicle but the vehicle's speed, its distance from the next vehicle on the road, and other parameters are controlled by the vehicle. In Autonomous Drive mode the vehicle is driven and steered automatically without driver input.

The user enters Adaptive Cruise Control mode from Normal Drive mode by performing a double-tap gesture. The user enters Autonomous Drive mode from Normal Drive mode and from Adaptive Cruise Control mode by performing a multi-touch double-tap gesture. These gestures are described below. In order to alert the driver that Autonomous Drive mode will begin shortly, the steering wheel is illuminated with an illumination pattern that indicates a countdown until Autonomous Drive is activated.

The user exits Adaptive Cruise Control mode by performing a double-tap gesture that opens a menu on the HUD for changing the mode **1015** of cruise control. The user performs clockwise or counter-clockwise swipe gestures to scroll through the different modes on the HUD, and performs a single-tap gesture to select the displayed mode. One of the modes is Exit ACC **1018**, and selecting this mode exits Adaptive Cruise Control. Another mode configures the cruise control application to follow the road signage **1019**.

The user exits Autonomous Drive mode **1013** by grabbing the rim of the steering wheel. In order to alert the driver that Autonomous Drive mode is about to exit, the steering wheel is illuminated with an illumination pattern that indicates a countdown until Autonomous Drive is deactivated. Upon exiting Autonomous Drive mode, the vehicle enters Adaptive Cruise Control mode.

In Adaptive Cruise Control mode **1002** the user adjusts a distance **1016** between the vehicle and the vehicle directly in front of it, by performing a clockwise or counter-clockwise swipe gesture. The user adjusts the speed of the vehicle by performing either a tap gesture or an extended touch gesture. When the vehicle enters Adaptive Cruise Control mode **1002** a segment of the steering wheel is illuminated. A tap gesture or extended touch gesture at one end of the illuminated segment increases the vehicle speed, and a tap gesture or extended touch gesture at the other end of illuminated segment decreases the vehicle speed.

A voice control state **1004** can be entered from Normal Drive mode and Adaptive Cruise Control mode. In this state, the user can initiate a phone call by saying "call" and the name of a contact from his phone's contact list. Once the call has been connected, the user can hang up **1010** by performing a clockwise swipe gesture. The user can also adjust the volume **1011** by saying the word "volume" and then performing a counter-clockwise swipe gesture to raise the volume, or a clockwise swipe gesture to lower the volume.

When an incoming phone call **1005** is received, the user can answer the call **1012** by performing a counter-clockwise swipe gesture, or decline the call **1012** by performing a clockwise swipe gesture.

Reference is made to FIG. **14**, which is a simplified illustration of user interface gestures performed on a steering wheel for an exemplary adaptive cruise control function, in accordance with an embodiment of the present invention. In order to enter Adaptive Cruise Control mode from Normal Drive mode the user performs a single object double-tap gesture. Namely, the user taps twice with his thumb on the thumb notch in the steering wheel. This gesture is illustrated in drawing (a) in FIG. **14**, showing steering wheel **410**, hand **419** gripping steering wheel **410**, and double-tap gesture **430**. The present invention enables the user to perform the double-tap gesture **430** at any location along the perimeter of steering wheel **410**.

When Adaptive Cruise Control is active the user has four options; namely, adjust cruise control speed, adjust the distance between the vehicle and the vehicle ahead, open an adaptive cruise control menu, and activate Autonomous Drive mode. As mentioned above Adaptive Cruise Control is activated when the user taps twice with his thumb in the steering wheel thumb notch. The location of these taps is subsequently illuminated to indicate to the user where to perform future gestures. This is illustrated in drawing (b) in FIG. **14**, showing illuminated segment **436** of the steering wheel **410** at the location at which double-tap **430** was performed. Thus, to increase the cruise control speed the user performs a gesture, e.g. a single-tap, above the illuminated portion. This is illustrated in drawing (d) in FIG. **14** showing tap gesture **438** at the counter-clockwise edge of illuminated portion **436**. The "+" indicates that this gesture increases the speed of the vehicle. Drawing (e) in FIG. **14** shows gesture **438** performed at the clockwise end of illuminated portion **436**, and the "−" indicates that the gesture decreases the speed of the vehicle.

If the user slides his hand **419** along steering wheel **410**, the illuminated portion **436** moves with the hand so that the user's thumb is always next to the illuminated portion of the steering wheel. This is illustrated in drawing (c) in FIG. **14**, in which hand **419** gripping steering wheel **410** slides clockwise as indicated by arrow **428**, and illuminated portion **436** also slides in the same direction as indicated by arrow **437**.

In some embodiments the cruise control speed is also adjusted in response to extended touch gestures above and below the illuminated portion of the steering wheel. For example, the speed is adjusted by 5 km/h in response to a tap gesture, and is adjusted by 1 km/h in response to an extended touch gesture.

In order to increase or decrease the distance between the vehicle and the vehicle in front of it on the road, the user performs clockwise and counter-clockwise swipe gestures. These are illustrated in drawings (f) and (g) in FIG. **14**. Drawing (f) illustrates a counter-clockwise gesture **431** to increase the distance between vehicles, and drawing (g) illustrates a clockwise gesture **432** to decrease the distance between vehicles.

In order to change the mode of Adaptive Cruise Control the user performs a radial swipe gesture with his thumb across the width of the steering wheel thumb notch. This is illustrated in drawings (h) and (i) in FIG. **14**. Drawing (h) illustrates swipe gesture **433** that moves outward across the width of illuminated portion **436**. Drawing (i) illustrates swipe gesture **434** that moves inward across the width of illuminated portion **436**. Either gesture causes the HUD to present a mode option for selection. The user performs a single-tap gesture with his thumb in the steering wheel notch to accept the displayed mode. The mode displayed in the HUD is changed in response to a swipe gesture. For example, a first mode is to follow road signage. If the user performs a single-tap when this mode is displayed on the HUD, a Follow Road Signage mode is activated. If the user swipes clockwise or counter-clockwise, a next or previous mode is displayed such as exit Adaptive Cruise Control. The user performs a single-tap to activate this mode. If no interaction from the user is received within a fixed amount of time, such as 5 seconds, then the change mode user interface is deactivated.

Reference is made to FIG. **15**, which is a simplified illustration of a multi-touch double-tap gesture and an exemplary user interface to activate an autonomous drive mode, in accordance with an embodiment of the present invention. Drawing (a) in FIG. **15** illustrates two fingers, **418** and **426**, simultaneously tapping at two locations on steering wheel **410**. The upper part of this drawing is a view from above, and the lower part of this drawing is a view from the side of each of the fingers **418** and **426**. The tap gesture is a brief down and up gesture illustrated by arrows **421** and **428** touching surface **420** of the steering wheel.

Once the user performs this multi-touch double-tap gesture, a series of locations on the steering wheel are sequentially illuminated over time to indicate a countdown until Autonomous Drive is activated, as illustrated in drawings (b) and (c). For example, viewing the upright steering wheel as a clock, drawing (b) illustrates a sequence of illuminations that begins with (i) the 2:30 and 9:30 clock positions indicated by a 1; followed by (ii) the 1:30 and 10:30 clock positions indicated by 2; followed by (iii) the 12:30 and 11:30 clock positions indicated by 3. Drawing (c) illustrates finally illuminating the 12 o'clock position indicated by the word "Go" to inform the user that Autonomous Drive is activated and the user can safely take his hands off the wheel.

In order to exit Autonomous Drive mode and enter Adaptive Cruise Control mode, the user grabs the steering wheel. Reference is made to FIG. **16**, which is a simplified illustration of a gesture and an exemplary user interface for exiting autonomous drive mode, in accordance with an embodiment of the present invention. FIG. **16** shows two hands **419** gripping steering wheel **410**, in accordance with an embodiment of the present invention. A series of locations on the steering wheel is then sequentially illuminated to indicate that Autonomous Drive mode is about to be the deactivated. For example, drawing (a) illustrates a sequence of illuminations that begins with (i) the 11:30 and 12:30 clock positions indicated by a 1; followed by (ii) the 10:30 and 1:30 clock positions indicated by 2; followed by (iii) the 9:30 and 2:30 clock positions indicated by 3. When Autonomous Drive mode is deactivated the vehicle enters Adaptive Cruise Control mode, and a portion **436** of steering wheel **410** next to one of the hands **419** gripping the steering wheel is illuminated, as illustrated in drawing (b) of FIG. **16**, and as discussed above with reference to FIG. **14**.

In both Normal Drive mode and Adaptive Cruise Control mode the user can enable voice activated controls by tapping twice on the outer rim of the steering wheel. When voice-activated controls are enabled the user disables these controls by repeating the same double-tap gesture.

Two voice-activated controls are illustrated in FIG. **13**: placing a phone call and enabling volume adjustments. To place a phone call the user says "call" and the name of the person to call, e.g., "call Mom". In order to hang up the call the user performs a swipe gesture along the thumb notch in the steering wheel. To adjust the volume of a call or the stereo system, the user says the word "volume" and then adjusts the volume up or down by swiping clockwise or counter-clockwise along the thumb notch in the steering wheel.

Reference is made to FIG. **17**, which is a simplified illustration showing how an incoming call is received, in accordance with an embodiment of the present invention. FIG. **17** shows that when an incoming call is received, the user answers or declines the call by swiping finger **418** clockwise or counter-clockwise along the thumb notch of the steering wheel, e.g. swipe counter-clockwise to accept the call and swipe clockwise to reject the call.

Reference is made to FIG. **18**, which is a simplified illustration showing how to hang up a call, in accordance with an embodiment of the present invention. The gesture to hang up a call is a clockwise swipe gesture. However, when a call has been active for a certain amount of time, the system ignores clockwise swipe gestures so that the user does not inadvertently hang up the call. In order to hang up the call, the user first taps the outer rim of the steering wheel, as shown by hand **419**, to indicate that the system should respond to the next swipe gesture, followed by a clockwise swipe gesture by finger **418** to hang up the call.

In a city scenario the user interface provides a park assist function that automatically parks the car without the user's intervention. Reference is made to FIG. **19**, which is a simplified illustration of a user interface for a park assist function, in accordance with an embodiment of the present invention. When the vehicle is moving at less than 30 km/h, the Park Assist function begins automatically scanning for available parking spaces. In addition, a faded Park Assist icon appears on the HUD, as illustrated in drawing (a) of FIG. **19**. As the car further slows down, this icon becomes bolder until the car has stopped moving, as illustrated in drawings (b) and (c) of FIG. **19**. The HUD then presents information about available parking spots; e.g. whether the vehicle can fit into that spot. The user performs a double-tap on the outer rim of the steering wheel, as illustrated in drawing (d), by hand **419** to begin the automated parking. To indicate to the Park Assist function that the parking space is on the left side of the car, the user performs this double-tap on of the left half of steering wheel rim. To indicate to the Park Assist function that the parking space is on the right side of the car, the user performs this double-tap on of the right half of steering wheel rim.

In the foregoing specification, the invention has been described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made to the specific exemplary embodiments without departing from the broader spirit and scope of the invention. In particular, sensors other than optical sensors may be used to implement the user interface, inter alia capacitive sensors disposed along the circumference of the steering wheel, and cameras that captured images of the steering wheel. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense.

What is claimed is:

1. A non-transitory computer readable medium storing instructions which, when executed by a processor connected to a curved touch-sensitive user input device, cause the processor to generate one or more data structures for an object moving along the perimeter of the curved user input device, each data structure corresponding to a component gesture and comprising:

a) a time stamp,

b) a polar angle at which the moving object starts,

c) a polar angle at which the moving object ends,

d) a middle polar angle of the moving object, and

e) an assigned state being one of the group RECOGNIZED, UPDATED and ENDED,

wherein the instructions cause the processor to assign the RECOGNIZED state to the data structure when the moving object is initially detected on the perimeter of the user input device, to assign the UPDATED state to the data structure when the moving object is further detected on the perimeter of the user input device after the initial detection, and to assign the ENDED state to the data structure when the moving object ceases to be detected on the perimeter of the user input device.

2. The computer readable medium of claim **1** wherein the instructions cause the processor to discriminate between large and small objects based on the polar angles in the data structure.

3. The computer readable medium of claim **2** wherein the instructions cause the processor to identify a component gesture of the moving object as consisting of one of the types: (i) a small-object tap gesture, (ii) a small-object glide gesture, (iii) a small-object touch-and-hold gesture, (iv) a large-object tap gesture, and (v) a large-object grab gesture.

4. The computer readable medium of claim **3** wherein the instructions cause the processor to combine at least two component gestures of the same type, having assigned states ENDED, to further identify a compound gesture.

5. The computer readable medium of claim **4** wherein the compound gesture is a double-tap gesture, combining two small-object tap gestures.

6. The computer readable medium of claim **3** wherein the instructions cause the processor to combine at least two component gestures of the same type, having assigned states RECOGNIZED and UPDATED, to further identify a compound gesture.

7. The computer readable medium of claim **6** wherein the compound gesture is a swipe gesture, combining two small-object glide gestures having different middle polar angles.

8. The computer readable medium of claim **6** wherein the compound gesture is a slide gesture, combining two consecutive large-object grab gestures having different middle polar angles.

9. The computer readable medium of claim **8**, wherein the user input device comprises visible light illumination means connected to the processor, and the instructions cause the processor to selectively illuminate locations on the user input device perimeter in accordance with the polar angles of the detected slide gesture.

10. The computer readable medium of claim **6** wherein the compound gesture is an extended touch gesture, combining two consecutive small-object touch-and-hold gestures.

11. The computer readable medium of claim **1** wherein the instructions cause the processor to determine a radial coordinate of the object, and to combine at least two component gestures having similar middle polar angles and different radial coordinates to identify a radial swipe gesture.

12. The computer readable medium of claim **11** wherein the instructions cause the processor to open a menu of options for an active application on a display in response to an identified radial swipe gesture.

13. The computer readable medium of claim **1** wherein the user input device comprises visible light illumination means connected to the processor, and the instructions cause the processor to combine at least two component gestures to further identify a compound gesture, and to selectively illuminate that portion of the user input device perimeter at which the compound gesture is performed.

14. The computer readable medium of claim **13** wherein the instructions cause the processor to issue a first command in response to a first gesture identified at one end of the illuminated portion, and cause the processor to issue a second command in response to a second gesture identified at the other end of the illuminated portion, the second command being an opposite of the first command.

15. The computer readable medium of claim **13** wherein the instructions cause the processor to issue a first command in response to a first sweep gesture in a first direction along the illuminated portion, and cause the processor to issue a second command in response to a second sweep gesture in the direction opposite the first direction along illuminated portion, the second command being an opposite of the first command.

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