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(71) Applicant: **FORD GLOBAL TECHNOLOGIES, LLC**
[US/US]; Fairlane Plaza South, Suite 800, 330 Town Center Drive, Dearborn, Michigan 48126 (US).

(72) Inventors: **NASRALLAH, Hussein F.**; 23355 Beechcrest St., Dearborn Heights, Michigan 48127 (US). **HATTON, David Anthony**; 2848 Kenmore Rd, Berkley, Michigan 48072 (US). **KRISTINSSON, Johannes Geir**; 1411 Saunders Crescent, Ann Arbor, Michigan 48103 (US). **NELSON, Thomas**; 686 Kellogg St., Plymouth, Michigan 48170 (US). **PRASAD, Krishnaswamy Venkatesh**; 2122 Ascot Road, Ann Arbor, Michigan 48103 (US). **GREENBERG, Jeffrey Allen**; 1722 Bent Pine Ct., Ann Arbor, Michigan 48108 (US). **IGNACZAK, Brad Alan**; 51278 Glen Hollow Ave., Canton, Michigan 48188 (US). **SIDIQUI, Adil Nizam**; 27159 Arden Park Circle, Farmington Hills, Michigan 48334 (US). **VAN WIEMEERSCH, John Robert**; 45500 Addington Lane, Novi, MI 48374 (US). **HOLUB, Patrick Kevin**; 47321 Autumn Park Court, Novi, Michigan 48374 (US).

(74) Agents: **STASA, Benjamin C.** et al.; Brooks Kushman, 1000 Town Center, Twenty-Second Floor, Southfield, Michigan 48075 (US).

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(54) Title: SPATIAL CLUSTERING OF PERSONAL DEVICES IN VEHICLES

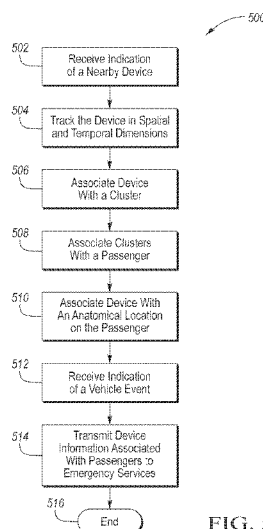


FIG. 5

(57) Abstract: A vehicle may include a controller programmed to assign an identified wearable device to an occupant seated in a particular location of the vehicle based on data defining positions of the wearable device relative to the particular location during a period of time such that changes associated with the positions may describe movement of the occupant.

SPATIAL CLUSTERING OF PERSONAL DEVICES IN VEHICLES

TECHNICAL FIELD

[0001] The present disclosure relates to in-vehicle spatial clustering of wireless communication devices.

BACKGROUND

[0002] Vehicular accidents may leave emergency responders with limited information related to the condition of passengers. Personal devices may be configured to indicate passenger state and condition. Emergency responders in some circumstances may not have access to passenger state and condition information, which may cause a reduction in care provided.

SUMMARY

[0003] A vehicle may include a controller programmed to assign an identified wearable device to an occupant seated in a particular location of the vehicle. The controller may be programmed to assign the wearable device based on data defining positions of the wearable device relative to the particular location during a period of time. Changes associated with the positions may describe movement of the occupant. The controller may be further programmed to assign the identified wearable device to an anatomical location of the occupant based on the movement of the occupant. Assigning the identified wearable device to the anatomical location may include matching a portion of the movement to a characteristic movement pattern indicative of the anatomical location. The anatomical location may be head, torso, upper extremity, or lower extremity. The controller may be further programmed to send occupant status information from the wearable device off-board the vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0004] Figure 1 is a schematic diagram of a vehicle control system configured to notify emergency services of passenger status;
- [0005] Figure 2 is a diagram of a data structure for storing information created by a device in a cluster;
- [0006] Figure 3 is a diagram of a data structure containing location data related to each device and associated with a passenger;
- [0007] Figure 4 is a representation of a vehicle having passengers, clusters, and devices.
- [0008] Figure 5 depicts an algorithm for associating devices with passengers.

DETAILED DESCRIPTION

[0009] Embodiments of the present disclosure are described herein. It is to be understood, however, that the disclosed embodiments are merely examples and other embodiments may take various and alternative forms. The figures are not necessarily to scale; some features could be exaggerated or minimized to show details of particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art to variously employ the present invention. As those of ordinary skill in the art will understand, various features illustrated and described with reference to any one of the figures may be combined with features illustrated in one or more other figures to produce embodiments that are not explicitly illustrated or described. The combinations of features illustrated provide representative embodiments for typical applications. Various combinations and modifications of the features consistent with the teachings of this disclosure, however, could be desired for particular applications or implementations.

[0010] Emergency or security services may arrive at the scene of an incident or accident without information related to the status of passengers or occupants. Emergency responders in possession of passenger status information may change the outcome of a trauma. In emergency

medicine, applying proper medical treatment soon after traumatic injury can prevent or reduce permanent impairment. Receipt of passenger status information may reduce the risk of permanent impairment by allowing first responders to readily find accident victims and prepare treatment during transit to the accident site.

[0011] Passengers or vehicle occupants may wear, possess, or otherwise interact with personal devices while occupying the vehicle. Passenger status information may include indication of blood pressure, heart rate, blood chemistry, proximity to the vehicle, recent acceleration and deceleration magnitudes and rates, or other information related to the passenger or vehicle. Personal devices may transmit generic information about the passenger or they may transmit personally identifiable information to a vehicle controller or server system. For instance, a heart rate sensor may indicate circulatory status to a vehicle system configured to receive passenger status information. The system may also be configured to receive voice recording data or pressure sensor information related to a position of the passenger in the vehicle. Any type of sensor or device may be used to provide valuable information to emergency responders including cellular phones.

[0012] Each of the personal devices may be worn, carried, or internally implemented. Each personal device may be wirelessly connected to a central server or repository. The personal devices may use different ad-hoc communication protocols (e.g., iBeacon, NFC, AirDrop, WifiDirect). The location of each personal device may be determined using a system of beacons placed throughout the vehicle. The location may be triangulated. The location of each of the personal devices may be computed by first finding the distance between the personal devices and known reference points. Other location methods may be used. For example, Received Signal Strength (RSSI), Time of Flight (ToF), Time Of Arrival (TOA) / Time Difference of Arrival (TDoA), Range-Free Localization (Proximity), and Angle of Arrival (AOA) may be used to determine the distance between each personal device and the sensors. Using at least two known distances, an algorithm may be applied to determine the location of the personal devices. For example, triangulation, Reverse Nearest Neighbor (RNN), or Voronoi diagrams may be used to determine the location. Results may be improved using more than one method. Some of these methods may be innate to each personal device. The devices may be configured to intercommunicate and determine locations ad-hoc.

[0013] The location of each personal device may be recorded in a database or data store using a relational database. The database may be located remotely or within the vehicle. One table in the database may include information related to the type of device and the data found. Another table may include location data of the device over time with the parameters used to determine location. The tables may be correlated on clusters used to predict the passenger in possession of each device.

[0014] An $m \times n$ matrix may be stored in a database representing m potential vehicle occupants, each with up to n possible wearables. Wearables may be detected as the car is started or the doors are shut. P wearables may be found in the vehicle interior or cabin. The wearables may also be found in a rear cargo hold or other vehicle area. Spatial clustering may be used to identify Q possible clusters. Each cluster may represent a potential passenger or occupant m .

[0015] Clustering recognizes association patterns between devices to determine passengers in possession of each device. The devices may be given respective coordinates to determine clusters. Each cluster, Q , may be identified using a partitioning method (k-means, expectation maximization, k-medoid, etc.), hierarchical method (agglomerative nesting, clustering using representatives, etc.), density method (DBSCAN, OPTICS, etc.), or other clustering method. Each cluster may correspond to or define an occupant of the vehicle. An additional dimension, time, may be used to determine clusters. A cluster may be recognized by observing the position of the device in 3-D space with respect to the devices relative movement in space. If all of the devices in a hypothetical cluster have similar movement patterns, the devices may be deemed to be in the same cluster and carried by the same passenger.

[0016] By observing devices in time-space or spatio-temporal dimensions, wearables, n , may be more accurately clustered or located anatomically on a passenger. Utilizing spatial and temporal dimensions to determine clusters may indicate the anatomical location of the wearable device. A combination of spatial and temporal dimensions may allow a processor to determine the relative positions of each device and develop position history. Using position or special history, a processor may link the device to a particular location of the passenger's anatomy. For example, a wearable device may be located on a passenger's wrist. Natural wrist motion causes the location of the device to move in recognizable patterns. Movements are tracked with respect to time and location. After an adequate period of time has passed, the movements may be associated with particular appendages or

regions of the body. The wrist, for example, would likely move in an arcing motion about a determinable focal point. A regression may be performed on the locations of the wearable device over time to determine an arc-plane equation and focal length.

[0017] A wearable device located on the wrist may be distinguished from an ankle by using available metrics related to anatomical parts. For instance, the average forearm length for adults is between 25 cm and 28 cm. Movements having an arcing motion having a radius between 25 cm and 28 cm may be recognized as a wrist. Additionally, devices with minimal movement, or movement within a defined space, may be identified as being located in a pocket or storage compartment.

[0018] A central device may also provide weighted clustering. For example, a driver typically has a set of keys in his or her pocket while driving. The keys could serve to signify clusters where they are otherwise not available. The keys may establish cluster anchors, which the controller or processor assumes a cluster surrounds that passenger. Keys may serve as an initial cluster hypothesis. Cluster recognition could also provide vehicle inputs. A cluster tracked near the rear of the vehicle could indicate the passenger's intention to open the gate.

[0019] Referring to Figure 1, a vehicle 102 may include a telematics control unit 108, a powertrain control module 104-A, a body control module 104-B, a radio transceiver module 104-C, a communications and entertainment unit 104-D, a climate control management module 104-E, a GPS module 104-F, and a user interface module 104-G. The vehicle 102 may be communicatively connected through a network 116 to security providers 118 and emergency services 120. The network 116 may be a local controller area network, cellular network, or the Internet. Data may be transmitted over any physical medium using wireless protocols (802.11, Bluetooth, GSM, or CDMA) or wired protocols. Data may be formed into packets and have guaranteed delivery (TCP). The telematics control unit 108 may include a processor 110 and a modem 114 to recognize clusters of devices. The processor may be used to package data for transmittal to a server (not shown) or recognize clusters on its own. The vehicle may also be tethered to a cellular phone or device configured to transmit vehicle emergency datasets (VEDS). For instance, a 911 assist feature or enhanced 911 assist may provide additional accident information from the vehicle to emergency services 120 via cellular device. This information may include event changes in velocity, seat belt fastener status, airbag status, event categorization, etc.

[0020] Referring now to Figure 2, a device diagram 200. The device diagram 200 includes data related to the devices. The data may be stored within the vehicle or off-board at a server. A plurality of devices 202 may transmit status information related to a passenger to a vehicle or server to improve security and emergency services. For example, a device 202 may transmit heart rate sensor information 204 to a data repository. The device may also transmit blood pressure information 206 to a repository. An acceleration tracking device, as included in many cellular phones, may indicate recent accelerations 208 experienced by the device. Passengers with heart problems or disease may be fitted with an electrocardiogram (EKG) to indicate irregular heart conditions. EKG information 210 may be stored in a data repository and sent to emergency assistance to improve response time.

[0021] Referring now to Figure 3, a cluster diagram 300 is shown. A passenger list 302 is populated. The device is populated based on devices 304 and clusters 306. The clusters are determined by applying a spatial clustering algorithm to the location history data 308, as disclosed above. The location history data 308 contains Cartesian coordinates of the device in three-dimensional space. The coordinates may be retrieved by one of the location algorithms described above. The coordinates may be retrieved every 10ms to determine the temporal element of the devices position. As shown in the location history data 308, the data may be semicolon separated to indicate the temporal aspect. Separate diagrams (not shown) may be created for each device to house the spatial data alongside the temporal data. For example, the processor may create a new entry each time a request for triangulation of a particular device responds. The new entry may include a cell for the Cartesian coordinates and a cell with a timestamp. From the spatial and temporal data 308, clusters can be formed 306. The relative movements of the devices may allow an algorithm to determine the anatomical location of the device 310. For example, a device that moves within a cluster but not in unison with the rest of the cluster may be hypothesized to be located on an extremity. A device that moves similarly to other devices, including those in different clusters, may be hypothesized to be located in the passengers pocket or a storage compartment.

[0022] Referring now to Figure 4, a vehicle 400 is shown. The vehicle 400 includes a set of positional sensors 420 to determine the coordinates of each device. Passengers 402, 412 are located in the front seats of the vehicle. A processor programmed with an algorithm for determining clusters is able to develop clusters 404, 414 for each of the passengers. The processor may determine the

clusters 404, 414 by monitoring the spatio-temporal data from Figure 3. The devices 406, 407, 408, and 409 are identified as cluster 404. The devices 416, 417, 418, and 419 are identified as cluster 414. Once identified, clusters 404, 414 may remain stagnant with the assigned devices with periodic updates to ensure validity of the clusters. The clustered devices allow transmission of data, without identification, to emergency and security personnel to better assists passengers during events.

[0023] Now referring to Figure 5, an algorithm 500 is shown. The controller or processor receives indication of a nearby device in step 502 and initiates communication with the device. The device's spatial and temporal dimensions are tracked over time to establish a location history in step 504 stored in a database. In step 506, the device is associated with a cluster based on the temporal and spatial data. In step 508, the clusters are associated with a passenger based on the general area occupied by the cluster. In step 510, the devices may be associated with an anatomical location on the passenger based on relative movements of the device and position relative to other devices. In step 512, the vehicle may receive indication of an event. The event may include an accident or health problem of the passenger. In step 514, the relevant health information is transmitted to emergency services to notify of them of the passenger's status. In step 516, the algorithm 500 ends. Any of the steps indicated may be carried out in different orders or repeated as required.

[0024] The processes, methods, or algorithms disclosed herein may be deliverable to or implemented by a processing device, controller, or computer, which may include any existing programmable electronic control unit or dedicated electronic control unit. Similarly, the processes, methods, or algorithms may be stored as data and instructions executable by a controller or computer in many forms including, but not limited to, information permanently stored on non-writable storage media such as ROM devices and information alterably stored on writeable storage media such as floppy disks, magnetic tapes, CDs, RAM devices, and other magnetic and optical media. The processes, methods, or algorithms may also be implemented in a software executable object. Alternatively, the processes, methods, or algorithms may be embodied in whole or in part using suitable hardware components, such as Application Specific Integrated Circuits (ASICs), Field-Programmable Gate Arrays (FPGAs), state machines, controllers or other hardware components or devices, or a combination of hardware, software and firmware components.

[0025] The words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the disclosure. As previously described, the features of various embodiments may be combined to form further embodiments of the invention that may not be explicitly described or illustrated. While various embodiments could have been described as providing advantages or being preferred over other embodiments or prior art implementations with respect to one or more desired characteristics, those of ordinary skill in the art recognize that one or more features or characteristics may be compromised to achieve desired overall system attributes, which depend on the specific application and implementation. These attributes may include, but are not limited to cost, strength, durability, life cycle cost, marketability, appearance, packaging, size, serviceability, weight, manufacturability, ease of assembly, etc. As such, embodiments described as less desirable than other embodiments or prior art implementations with respect to one or more characteristics are not outside the scope of the disclosure and may be desirable for particular applications.

WHAT IS CLAIMED IS:

1. A vehicle comprising:
a controller programmed to assign an identified wearable device to an occupant seated in a particular location of the vehicle based on data defining positions of the wearable device relative to the particular location during a period of time such that changes associated with the positions describe movement of the occupant.
2. The vehicle of claim 1, wherein the controller is further programmed to assign the identified wearable device to an anatomical location of the occupant based on the movement of the occupant.
3. The vehicle of claim 2, wherein the assigning the identified wearable device to the anatomical location includes matching a portion of the movement to a characteristic movement pattern indicative of the anatomical location.
4. The vehicle of claim 2, wherein the anatomical location is head, torso, upper extremity, or lower extremity.
5. The vehicle of claim 1, wherein the controller is further programmed to send occupant status information from the wearable device off-board the vehicle.
6. A vehicle comprising:
a controller programmed to assign an identified wearable device to an anatomical location of an occupant of the vehicle based on data defining movements of the wearable device during a period of time and a location of the occupant within the vehicle.
7. The vehicle of claim 6, wherein the assigning includes matching portions of the movements to characteristic movement patterns indicative of the anatomical location.

8. The vehicle of claim 7, wherein the anatomical location is head, torso, upper extremity, or lower extremity.

9. The vehicle of claim 6, wherein the controller is further programmed to send occupant status information from the wearable device off-board the vehicle.

10. A method comprising:

in response to detecting position data for each of two wearable devices within an occupant zone, assigning by a controller one of the two wearable devices to an occupant in the occupant zone and excluding by the controller assignment of the other of the two wearable devices from the occupant based on movements defined by the position data.

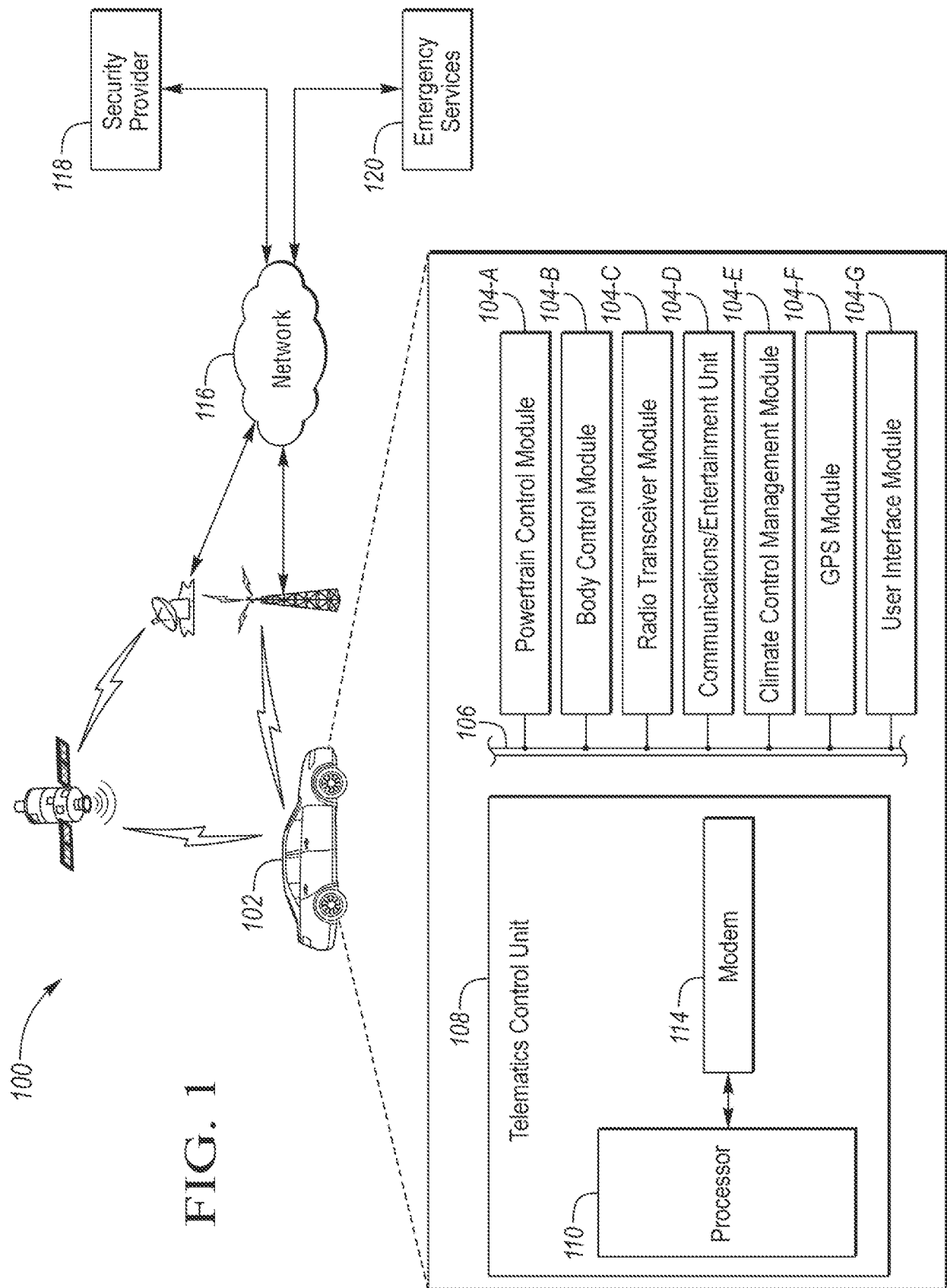
11. The method of claim 10, wherein the assigning and excluding are further based on characteristic movement patterns associated with anatomical locations for the wearable devices.

12. The method of claim 10, wherein the assigning includes associating the one of the two wearable devices to an anatomical location of the occupant.

13. The method of claim 12, wherein the associating includes matching a portion of the movements to a characteristic movement pattern indicative of the anatomical location.

14. The method of claim 12, wherein the anatomical location is head, torso, upper extremity, or lower extremity.

15. The vehicle of claim 10, wherein the controller is further programmed to send occupant status information from the wearable device off-board the vehicle.



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Device	Heart Rate	Blood Pressure	Recent Maximum Acceleration	EKG
A	90	112/70	-	-
B	75	140/90	-	-
C	-	-	5G	-
D	150	50/50	-	-
E	-	-	5G	-
F	-	-	5G	-
G	-	-	-	Normal
H	-	-	-	Atrial Fib.

FIG. 2

Passenger	Device	Cluster	Location History Data	Anatomical Location
Passenger 1	A	Cluster 1	(x,y,z);(x,y,z);(x,y,z);(x,y,z);	Left Wrist
Passenger 2	B	Cluster 2	(x,y,z);(x,y,z);(x,y,z);(x,y,z);	Left Wrist
Passenger 3	C	Cluster 3	(x,y,z);(x,y,z);(x,y,z);(x,y,z);	Pocket
Passenger 3	D	Cluster 3	(x,y,z);(x,y,z);(x,y,z);(x,y,z);	Left Wrist
Passenger 1	E	Cluster 1	(x,y,z);(x,y,z);(x,y,z);(x,y,z);	Pocket
Passenger 2	F	Cluster 2	(x,y,z);(x,y,z);(x,y,z);(x,y,z);	Pocket
Passenger 2	G	Cluster 2	(x,y,z);(x,y,z);(x,y,z);(x,y,z);	Chest
Passenger 3	H	Cluster 3	(x,y,z);(x,y,z);(x,y,z);(x,y,z);	Chest

FIG. 3

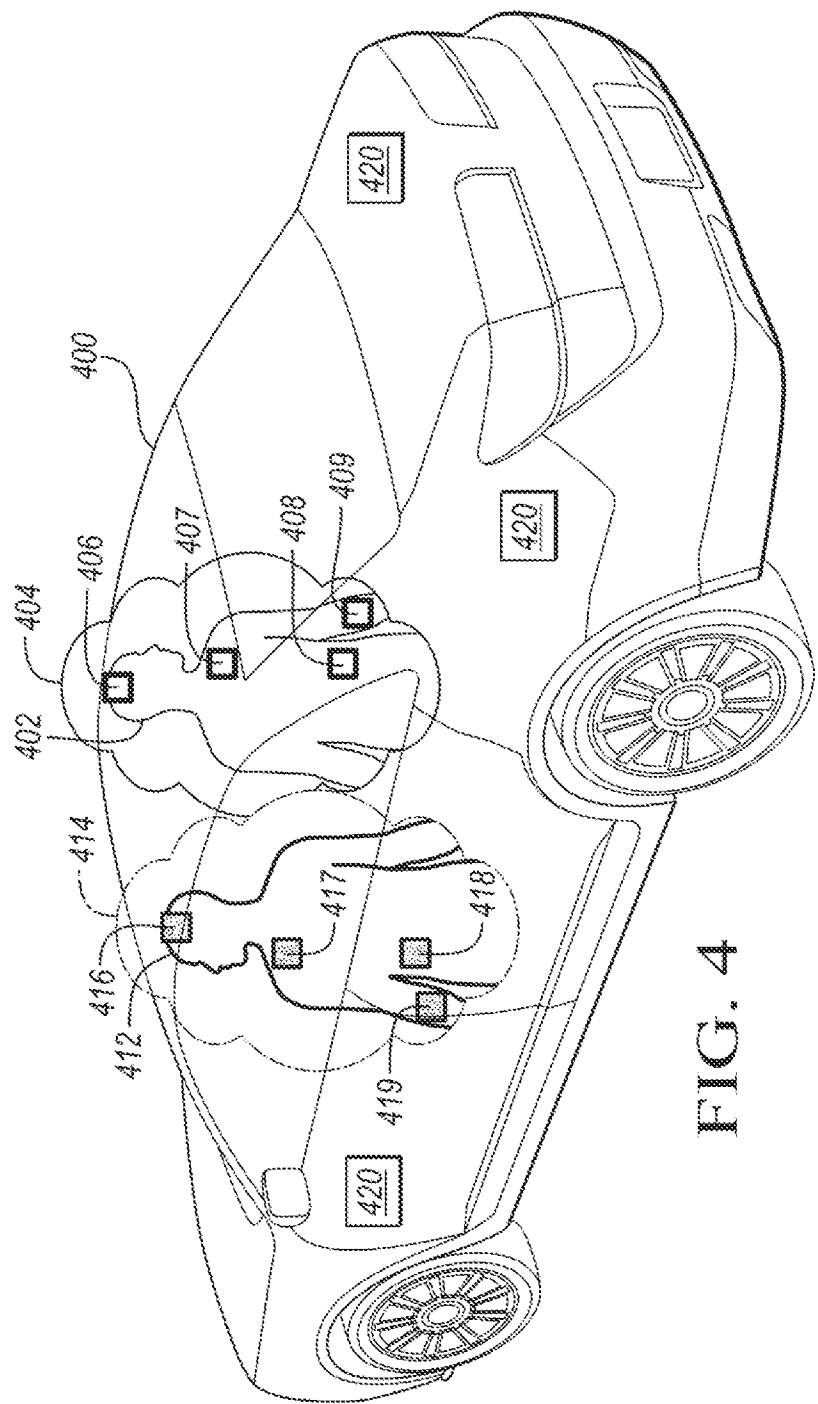


FIG. 4

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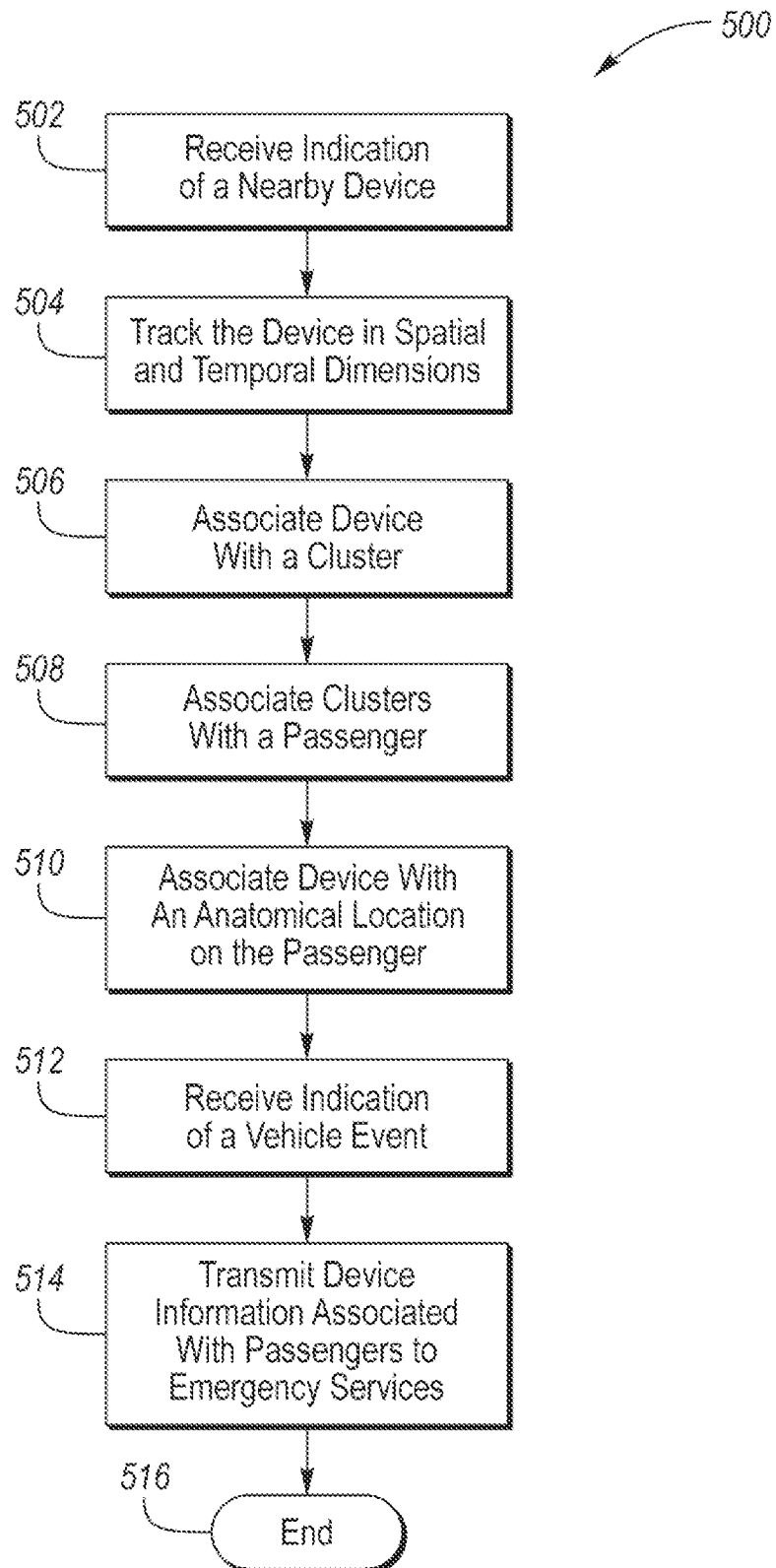


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US16/17442

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61B 5/18, 5/11; B60W 40/08; G07C 9/00; G06F 3/01 (2016.01)

CPC - B60W 40/08; G02B 27/017; G06K 9/00845

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8): A61B 5/18, 5/11; B60W 40/08; G07C 9/00; G06F 3/01 (2016.01)

CPC: B60W 40/08, 2040/0827; G02B 27/017; G06K 9/00845

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, Other Countries (INPADOC), RU, AT, CH, TH, BR, PH); Google Patents; Google; Google Scholar; EBSCO; ACM Digital Library; Search terms used: automobile, vehicle, car, controller, computer, processor, "wearable device", bracelet, "wrist band", necklace, pendant, broach, necklet, armlet, wristlet, passenger, driver, occupant

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US 2015/0194035 A1 (HARMAN INTERNATIONAL INDUSTRIES, INCORPORATED) July 09, 2015; figures 2A-B; paragraphs [0012], [0015], [0045]-[0047], [0059]-[0060]; claim 7	1-4, 6-8 ----- 5
Y -- A	US 2015/0288804 A1 (GOOGLE, INC.) October 08, 2015; figures 1, 2; paragraphs [0004], [0020]-[0022], [0028], [0054]	5, 9 ----- 10-15
A	US 2015/0362997 A1 (FORD GLOBAL TECHNOLOGIES, LLC) December 17, 2015; figure 3B; paragraphs [0029], [0057], [0061]	10-15
A	US 2015/0088397 A1 (BURTON, D) March 26, 2015; paragraphs [0124]-[0136], [0378]	10-15
A	US 2015/0351681 A1 (LG ELECTRONICS INC.) December 10, 2015; figure 1; paragraphs [0043], [0076]	10-15



Further documents are listed in the continuation of Box C.



See patent family annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search

28 March 2016 (28.03.2016)

Date of mailing of the international search report

22 APR 2016

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