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(54) **CONTROLLING SPACING OF SELF-DRIVING VEHICLES BASED ON SOCIAL NETWORK RELATIONSHIPS**

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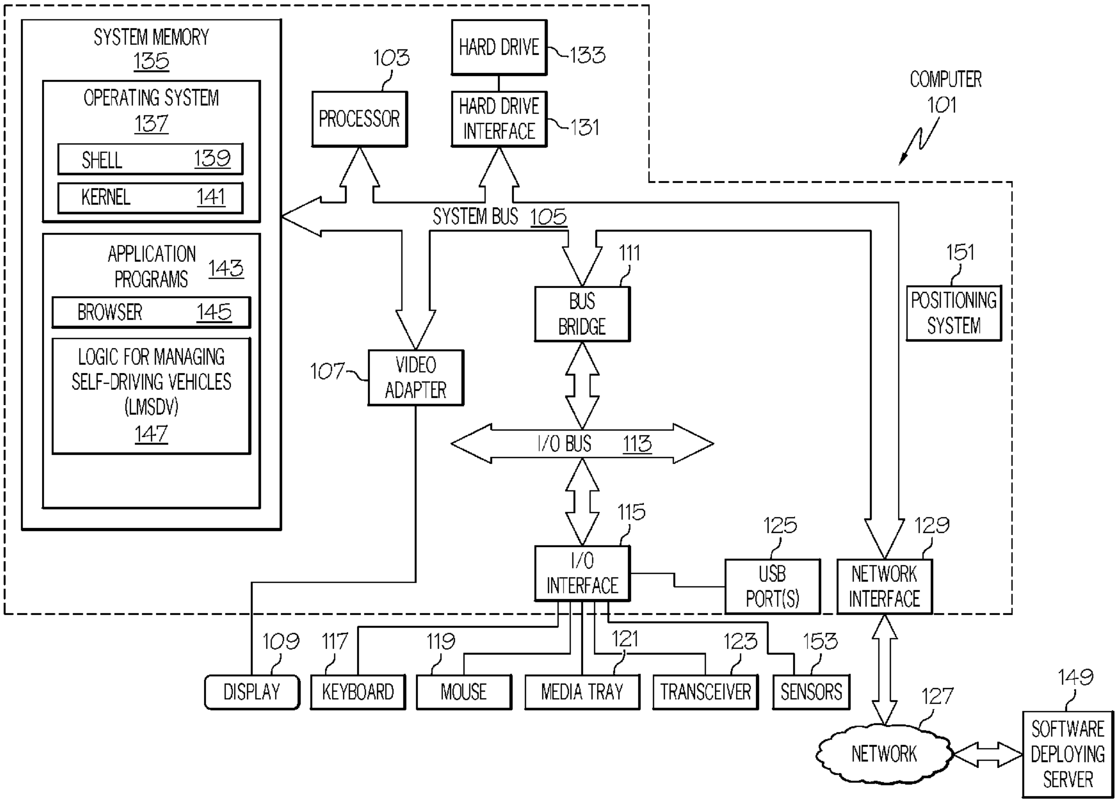
(57) **ABSTRACT**

A method and/or computer program product controls a physical spacing between self-driving vehicles (SDVs). One or more processors receive a social network node graph. The social network node graph describes a graphical distance between a first node on the social network node graph and a second node on the social network node graph. The first node represents a first passenger in a first SDV; the second node represents a second passenger in a second SDV; and the graphical distance between the first node and the second node describes a relationship level in a social network between the first passenger and the second passenger. An SDV on-board computer on at least one of the first SDV and the second SDV adjusts a physical spacing between the first SDV and the second SDV proportional to the graphical distance between the first node and the second node.



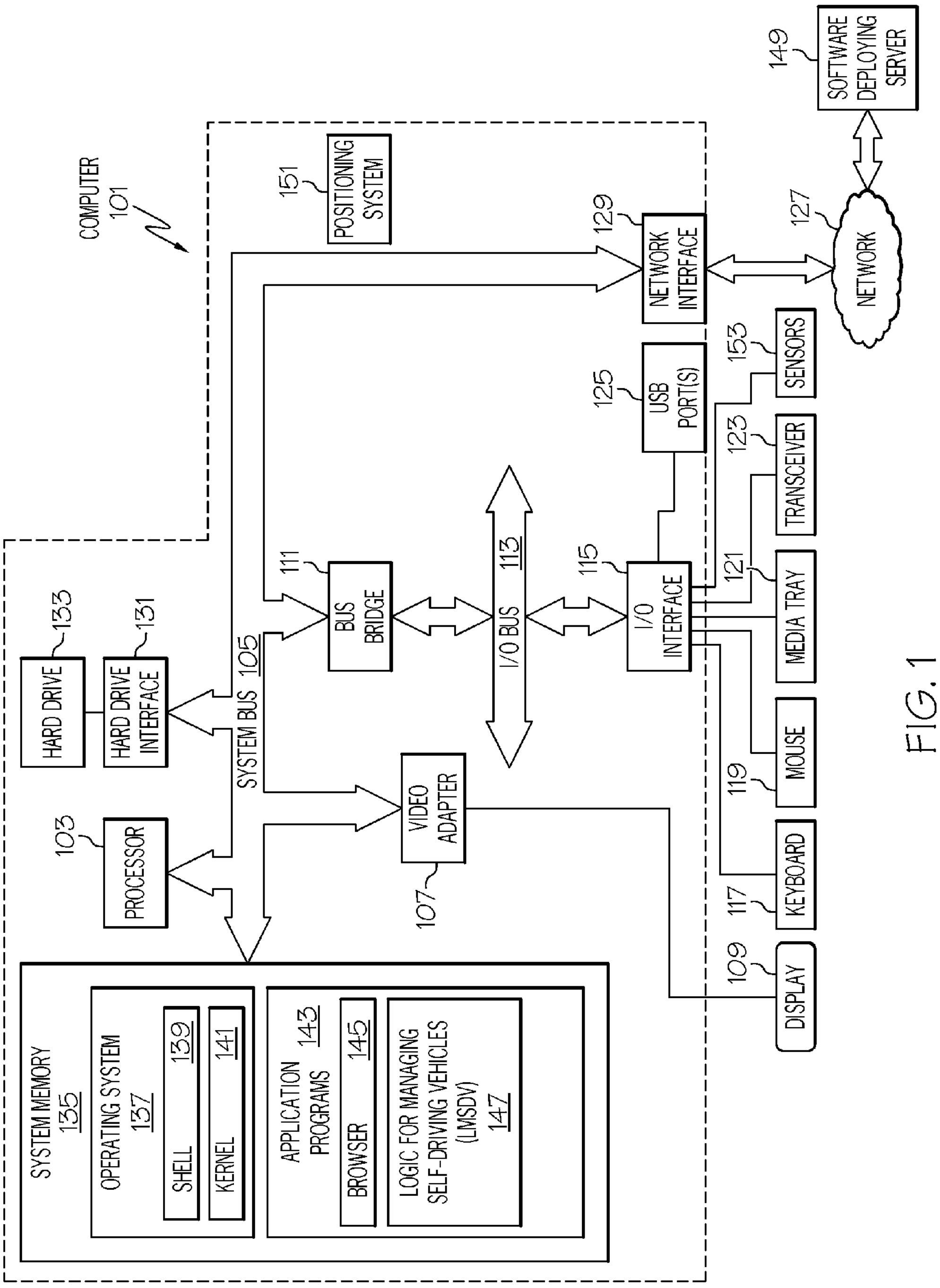

COMPUTER 101
151 POSITIONING SYSTEM
149 SOFTWARE DEPLOYING SERVER
129 NETWORK INTERFACE
127 NETWORK
125 USB PORT(S)
153 SENSORS
123 TRANSCEIVER
121 MEDIA TRAY
119 MOUSE
117 KEYBOARD
109 DISPLAY
115 I/O INTERFACE
I/O BUS 113
111 BUS BRIDGE
SYSTEM BUS 105
133 HARD DRIVE
131 HARD DRIVE INTERFACE
103 PROCESSOR
107 VIDEO ADAPTER
SYSTEM MEMORY 135
OPERATING SYSTEM 137
SHELL 139
KERNEL 141
APPLICATION PROGRAMS 143
BROWSER 145
LOGIC FOR MANAGING SELF-DRIVING VEHICLES (LMSDV) 147

FIG. 1

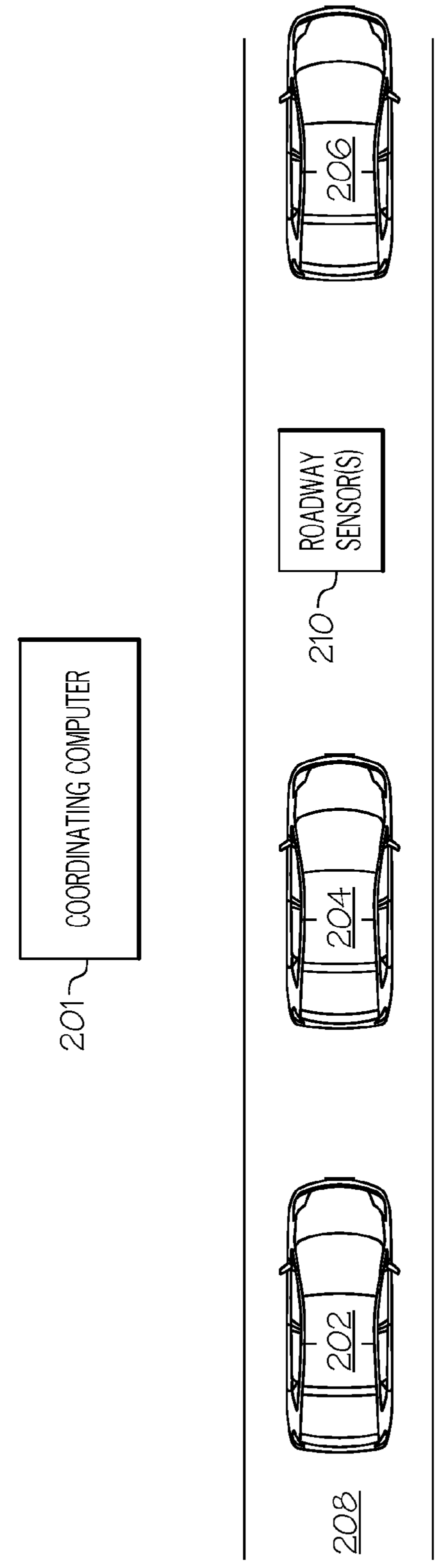

201
COORDINATING COMPUTER
206
ROADWAY SENSOR(S)
210
204
202
208

FIG. 2

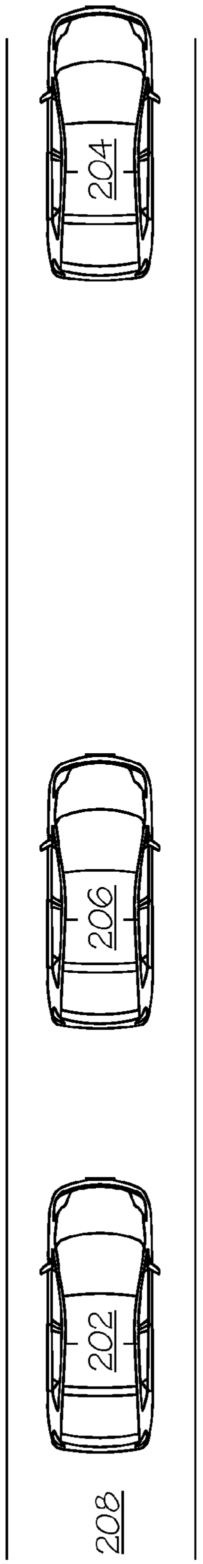

204
206
202
208

FIG. 3

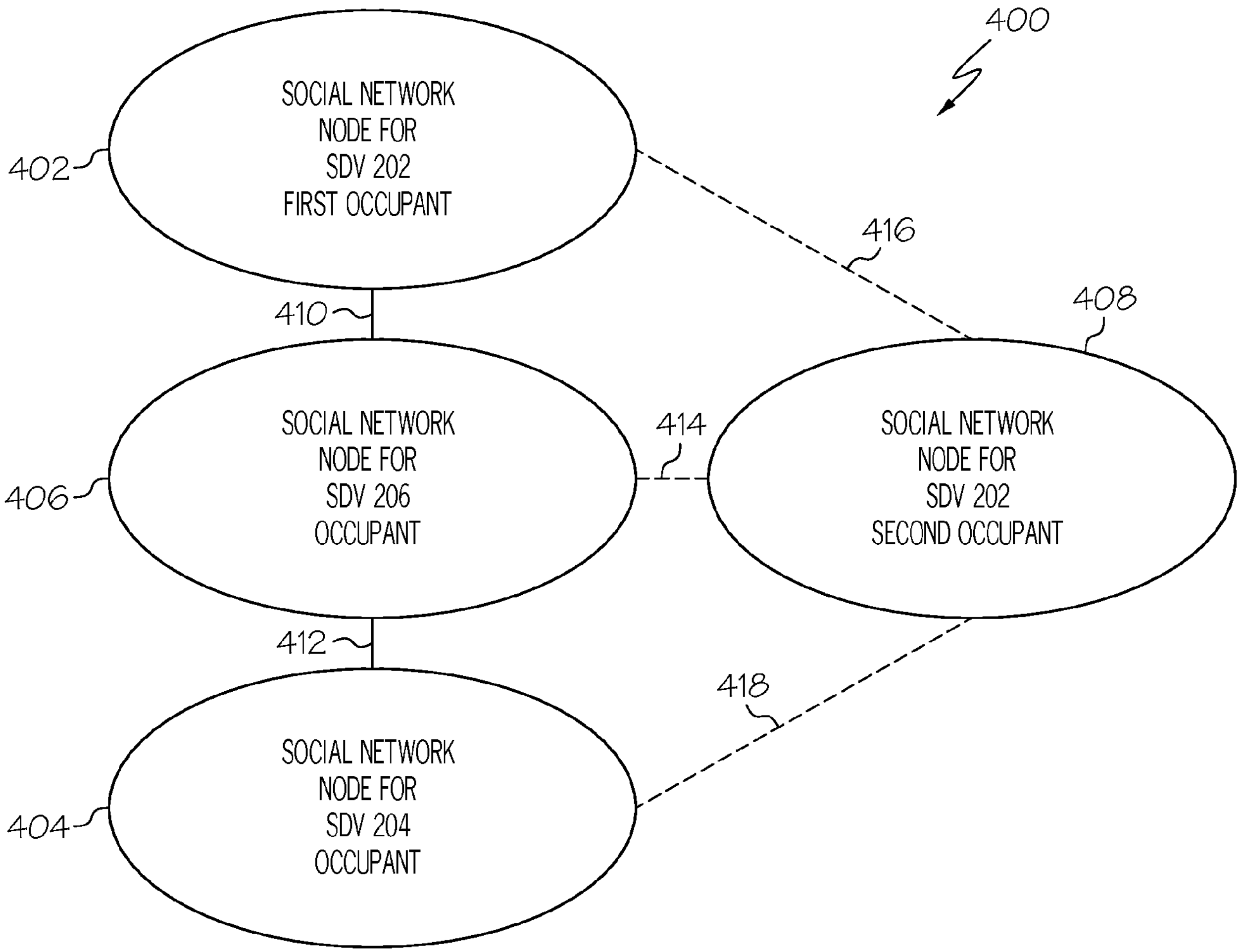

400
SOCIAL NETWORK NODE FOR SDV 202 FIRST OCCUPANT
402
410
416
SOCIAL NETWORK NODE FOR SDV 206 OCCUPANT
406
414
SOCIAL NETWORK NODE FOR SDV 202 SECOND OCCUPANT
408
412
418
SOCIAL NETWORK NODE FOR SDV 204 OCCUPANT
404

FIG. 4

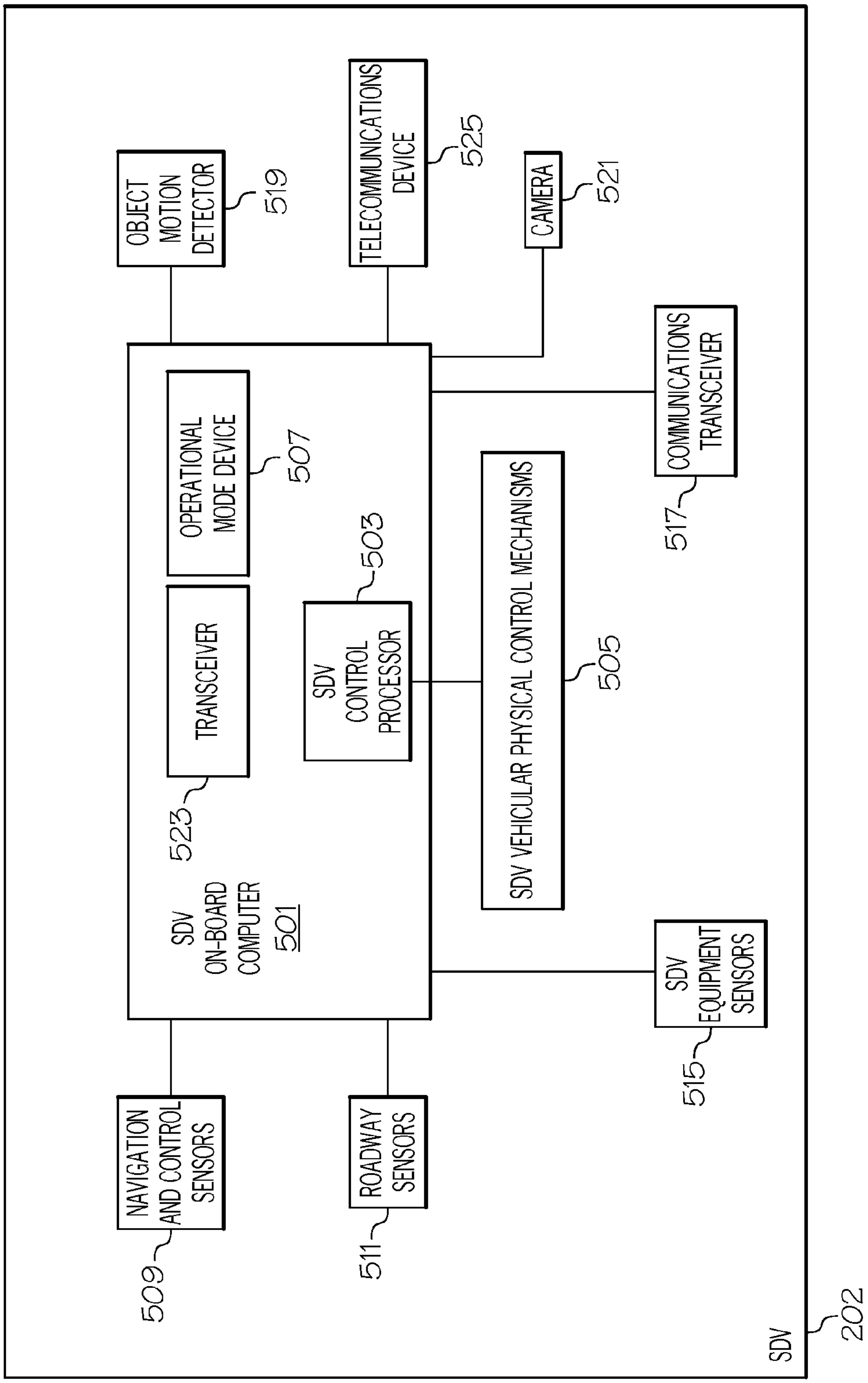

OBJECT MOTION DETECTOR
519
TELECOMMUNICATIONS DEVICE
525
CAMERA
521
COMMUNICATIONS TRANSCEIVER
517
OPERATIONAL MODE DEVICE
507
TRANSCEIVER
523
SDV CONTROL PROCESSOR
503
SDV VEHICULAR PHYSICAL CONTROL MECHANISMS
505
SDV ON-BOARD COMPUTER
501
SDV EQUIPMENT SENSORS
515
NAVIGATION AND CONTROL SENSORS
509
ROADWAY SENSORS
511
SDV
202

FIG. 5

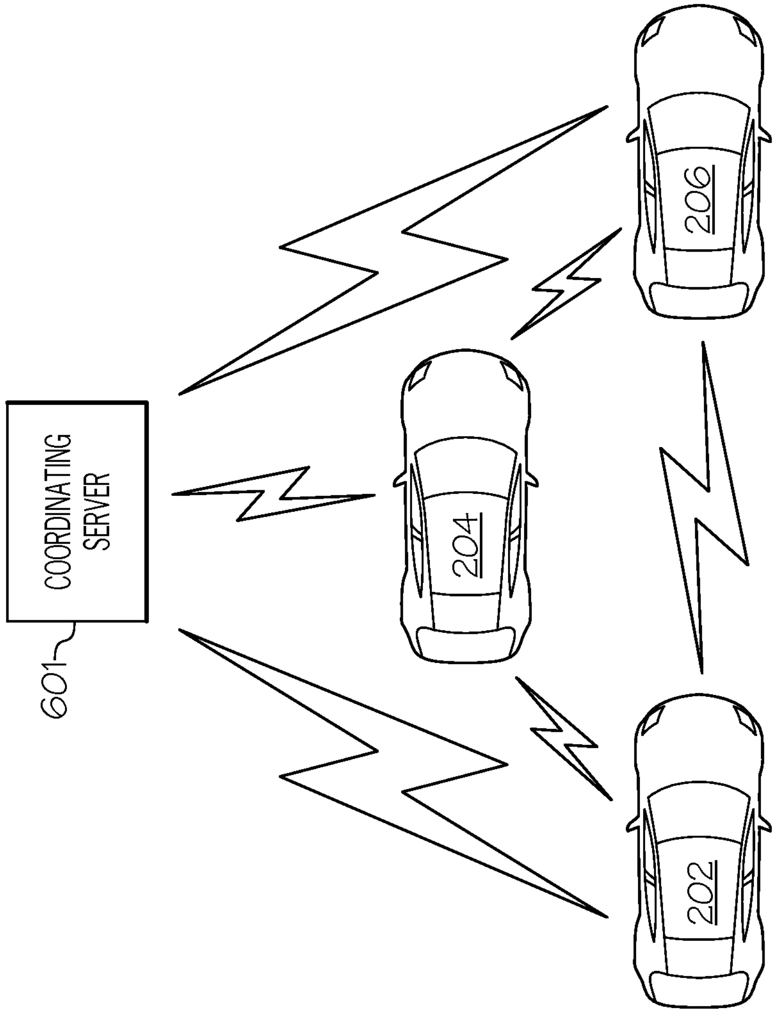


FIG. 6

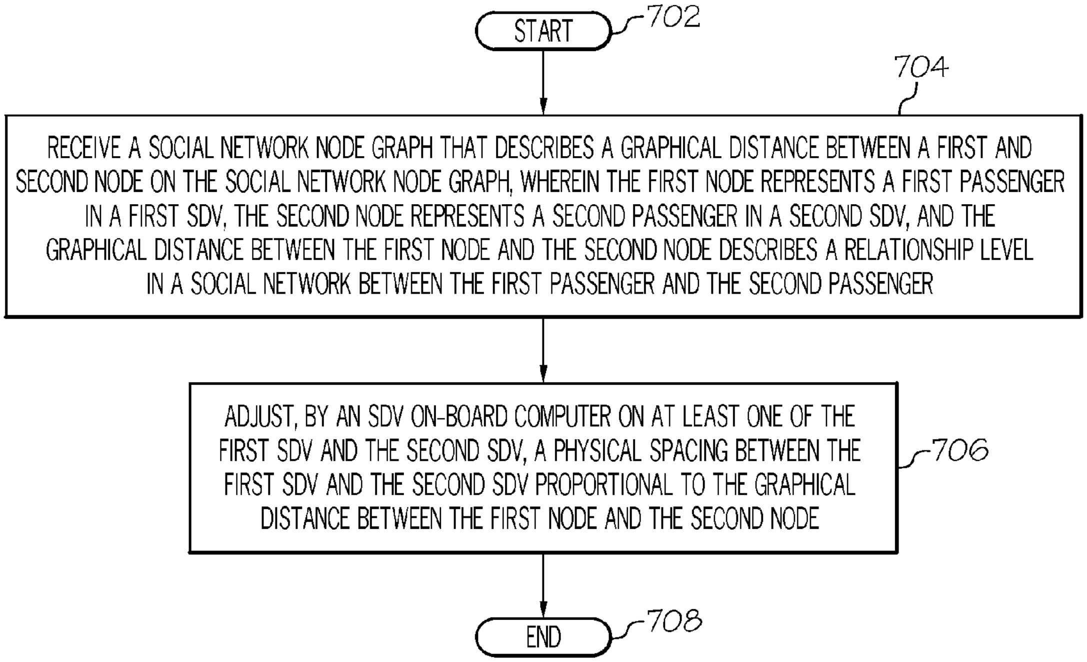

START
702
704
RECEIVE A SOCIAL NETWORK NODE GRAPH THAT DESCRIBES A GRAPHICAL DISTANCE BETWEEN A FIRST AND SECOND NODE ON THE SOCIAL NETWORK NODE GRAPH, WHEREIN THE FIRST NODE REPRESENTS A FIRST PASSENGER IN A FIRST SDV, THE SECOND NODE REPRESENTS A SECOND PASSENGER IN A SECOND SDV, AND THE GRAPHICAL DISTANCE BETWEEN THE FIRST NODE AND THE SECOND NODE DESCRIBES A RELATIONSHIP LEVEL IN A SOCIAL NETWORK BETWEEN THE FIRST PASSENGER AND THE SECOND PASSENGER
ADJUST, BY AN SDV ON-BOARD COMPUTER ON AT LEAST ONE OF THE FIRST SDV AND THE SECOND SDV, A PHYSICAL SPACING BETWEEN THE FIRST SDV AND THE SECOND SDV PROPORTIONAL TO THE GRAPHICAL DISTANCE BETWEEN THE FIRST NODE AND THE SECOND NODE
706
END
708

FIG. 7

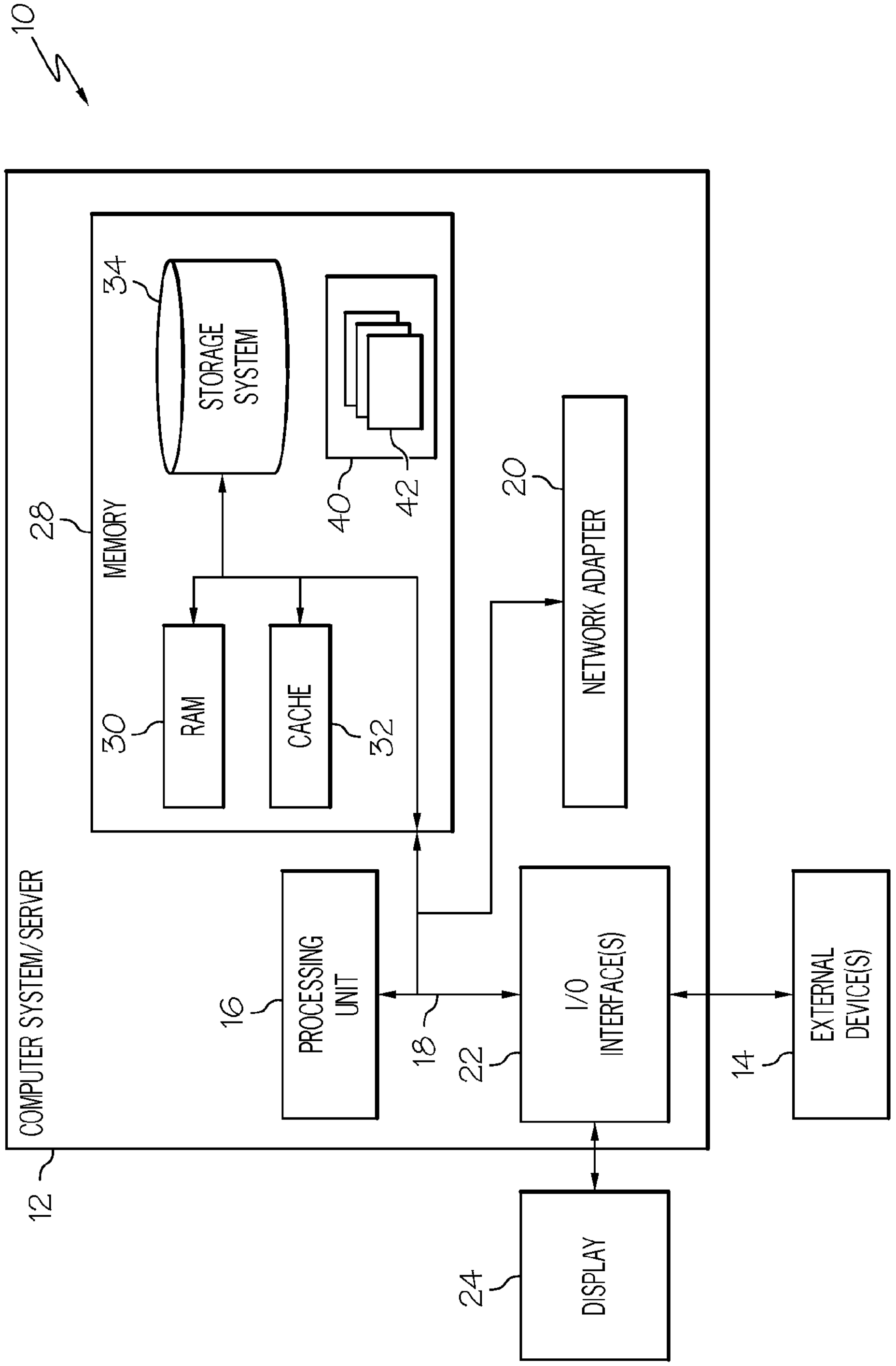

10
COMPUTER SYSTEM/SERVER
12
MEMORY
28
RAM
30
CACHE
32
STORAGE SYSTEM
34
40
42
PROCESSING UNIT
16
18
NETWORK ADAPTER
20
I/O INTERFACE(S)
22
EXTERNAL DEVICE(S)
14
DISPLAY
24

FIG. 8

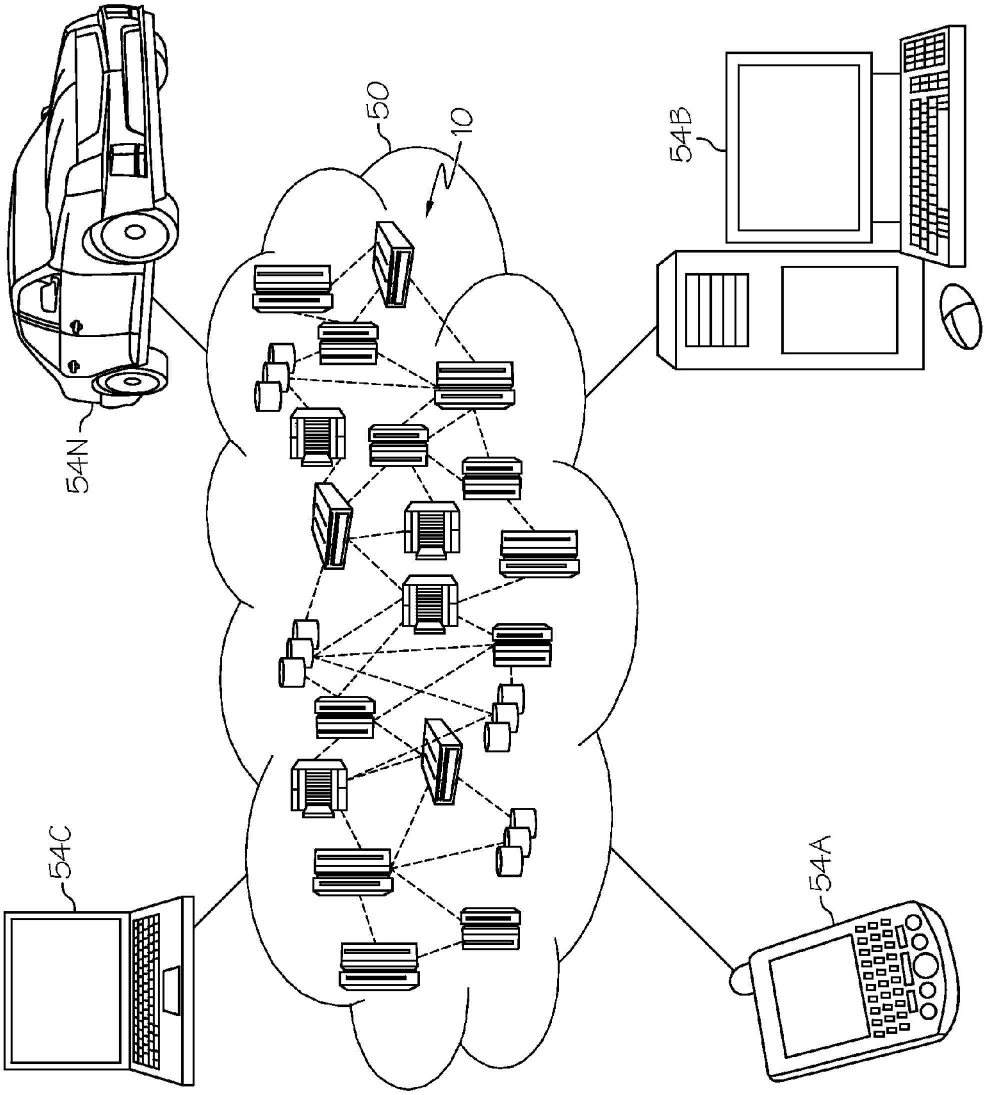


FIG. 9

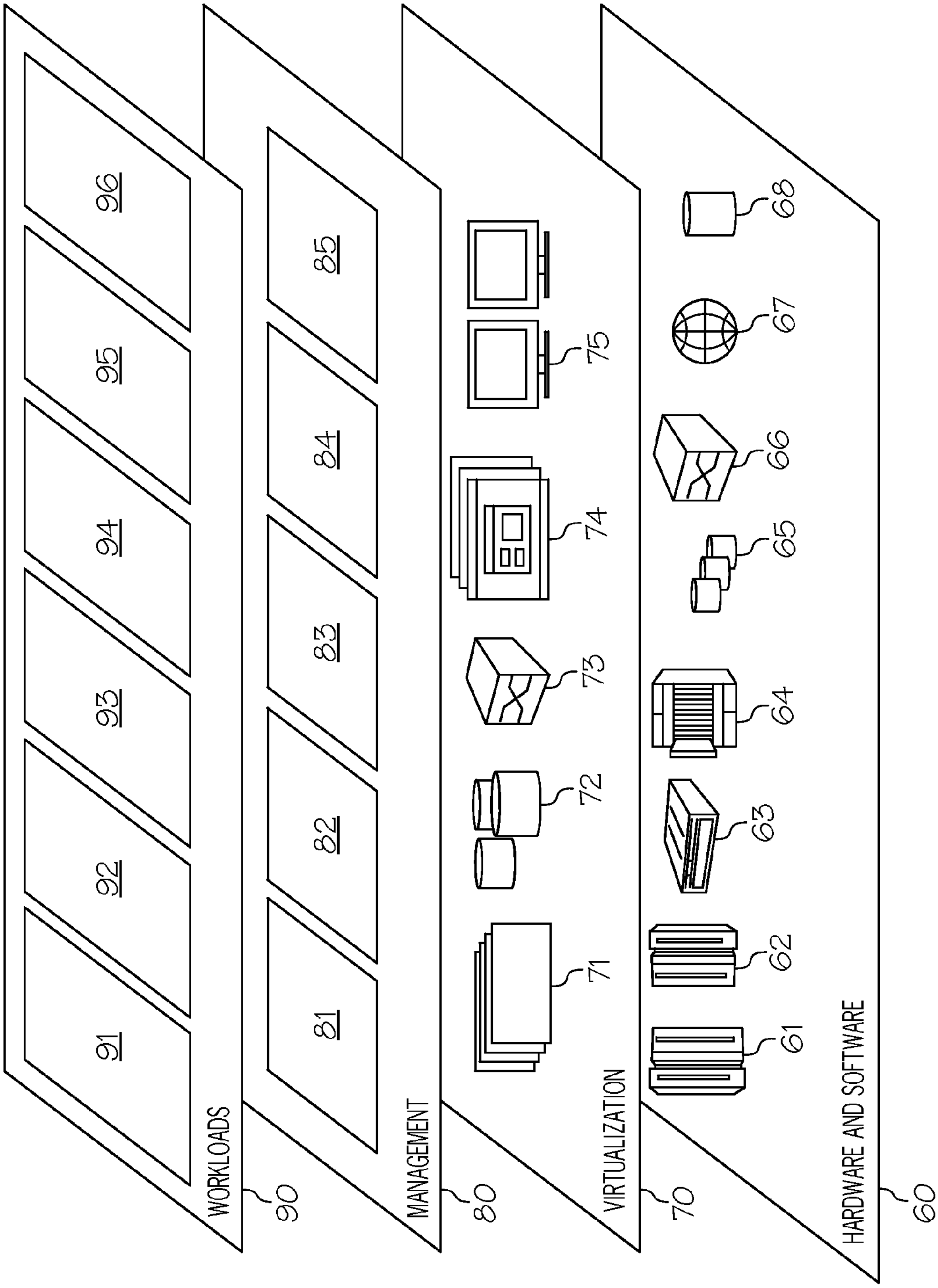

WORKLOADS
90
91
92
93
94
95
96
MANAGEMENT
80
81
82
83
84
85
VIRTUALIZATION
70
71
72
73
74
75
HARDWARE AND SOFTWARE
60
61
62
63
64
65
66
67
68

FIG. 10

# CONTROLLING SPACING OF SELF-DRIVING VEHICLES BASED ON SOCIAL NETWORK RELATIONSHIPS

## BACKGROUND

**[0001]** The present disclosure relates to the field of vehicles, and specifically to the field of self-driving vehicles. Still more specifically, the present disclosure relates to the field of controlling spacing between self-driving vehicles based on social network relationships between passengers in the self-driving vehicles.

**[0002]** Self-driving vehicles (SDVs) are vehicles that are able to autonomously drive themselves through private and/or public spaces. Using a system of sensors that detect the location and/or surroundings of the SDV, logic within or associated with the SDV controls the speed, propulsion, braking, and steering of the SDV based on the sensor-detected location and surroundings of the SDV.

## SUMMARY

**[0003]** In one or more embodiments of the present invention, a method and or computer program product control a physical spacing between self-driving vehicles (SDVs). One or more processors receive a social network node graph. The social network node graph describes a graphical distance between a first node on the social network node graph and a second node on the social network node graph. The first node represents a first passenger in a first SDV; the second node represents a second passenger in a second SDV; and the graphical distance between the first node and the second node describes a relationship level in a social network between the first passenger and the second passenger. An SDV on-board computer on at least one of the first SDV and the second SDV adjusts a physical spacing between the first SDV and the second SDV proportional to the graphical distance between the first node and the second node.

**[0004]** In an embodiment of the present invention, a self-driving vehicle includes a processor, a computer readable memory, and a non-transitory computer readable storage medium. Stored on the non-transitory computer readable storage medium are first and second program instructions. The first program instructions are designed to receive a social network node graph, which describes a graphical distance between a first node on the social network node graph and a second node on the social network node graph. The self-driving vehicle is a first self-driving vehicle (SDV), such that the first node represents a first passenger in a first SDV; the second node represents a second passenger in a second SDV; and the graphical distance between the first node and the second node describes a relationship level in a social network between the first passenger and the second passenger. The second program instructions are designed to direct an SDV on-board computer on the first SDV to adjust a physical spacing between the first SDV and the second SDV proportional to the graphical distance between the first node and the second node. Thus, the first and second program instructions are stored on the non-transitory computer readable storage medium for execution by one or more processors via the computer readable memory.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0005]** FIG. **1** depicts an exemplary system and network in which the present disclosure may be implemented;

**[0006]** FIG. **2** illustrates exemplary SDVs traveling on a roadway;

**[0007]** FIG. **3** illustrates the SDVs shown in FIG. **2** after being spatially repositioned according to social network relationships of passengers in the SDVs in accordance with one or more embodiments of the present invention;

**[0008]** FIG. **4** illustrates an exemplary social network node graph of passengers of one or more self-driving vehicles (SDVs);

**[0009]** FIG. **5** depicts additional detail of control hardware within an SDV;

**[0010]** FIG. **6** depicts communication linkages among SDVs and a coordinating server;

**[0011]** FIG. **7** is a high-level flow chart of one or more steps performed by one or more processors and/or other hardware devices to control a physical spacing between SDVs in accordance with one or more embodiments of the present invention;

**[0012]** FIG. **8** depicts a cloud computing node according to an embodiment of the present disclosure;

**[0013]** FIG. **9** depicts a cloud computing environment according to an embodiment of the present disclosure; and

**[0014]** FIG. **10** depicts abstraction model layers according to an embodiment of the present disclosure.

## DETAILED DESCRIPTION

**[0015]** The present invention may be a system, a method, and/or a computer program product. The computer program product may include a computer readable storage medium (or media) having computer readable program instructions thereon for causing a processor to carry out aspects of the present invention.

**[0016]** The computer readable storage medium can be a tangible device that can retain and store instructions for use by an instruction execution device. The computer readable storage medium may be, for example, but is not limited to, an electronic storage device, a magnetic storage device, an optical storage device, an electromagnetic storage device, a semiconductor storage device, or any suitable combination of the foregoing. A non-exhaustive list of more specific examples of the computer readable storage medium includes the following: a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a static random access memory (SRAM), a portable compact disc read-only memory (CD-ROM), a digital versatile disk (DVD), a memory stick, a floppy disk, a mechanically encoded device such as punch-cards or raised structures in a groove having instructions recorded thereon, and any suitable combination of the foregoing. A computer readable storage medium, as used herein, is not to be construed as being transitory signals per se, such as radio waves or other freely propagating electromagnetic waves, electromagnetic waves propagating through a waveguide or other transmission media (e.g., light pulses passing through a fiber-optic cable), or electrical signals transmitted through a wire.

**[0017]** Computer readable program instructions described herein can be downloaded to respective computing/processing devices from a computer readable storage medium or to an external computer or external storage device via a network, for example, the Internet, a local area network, a wide area network and/or a wireless network. The network may comprise copper transmission cables, optical transmission fibers, wireless transmission, routers, firewalls, switches, gateway computers and/or edge servers. A network adapter card or network interface in each computing/processing device receives computer readable program instructions from the network and forwards the computer readable program instructions for storage in a computer readable storage medium within the respective computing/processing device.

**[0018]** Computer readable program instructions for carrying out operations of the present invention may be assembler instructions, instruction-set-architecture (ISA) instructions, machine instructions, machine dependent instructions, microcode, firmware instructions, state-setting data, or either source code or object code written in any combination of one or more programming languages, including an object oriented programming language such as Java, Smalltalk, C++ or the like, and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The computer readable program instructions may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider). In some embodiments, electronic circuitry including, for example, programmable logic circuitry, field-programmable gate arrays (FPGA), or programmable logic arrays (PLA) may execute the computer readable program instructions by utilizing state information of the computer readable program instructions to personalize the electronic circuitry, in order to perform aspects of the present invention.

**[0019]** Aspects of the present invention are described herein with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems), and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer readable program instructions.

**[0020]** These computer readable program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks. These computer readable program instructions may also be stored in a computer readable storage medium that can direct a computer, a programmable data processing apparatus, and/or other devices to function in a particular manner, such that the computer readable storage medium having instructions stored therein comprises an article of manufacture including instructions which implement aspects of the function/act specified in the flowchart and/or block diagram block or blocks.

**[0021]** The computer readable program instructions may also be loaded onto a computer, other programmable data processing apparatus, or other device to cause a series of operational steps to be performed on the computer, other programmable apparatus or other device to produce a computer implemented process, such that the instructions which execute on the computer, other programmable apparatus, or other device implement the functions/acts specified in the flowchart and/or block diagram block or blocks.

**[0022]** The flowchart and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products according to various embodiments of the present invention. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of instructions, which comprises one or more executable instructions for implementing the specified logical function(s). In some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts or carry out combinations of special purpose hardware and computer instructions.

**[0023]** With reference now to the figures, and in particular to FIG. **1**, there is depicted a block diagram of an exemplary system and network that may be utilized by and/or in the implementation of the present invention. Some or all of the exemplary architecture, including both depicted hardware and software, shown for and within computer **101** may be utilized by software deploying server **149** shown in FIG. **1**, and/or coordinating computer **201** shown in FIG. **2**, and/or a self-driving vehicle (SDV) on-board computer **501** shown in FIG. **5**, and/or a coordinating server **601** depicted in FIG. **6**.

**[0024]** Exemplary computer **101** includes a processor **103** that is coupled to a system bus **105**. Processor **103** may utilize one or more processors, each of which has one or more processor cores. A video adapter **107**, which drives/supports a display **109**, is also coupled to system bus **105**. System bus **105** is coupled via a bus bridge **111** to an input/output (I/O) bus **113**. An I/O interface **115** is coupled to I/O bus **113**. I/O interface **115** affords communication with various I/O devices, including a keyboard **117**, a mouse **119**, a media tray **121** (which may include storage devices such as CD-ROM drives, multi-media interfaces, etc.), a transceiver **123** (capable of transmitting and/or receiving electronic communication signals), and external USB port(s) **125**. While the format of the ports connected to I/O interface **115** may be any known to those skilled in the art of computer architecture, in one embodiment some or all of these ports are universal serial bus (USB) ports.

**[0025]** As depicted, computer **101** is able to communicate with a software deploying server **149** and/or other devices/systems (e.g., establishing communication among SDV **202**, SDV **204**, SDV **206**, and/or coordinating server **601** depicted in the figures below) using a network interface **129**. Network interface **129** is a hardware network interface, such as a network interface card (NIC), etc. Network **127** may be an external network such as the Internet, or an internal network such as an Ethernet or a virtual private network (VPN). In one or more embodiments, network **127** is a wireless network, such as a Wi-Fi network, a cellular network, etc.

**[0026]** A hard drive interface **131** is also coupled to system bus **105**. Hard drive interface **131** interfaces with a hard drive **133**. In one embodiment, hard drive **133** populates a system memory **135**, which is also coupled to system bus **105**. System memory is defined as a lowest level of volatile memory in computer **101**. This volatile memory includes additional higher levels of volatile memory (not shown), including, but not limited to, cache memory, registers and buffers. Data that populates system memory **135** includes computer **101**'s operating system (OS) **137** and application programs **143**.

**[0027]** OS **137** includes a shell **139**, for providing transparent user access to resources such as application programs **143**. Generally, shell **139** is a program that provides an interpreter and an interface between the user and the operating system. More specifically, shell **139** executes commands that are entered into a command line user interface or from a file. Thus, shell **139**, also called a command processor, is generally the highest level of the operating system software hierarchy and serves as a command interpreter. The shell provides a system prompt, interprets commands entered by keyboard, mouse, or other user input media, and sends the interpreted command(s) to the appropriate lower levels of the operating system (e.g., a kernel **141**) for processing. While shell **139** is a text-based, line-oriented user interface, the present invention will equally well support other user interface modes, such as graphical, voice, gestural, etc.

**[0028]** As depicted, OS **137** also includes kernel **141**, which includes lower levels of functionality for OS **137**, including providing essential services required by other parts of OS **137** and application programs **143**, including memory management, process and task management, disk management, and mouse and keyboard management.

**[0029]** Application programs **143** include a renderer, shown in exemplary manner as a browser **145**. Browser **145** includes program modules and instructions enabling a world wide web (WWW) client (i.e., computer **101**) to send and receive network messages to the Internet using hypertext transfer protocol (HTTP) messaging, thus enabling communication with software deploying server **149** and other systems.

**[0030]** Application programs **143** in computer **101**'s system memory (as well as software deploying server **149**'s system memory) also include Logic for Managing Self-Driving Vehicles (LMSDV) **147**. LMSDV **147** includes code for implementing the processes described below, including those described in FIGS. **2-7**. In one embodiment, computer **101** is able to download LMSDV **147** from software deploying server **149**, including in an on-demand basis, wherein the code in LMSDV **147** is not downloaded until needed for execution. In one embodiment of the present invention, software deploying server **149** performs all of the functions associated with the present invention (including execution of LMSDV **147**), thus freeing computer **101** from having to use its own internal computing resources to execute LMSDV **147**.

**[0031]** Also within computer **101** is a positioning system **151**, which determines a real-time current location of computer **101** (particularly when part of an emergency vehicle and/or a self-driving vehicle as described herein). Positioning system **151** may be a combination of accelerometers, speedometers, etc., or it may be a global positioning system (GPS) that utilizes space-based satellites to provide triangulated signals used to determine two-dimensional or three-dimensional locations.

**[0032]** Also associated with computer **101** are sensors **153**, which detect an environment of the computer **101**. More specifically, sensors **153** are able to detect vehicles, road obstructions, pavement, etc. For example, if computer **101** is on board a self-driving vehicle (SDV), then sensors **153** may be cameras, radar transceivers, etc. that allow the SDV to detect the environment (e.g., other vehicles, road obstructions, pavement, etc.) of that SDV, thus enabling it to be autonomously self-driven. Similarly, sensors **153** may be cameras, thermometers, moisture detectors, etc. that detect ambient weather conditions and other environmental conditions of a roadway upon which the SDV is traveling.

**[0033]** The hardware elements depicted in computer **101** are not intended to be exhaustive, but rather are representative to highlight essential components required by the present invention. For instance, computer **101** may include alternate memory storage devices such as magnetic cassettes, digital versatile disks (DVDs), Bernoulli cartridges, and the like. These and other variations are intended to be within the spirit and scope of the present invention.

**[0034]** With reference now to FIG. **2**, an exemplary self-driving vehicle (SDV) **202**, SDV **204**, and SDV **206** are depicted traveling along a roadway **208** in accordance with one or more embodiments of the present invention. Roadway **208** may be a public roadway, a private roadway, a parking lot, a paved road, an unpaved road, and/or any other surface capable of supporting vehicles, which may be wheeled (e.g., cars), tracked (e.g., trains), or a combination thereof.

**[0035]** As depicted in FIG. **2**, initially SDV **202** is traveling close to SDV **204**, but distant from SDV **206**. However, as described herein, occupants/passengers of the different SDVs (i.e., any passenger of the SDVs, including the nominal driver, non-driving passengers, pets, etc.) may be related according to a social network node graph.

**[0036]** For example, consider FIG. **4**, which shows a social network node graph **400** for passengers in the SDVs **202/204/206** shown in FIG. **2**. A social network is defined as a social structure made up of entities, whose relationships are identified according to relationship levels, which are defined by dyadic ties. For example, in social network node graph **400**, social network nodes **402/404/406/408** depict various relationship levels in a social network of passengers of the SDVs **202/204/206** shown in FIG. **2**.

**[0037]** For example and as shown in FIG. **4**, social network node **402** for a first passenger of the SDV **202** shown in FIG. **2** is directly connected to the social network node **406** for any passenger of the SDV **206** shown in FIG. **2** by dyadic tie **410**, indicating that these two entities have a "first order" relationship level. That is, there is only one "hop" (connection distance) from social network node **402** to social network node **406**. This single hop relationship level is due to the first passenger of SDV **202** being in a first level circle of friends with the passenger of SDV **206**. In accordance with various embodiments of the present invention, this first level circle of friends is the result of 1) the first passenger of the SDV **202** and the (i.e., any) passenger of the SDV **206** having directly agreed to be "friends" in the social network; 2) the first passenger of the SDV **202** and the (i.e., any) passenger of the SDV **206** being in a same social network group, such as a common group of persons working on a same project, fans of a same team, residents of a same city, etc.; 3) the first passenger of the SDV **202** and the (i.e., any) passenger of the SDV **206** both being members of a same dating service; 4) the first passenger of the SDV **202** and the (i.e., any) passenger of the SDV **206** both being members of an emergency relief team (e.g., volunteer firefighters); 5) the first passenger of the SDV **202** and the (i.e., any) passenger of the SDV **206** both being members of a same family; and/or 6) any other dyadic (i.e., one-to-one) relationship defined by the social network that relates the first passenger of the SDV **202** and the (i.e., any) passenger of the SDV **206** to one another.

**[0038]** As shown in FIG. **4**, the social network node **402** for the first passenger of the SDV **202** is not directly tied to the social network node **404** for the (i.e., any) passenger of the SDV **204** shown in FIG. **2**. Rather, social network node **406** is directly connected to social network node **404** by dyadic tie **412**, thus giving the passenger of the SDV **206** and the (i.e., any) passenger of the SDV **204** a relationship level that is "first order". This leads to the first passenger of the SDV **202** having a "second order" relationship with the (i.e., any) passenger of the SDV **204**, as indicated by the two "hops" (e.g., based on dyadic tie **410** and dyadic tie **412**) between social network node **402** and social network node **404**.

**[0039]** For example, the first passenger of the SDV **202** may be a member of a first group of persons in the social network as is the passenger of SDV **206**. Similarly, the passenger of the SDV **206** may be a member of a second group of persons in the social network as is the passenger of the SDV **204**. However, the first passenger of the SDV **202** is not a member of the second group, and therefore has a "second order" relationship with the passenger of the SDV **204**. For example, these two persons (riding in SDV **202** and **204**) may have a mutual friend (the passenger of SDV **206**), but are not directly friends with one another. The present invention utilizes these social network node graphical ties to determine how closely SDVs are positioned to one another.

**[0040]** As described herein, the social network relationships between passenger(s) in SDV **202** and passenger(s) in SDV **204** are used to determine how physically close SDV **202** and SDV **204** are to one another. Thus, in one or more embodiments these relationships are not one-to-one (i.e., between one passenger in SDV **202** and one passenger in SDV **204**), but are based on multiple passengers in SDV **202** and/or SDV **204**.

**[0041]** In one embodiment, the social relationships between multiple passengers are additive. That is, the number of "hops" between nodes in a social network graph (described herein) for all of the passengers are merely added together in order to determine the physical spacing between SDV **202** and SDV **204**. In another embodiment, however the social relationships are weighted. For example, if the driver of SDV **202** and the driver of SDV **204** are the only two persons of interest, then the number of "hops" between nodes in the social network graph for other passengers in SDVs **202**/**204** are irrelevant, and only the number of "hops" between nodes in the social network graph for the drivers of SDVs **202**/**204** are considered. Alternatively, the weighting may be proportional, such that the number of "hops" on the social network for certain pairs of passengers from SDVs **202**/**204** are weighted more heavily than other pairs of passengers from SDVs **202**/**204**, such that the more heavily weighted pairs of passengers from SDVs **202**/**204** have a greater impact on the physical spacing between SDVs **202**/**204**.

**[0042]** Returning now to FIG. **2**, as described in FIG. **4** the first passenger of SDV **202** is closely aligned in a social network with the passenger of SDV **206**, but is less closely aligned with the passenger of SDV **204**. The present invention utilizes this social network relational alignment to determine how closely together SDVs **202**/**204**/**206** are positioned relative to one another. That is, there is a proportional relationship between how far apart nodes on a social network node graph are and the physical spacing distance between SDVs.

**[0043]** Thus, as shown in FIG. **4**, since the social network node **402** is graphically/logically close to the social network node **406** (i.e., there is only a single dyadic tie **410** between these two nodes), then SDV **202** and SDV **206** are repositioned in FIG. **3** to be physically close to one another. Furthermore, since the social network node **402** in FIG. **4** is distant from the social network node **404** (i.e., there are two "hops" between these nodes as depicted by dyadic tie **410** and dyadic tie **412**), then SDV **202** and SDV **204** are repositioned in FIG. **3** to be physically spaced farther in FIG. **3** as compared to FIG. **2**. In one or more embodiments of the preset invention, this repositioning is performed autonomously by the SDV(s) utilizing the SDV on-board computer **501** and/or SDV control processor **503** depicted in FIG. **5**.

**[0044]** In one or more embodiments of the present invention, the physical spacing between SDVs and the logical/graphical distance between social network node graph nodes is linear. For example, each "hop" between social network node graph nodes (i.e., each dyadic tie) may map to a certain physical distance between SDVs (e.g., 0.1 kilometer). In this example, the present invention would maintain the physical distance between SDV **202** and SDV **206** at 0.1 kilometer, the physical distance between SDV **206** and SDV **204** at 0.1 kilometer, and the physical distance between SDV **202** and SDV **204** at 2.0 kilometers. This allows passengers in SDV **202** to be able to see passengers in SDV **206** and passengers in SDV **202** to be able to see passengers in SDV **204**, and to arrive at their destination as essentially the same time.

**[0045]** Alternatively, the physical spacing/hop relationship may be on a sliding scale. For example, if there is only one hop between a first social network node (e.g., social network node **402** shown in FIG. **4**) and a second social network node (e.g., social network node **406**), then the physical separation between corresponding SDV **402** and SDV **406** may be 100 meters. However, if there are two hops between a first social network node (e.g., social network node **402** shown in FIG. **4**) and a second social network node (e.g., social network node **404**), then the physical separation between corresponding SDV **402** and SDV **404** may be 1 kilometer. In one or more embodiments of the present invention, the physical separation is controlled by the SDV on-board computer **501** shown in FIG. **5**, either autonomously or under the direction of the coordinating server **601** shown in FIG. **6**.

**[0046]** Thus, the present invention does not physically "cluster" SDVs based just on passengers of SDVs being in a same social network, but rather establishes the physical distance between SDVs based on the relationship level in the social network (e.g., one hop first order, two hop second order, etc.) of the passengers of the different SDVs.

**[0047]** The physical spacing between SDVs may be further adjusted based on current conditions of the roadway **208**, including weather conditions, traffic conditions, construction events, accident events, etc., can be determined and transmitted by a coordinating computer **201**. That is, coordinating computer **201** is able to determine current roadway conditions based on internal sensors **153** shown in FIG. **1**, and/or roadway sensor(s) **210** (e.g., mechanical, visual, and/or electrical sensors that are able to detect the number and speed of vehicles traveling on the roadway **208**, the amount and/or type of precipitation on the roadway **208**, the temperature of the roadway **208** and/or ambient air around the roadway **208**, the movement of vehicles traveling along roadway **208**, etc.), as well as information received from sensors and/or on-board computers within SDVs **202**/**204**/**206**, and/or from information received by an information service (e.g., a weather station). In one or more embodiments, these roadway conditions are utilized in establishing spacing distances and/or operational/driving modes of one or more of the SDVs **202**/**204**/**206**.

**[0048]** In accordance with various embodiments of the present invention, at least one of the SDVs **202**/**204**/**206** operates in autonomous mode, such that spacing distances are automatically adjusted by on-board hardware, even if one or more of the SDVs **202**/**204**/**206** are being driven in manual mode. The terms "manual mode" or "autonomous mode" are referred to as either an operational mode or a driving mode, such that the terms "operational mode" and "driving mode" are synonymous and interchangeable.

**[0049]** As used and described herein, "manual mode" is defined as an SDV being at least partially under the input control of a human driver. That is, if exemplary SDV **202** is being steered by a human driver but has cruise control activated, then it is in manual mode, since SDV **202** is partially under the input control (steering) of the human driver. Thus, while in manual mode, SDV **202** operates as a traditional motor vehicle, in which a human driver controls the engine throttle, engine on/off switch, steering mechanism, braking system, horn, signals, etc. found on a motor vehicle. These vehicle mechanisms may be operated in a "drive-by-wire" manner, in which inputs to an SDV control processor **503** (shown in FIG. **5**) by the driver result in output signals that control the SDV vehicular physical control mechanisms **505** (e.g., the engine throttle, steering mechanisms, braking systems, turn signals, etc.).

**[0050]** As used and described herein, "autonomous mode" is defined as an SDV being totally controlled by hardware/software logic (e.g., SDV on-board computer **501** and/or operational mode device **507** and/or SDV control processor **503** shown in FIG. **5**) without inputs from the human driver. That is, if steering, braking, throttle control, obstacle/vehicle avoidance, etc. are all under the control of hardware/software logic such as the SDV on-board computer **501** shown in FIG. **5**, then SDV **202** is in an autonomous mode.

**[0051]** Additional details of one or more embodiments of the SDV **202** (which may have a same architecture as SDV **204** and/or SDV **206**) are presented in FIG. **5**. As shown in FIG. **5**, SDV **202** has an SDV on-board computer **501** that controls operations of the SDV **202**. According to directives from a operational mode device **507**, the SDV **202** can be selectively operated in manual mode or autonomous mode (including the nominal autonomous mode, evasive autonomous mode, and/or stopping autonomous mode described above). In a preferred embodiment, operational mode device **507** is a dedicated hardware device that selectively directs the SDV on-board computer **501** to operate the SDV **202** in one of the autonomous modes or in the manual mode.

**[0052]** While in autonomous mode, SDV **202** operates without the input of a human driver, such that the engine, steering mechanism, braking system, horn, signals, etc. are controlled by the SDV control processor **503**, which is now under the control of the SDV on-board computer **501**. That is, by the SDV on-board computer **501** processing inputs taken from navigation and control sensors **509** and the operational mode device **507** (indicating that the SDV **202** is to be controlled autonomously), then driver inputs to the SDV control processor **503** and/or SDV vehicular physical control mechanisms **505** are no longer needed.

**[0053]** As just mentioned, the SDV on-board computer **501** uses outputs from navigation and control sensors **509** to control the SDV **202**. Navigation and control sensors **509** include hardware sensors that 1) determine the location of the SDV **202**; 2) sense other cars and/or obstacles and/or physical structures around SDV **202**; 3) measure the speed and direction of the SDV **202**; and 4) provide any other inputs needed to safely control the movement of the SDV **202**.

**[0054]** With respect to the feature of 1) determining the location of the SDV **202**, this can be achieved through the use of a positioning system such as positioning system **151** shown in FIG. **1**. Positioning system **151** may use a global positioning system (GPS), which uses space-based satellites that provide positioning signals that are triangulated by a GPS receiver to determine a 3-D geophysical position of the SDV **202**. Positioning system **151** may also use, either alone or in conjunction with a GPS system, physical movement sensors such as accelerometers (which measure rates of changes to a vehicle in any direction), speedometers (which measure the instantaneous speed of a vehicle), airflow meters (which measure the flow of air around a vehicle), etc. Such physical movement sensors may incorporate the use of semiconductor strain gauges, electromechanical gauges that take readings from drivetrain rotations, barometric sensors, etc.

**[0055]** With respect to the feature of 2) sensing other cars and/or obstacles and/or physical structures around SDV **202**, the positioning system **151** may use radar or other electromagnetic energy that is emitted from an electromagnetic radiation transmitter (e.g., transceiver **523** shown in FIG. **3**), bounced off a physical structure (e.g., another car), and then received by an electromagnetic radiation receiver (e.g., transceiver **523**). By measuring the time it takes to receive back the emitted electromagnetic radiation, and/or evaluating a Doppler shift (i.e., a change in frequency to the electromagnetic radiation that is caused by the relative movement of the SDV **202** to objects being interrogated by the electromagnetic radiation) in the received electromagnetic radiation from when it was transmitted, the presence and location of other physical objects can be ascertained by the SDV on-board computer **501**.

**[0056]** With respect to the feature of 3) measuring the speed and direction of the SDV **202**, this can be accomplished by taking readings from an on-board speedometer (not depicted) on the SDV **202** and/or detecting movements to the steering mechanism (also not depicted) on the SDV **202** and/or the positioning system **151** discussed above.

**[0057]** With respect to the feature of 4) providing any other inputs needed to safely control the movement of the

SDV **202**, such inputs include, but are not limited to, control signals to activate a horn, turning indicators, flashing emergency lights, etc. on the SDV **202**.

**[0058]** In one or more embodiments of the present invention, SDV **202** includes roadway sensors **511** that are coupled to the SDV **202**. Roadway sensors **511** may include sensors that are able to detect the amount of water, snow, ice on the roadway **208** (e.g., using cameras, heat sensors, moisture sensors, thermometers, etc.). Roadway sensors **511** also include sensors that are able to detect "rough" roadways (e.g., roadways having potholes, poorly maintained pavement, no paving, etc.) using cameras, vibration sensors, etc. Roadway sensors **511** may also include sensors that are also able to detect how dark the roadway **208** is using light sensors.

**[0059]** Similarly, a dedicated camera **521** can be trained on roadway **208**, in order to provide photographic images capable of being evaluated, thereby recognizing erratic vehicular operations. For example, sequences of photographic images can show the velocity and any change in direction of EDV **204**, thus providing the recognition of the erratic/unsafe driving pattern for EDV **204**.

**[0060]** Similarly, a dedicated object motion detector **519** (e.g., a radar transceiver capable of detecting Doppler shifts indicative of the speed and direction of movement of EDV **204**) can be trained on roadway **208**, in order to detect the movement of other vehicles, such as SDVs **204/206** depicted in FIG. **2**.

**[0061]** In one or more embodiments of the present invention, also within the SDV **202** are SDV equipment sensors **515**. SDV equipment sensors **515** may include cameras aimed at tires on the SDV **202** to detect how much tread is left on the tire. SDV equipment sensors **515** may include electronic sensors that detect how much padding is left of brake calipers on disk brakes. SDV equipment sensors **515** may include drivetrain sensors that detect operating conditions within an engine (e.g., power, speed, revolutions per minute—RPMs of the engine, timing, cylinder compression, coolant levels, engine temperature, oil pressure, etc.), the transmission (e.g., transmission fluid level, conditions of the clutch, gears, etc.), etc. SDV equipment sensors **515** may include sensors that detect the condition of other components of the SDV **202**, including lights (e.g., using circuitry that detects if a bulb is broken), wipers (e.g., using circuitry that detects a faulty wiper blade, wiper motor, etc.), etc.

**[0062]** In one or more embodiments of the present invention, also within SDV **202** is a communications transceiver **517**, which is able to receive and transmit electronic communication signals (e.g., RF messages) from and to other communications transceivers found in other vehicles, servers, monitoring systems, etc.

**[0063]** In one or more embodiments of the present invention, also within SDV **202** is a telecommunication device **525** (e.g., a smart phone, a cell phone, a laptop computer, etc.), which may be connected (e.g., via a near field communication—NFC connection) to the SDV on-board computer **501**. Thus, alerts regarding the repositioning of SDV **202** may be transmitted to a smart phone within the other SDVs **204/206** or an agency (e.g., a local fire fighting station).

**[0064]** While various SDVs may communicate directly with one another (e.g., as shown in FIG. **6** by SDV **202** directly communicating with SDV **204** and/or SDV **206**), in one embodiment all communication between SDVs is via a coordinating server **601** (analogous to coordinating computer **201** shown in FIG. **2**).

**[0065]** With reference now to FIG. **7**, a high-level flow chart of one or more steps performed by one or more processors and/or other hardware devices to control a physical spacing between self-driving vehicles (SDVs) in accordance with one or more embodiments of the present invention is presented. Note that various actions described for the present invention may be performed by the SDV on-board computer **501** shown in FIG. **5**, the monitoring computer **601** shown in FIG. **6**, and/or the cloud computing environment **50** shown in FIG. **9**.

**[0066]** After initiator block **702**, one or more processors (e.g., within SDV on-board computer **501** shown in FIG. **5**) receive a social network node graph, as depicted in block **704**. The social network node graph (e.g., social network node graph **400** shown in FIG. **4**) describes a graphical distance between a first node on the social network node graph (e.g., social network node **402** shown in FIG. **4**) and a second node on the social network node graph (e.g., social network node **406**). As described herein and in an exemplary embodiment of the present invention, wherein the first node represents a first passenger in a first SDV (e.g., SDV **202** shown in FIG. **2**); the second node represents a second passenger in a second SDV (e.g., SDV **206** shown in FIG. **2**); and the graphical distance (i.e., number of "hops", number of dyadic ties) between the first node and the second node describes a relationship level in a social network between the first passenger and the second passenger.

**[0067]** As described in block **706**, an SDV on-board computer (e.g., SDV on-board computer **501** shown in FIG. **5**) on at least one of the first SDV and the second SDV adjusts a physical spacing between the first SDV and the second SDV proportional to the graphical distance between the first node and the second node. That is, the greater the graphical distance between the two nodes on the social network node graph, the greater the physical spacing distance between the two SDVs.

**[0068]** The flow-chart ends at terminator block **708**.

**[0069]** In an embodiment of the present invention, the SDV on-board computer on the first SDV and/or the second SDV alter a route of travel of the first and/or second SDVs based on the relationship level between the first passenger and the second passenger. For example, assume that the passenger of SDV **202** and the passenger of SDV **206** are both fans of public sculptures, as indicated by these two passengers both being members of a social network group devoted to public sculptures. Assume further that SDV **202** and SDV **206** are both traveling on an interstate highway en route to a museum. However, between the current location of SDVs **202/206** and the museum is a popular group of public sculptures, which are located on a side road. Leaving the interstate highway and taking this side road may add five minutes to the trip to the museum, but it would allow the passengers of the SDVs **202/206** to view the public sculptures, which (due to their membership in the social networking group dedicated to public sculptures) is likely to be of great interest to them. Thus, the system will 1) suggest the alternate route to the passengers of the SDVs **202/206** (e.g., via their smart phones) and 2) upon receipt of a signal/message indicating an interest in seeing the public sculptures, will automatically alter the travel route to take the "scenic" side road.

**[0070]** In an embodiment of the present invention, the social network node graph (e.g., social network node graph **400** shown in FIG. **4**) further describes a graphical distance between a third node on the social network node graph (e.g., social network node **408**) and the second node on the social network node graph (social network node **406**). That is, there are two social network nodes (e.g., social network nodes **402**/**408** shown in FIG. **4**) for two different passengers in SDV **202**, and one social network node **406** for the passenger in SDV **206**. Thus, the first node (e.g., social network node **402** represents the first passenger in SDV **402**); the third node (e.g., social network node **408**) represents the third passenger in the first SDV **202**; and the second node (e.g., social network node **406**) represents the passenger in the second SDV **206**.

**[0071]** As shown in FIG. **4**, the graphical distance between the third node (e.g., social network node **408**) and the second node (e.g., social network node **406**) describes a relationship level in the social network between the third passenger and the second passenger. For example, if the second passenger in SDV **206** and the third passenger in SDV **202** are both in a same social circle in the social network (as indicated by dyadic tie **414** in FIG. **4**), then the first passenger in the SDV **202** and the third passenger in the SDV **202** both have a first order (single "hop") relationship with the second passenger of SDV **206** (as indicated by the single dyadic ties **410**/**414**). However, if the third passenger of SDV **202** is only associated with the second passenger of SDV **206** based on the relationship between the first passenger of SDV **202** and the third passenger of SDV **202** (as indicated by dyadic tie **416**), then the relationship between the third passenger of SDV **202** and the passenger of SDV **206** is weaker (i.e., is a two-hop relationship) than the relationship between the first passenger of SDV **202** and the second passenger of SDV **206** (which is a one-hop relationship).

**[0072]** Thus, in one or more embodiments in the scenario just described, one or more processors weight the first node (e.g., social network node **402** in FIG. **4**) and the third node (e.g., social network node **408**) based on the relationship level in the social network between the first passenger and the second passenger versus the relationship level in the social network between the third passenger and the second passenger. An SDV on-board computer on at least one of the first SDV and the second SDV then adjust a physical spacing between the first SDV and the second SDV based on the weighted first and third nodes. For example, if social network node **408** is associated with social network node **406** via a combination of dyadic tie **416** and dyadic tie **410** depicted in FIG. **4**, then social network node **408** will have little if any impact on the positioning of SDV **206** relative to SDV **202**, since it is the one-hop relationship between social network node **402** and social network node **406** that controls this SDV physical spacing.

**[0073]** However, assume now that social network node **408** has a single hop relationship with social network node **404**, as indicated by dyadic tie **418**. In this case, there will be a tension between which SDV (SDV **206** or SDV **204**) is moved closer to SDV **202**, since the two passengers in SDV **202** have one hop relationships with passengers in the two other SDVs (SDV **204** and SDV **206**).

**[0074]** In one or more embodiments of the present invention, a weighted voting system is used to weight the various variables used in making the decision to establish spacing distances between SDVs and/or to adjust their routes, particularly in the scenario just described in which two social network nodes have a same logical/graphical distance to another social network node. Such inputs may include: votes by other nearby cars (i.e., occupants of other SDVs that vote on which passenger in SDV **202** shown determines the positioning of SDVs **204**/**206**), a history of the efficiency of positioning certain SDVs in proximity of another SDV, etc. Such weighted voting approaches may be characterized primarily by three aspects—the inputs, the weights, and the quota. The inputs are (I1, I2, . . . , IN). N denotes the total number of inputs. An input's weight (w) is the number of "votes" associated with the input. The quota (q) is the minimum number of votes required to "pass a motion," which in this case refers primarily to a decision made regarding into the distance placed between SDVs on a roadway.

**[0075]** In an embodiment of the present invention, roadway sensors are used to adjust the physical spacing between the first SDV and the second SDV. For example, if the roadway **208** is wet, then physical spacing between SDV **202** and SDV **206** will be expanded from the physical spacing that would be allocated if the roadway **208** were dry.

**[0076]** In an embodiment of the present invention, roadway sensors are used to determine which operational mode to use on one or more of the SDVs discussed herein. For example, assume that a roadway sensor (e.g., one or more of roadway sensor(s) **210** shown in FIG. **2** and/or one or more of the roadway sensors **511** shown in FIG. **5**) detect a current roadway condition of a roadway upon which the first SDV is traveling (e.g., wet, icy, dark, etc.). Based on the sensor readings from such roadway sensors, an operational mode device **507** in FIG. **5** on the first SDV adjusts an operational mode (e.g., autonomous or manual) of the first SDV.

**[0077]** Thus, assume again that the SDV **202** shown in FIG. **2** is traveling on a roadway (e.g., roadway **208** shown in FIG. **2**). One or more processors (e.g., within SDV on-board computer **501**) receive sensor readings from multiple sensors (e.g., roadway sensor(s) **210** shown in FIG. **2**). In one embodiment, each of the multiple sensors detects a different type of current condition of the roadway. Based on the sensor readings (and thus the current roadway condition of the roadway), the SDV on-board computer (e.g., SDV on-board computer **501** shown in FIG. **5**) further adjusts the physical spacing between SDV **202** and other SDVs on the roadway. For example, if the roadway conditions are clear and dry, then the SDV on-board computer may cause the SDV to minimize the spacing. However, if the roadway conditions are dark and/or icy, then the SDV on-board computer may increase the amount of physical space between SDV **202** and other SDVs on the roadway.

**[0078]** In an embodiment of the present invention, the processor(s) weight each of the sensor readings for different current conditions of the roadway (e.g., snow on the roadway is weighted higher than rain on the roadway, but less than ice on the roadway). The processor(s) sum the weighted sensor readings for the different current conditions of the roadway, and determine whether the summed weighted sensor readings exceed a predefined level (e.g., some particular numerical value). In response to determining that the summed weighted sensor readings exceed a predefined level, the on-board SDV control processor adjusts the physical space between the SDV and other SDV(s) accordingly.

**[0079]** In one embodiment of the present invention, a decision to place the SDV (e.g., one or more of the SDVs

**202/204/206** described herein) into autonomous mode or manual mode is based on the driver of the SDV being part of a cohort of drivers that share certain traits. That is, in one embodiment of the present invention assume that the SDV **202** shown in FIG. **2** is traveling on roadway **210**. One or more processors (e.g., within coordinating computer **601** shown in FIG. **6**) retrieve driver profile information about the human driver of the SDV, and then assign the human driver of the SDV to a cohort of drivers traveling on the roadway in other vehicles (where the human driver of the SDV shares more than a predetermined quantity of traits with members of the cohort of drivers). The processor(s) retrieve traffic pattern data for the other vehicles while traveling on the roadway, and examine that traffic pattern data to determine a first traffic flow of the multiple vehicles (e.g., while operating in the autonomous mode described above) and a second traffic flow of the multiple SDVs (while operating in the manual mode described above). In response to determining that the first traffic flow has a lower accident rate than the second traffic flow, and assuming the SDV **202** is currently being operated in manual mode, the processor(s) change the operational mode of the SDV from manual mode to autonomous mode, since the data shows that autonomous mode is safer than manual mode in the present conditions.

**[0080]** In one embodiment of the present invention, the decision to place the SDV in manual or one of the autonomous modes described herein is further dependent on the current mechanical condition of the SDV (e.g., the condition of the tires, the condition of the brakes, the condition of the headlights, the condition of the windshield wipers, the condition of the engine, the condition of the transmission, the condition of the cooling system, etc.). Thus, one or more processor(s) (e.g., within the SDV on-board computer **501** shown in FIG. **5**) receive operational readings from one or more operational sensors (e.g., SDV equipment sensors **515** shown in FIG. **5**) on the SDV, which detect a current state of mechanical equipment on the SDV. Based on the received operational readings, the processor(s) detect a mechanical fault (e.g., faulty brakes, bald tires, etc.) with the mechanical equipment on the SDV. In response to detecting the mechanical fault with the mechanical equipment on the SDV, the operational mode device adjusts the operational mode of the SDV from manual mode to autonomous mode.

**[0081]** In one or more embodiments of the present invention, the operational mode device **507** along with the SDV on-board computer **501** shown in FIG. **5** provides a process for selectively switching between various types of autonomous modes and/or a manual mode. However, if such switching back and forth occurs too frequently, safety issues may arise. For example, if the operational mode device in FIG. **5** switches control of the SDV **202** from the manual mode to the autonomous mode, and then switches control of the SDV **202** back to the manual mode a few seconds later, the driver and/or SDV will likely become confused and/or ineffective.

**[0082]** Therefore, in one embodiment of the present invention, a predefined time limit and/or physical distance is set between switching back and forth between operational modes. For example, based on historical data that describes how long the current driver (and/or drivers from a cohort of drivers that have similar traits/characteristics as the current driver) needs to recover from relinquishing control of the SDV to the autonomous controller, the predefined time limit may be one minute. Similarly, based on historical data that describes how far the current driver must travel in order to recover from relinquishing control of the SDV to the autonomous controller, the predefined physical distance may be one mile. Therefore, if the system has switched from the manual mode to the autonomous mode, then one minute must pass and/or one mile must be traversed by the SDV before control can be returned back to the driver (e.g., manual mode is re-activated).

**[0083]** In one or more embodiments, the present invention is implemented in a cloud environment. It is understood in advance that although this disclosure includes a detailed description on cloud computing, implementation of the teachings recited herein are not limited to a cloud computing environment. Rather, embodiments of the present invention are capable of being implemented in conjunction with any other type of computing environment now known or later developed.

**[0084]** Cloud computing is a model of service delivery for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, network bandwidth, servers, processing, memory, storage, applications, virtual machines, and services) that can be rapidly provisioned and released with minimal management effort or interaction with a provider of the service. This cloud model may include at least five characteristics, at least three service models, and at least four deployment models.

**[0085]** Characteristics are as follows:

**[0086]** On-demand self-service: a cloud consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with the service's provider.

**[0087]** Broad network access: capabilities are available over a network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, laptops, and PDAs).

**[0088]** Resource pooling: the provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to demand. There is a sense of location independence in that the consumer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter).

**[0089]** Rapid elasticity: capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out and rapidly released to quickly scale in. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be purchased in any quantity at any time.

**[0090]** Measured service: cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported providing transparency for both the provider and consumer of the utilized service.

**[0091]** Service Models are as follows:

**[0092]** Software as a Service (SaaS): the capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-based e-mail). The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.

**[0093]** Platform as a Service (PaaS): the capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including networks, servers, operating systems, or storage, but has control over the deployed applications and possibly application hosting environment configurations.

**[0094]** Infrastructure as a Service (IaaS): the capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications, and possibly limited control of select networking components (e.g., host firewalls).

**[0095]** Deployment Models are as follows:

**[0096]** Private cloud: the cloud infrastructure is operated solely for an organization. It may be managed by the organization or a third party and may exist on-premises or off-premises.

**[0097]** Community cloud: the cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be managed by the organizations or a third party and may exist on-premises or off-premises.

**[0098]** Public cloud: the cloud infrastructure is made available to the general public or a large industry group and is owned by an organization selling cloud services.

**[0099]** Hybrid cloud: the cloud infrastructure is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load-balancing between clouds).

**[0100]** A cloud computing environment is service oriented with a focus on statelessness, low coupling, modularity, and semantic interoperability. At the heart of cloud computing is an infrastructure comprising a network of interconnected nodes.

**[0101]** Referring now to FIG. **8**, a schematic of an example of a cloud computing node is shown. Cloud computing node **10** is only one example of a suitable cloud computing node and is not intended to suggest any limitation as to the scope of use or functionality of embodiments of the invention described herein. Regardless, cloud computing node **10** is capable of being implemented and/or performing any of the functionality set forth hereinabove.

**[0102]** In cloud computing node **10** there is a computer system/server **12**, which is operational with numerous other general purpose or special purpose computing system environments or configurations. Examples of well-known computing systems, environments, and/or configurations that may be suitable for use with computer system/server **12** include, but are not limited to, personal computer systems, server computer systems, thin clients, thick clients, handheld or laptop devices, multiprocessor systems, microprocessor-based systems, set top boxes, programmable consumer electronics, network PCs, minicomputer systems, mainframe computer systems, and distributed cloud computing environments that include any of the above systems or devices, and the like.

**[0103]** Computer system/server **12** may be described in the general context of computer system-executable instructions, such as program modules, being executed by a computer system. Generally, program modules may include routines, programs, objects, components, logic, data structures, and so on that perform particular tasks or implement particular abstract data types. Computer system/server **12** may be practiced in distributed cloud computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed cloud computing environment, program modules may be located in both local and remote computer system storage media including memory storage devices.

**[0104]** As shown in FIG. **8**, computer system/server **12** in cloud computing node **10** is shown in the form of a general-purpose computing device. The components of computer system/server **12** may include, but are not limited to, one or more processors or processing units **16**, a system memory **28**, and a bus **18** that couples various system components including system memory **28** to processor **16**.

**[0105]** Bus **18** represents one or more of any of several types of bus structures, including a memory bus or memory controller, a peripheral bus, an accelerated graphics port, and a processor or local bus using any of a variety of bus architectures. By way of example, and not limitation, such architectures include Industry Standard Architecture (ISA) bus, Micro Channel Architecture (MCA) bus, Enhanced ISA (EISA) bus, Video Electronics Standards Association (VESA) local bus, and Peripheral Component Interconnects (PCI) bus.

**[0106]** Computer system/server **12** typically includes a variety of computer system readable media. Such media may be any available media that is accessible by computer system/server **12**, and it includes both volatile and non-volatile media, removable and non-removable media.

**[0107]** System memory **28** can include computer system readable media in the form of volatile memory, such as random access memory (RAM) **30** and/or cache memory **32**. Computer system/server **12** may further include other removable/non-removable, volatile/non-volatile computer system storage media. By way of example only, storage system **34** can be provided for reading from and writing to a non-removable, non-volatile magnetic media (not shown and typically called a "hard drive"). Although not shown, a magnetic disk drive for reading from and writing to a removable, non-volatile magnetic disk (e.g., a "floppy disk"), and an optical disk drive for reading from or writing to a removable, non-volatile optical disk such as a CD-ROM, DVD-ROM or other optical media can be provided. In such instances, each can be connected to bus **18** by one or more data media interfaces. As will be further depicted and described below, memory **28** may include at least one program product having a set (e.g., at least one) of program modules that are configured to carry out the functions of embodiments of the invention.

**[0108]** Program/utility **40**, having a set (at least one) of program modules **42**, may be stored in memory **28** by way of example, and not limitation, as well as an operating system, one or more application programs, other program modules, and program data. Each of the operating system, one or more application programs, other program modules, and program data or some combination thereof, may include an implementation of a networking environment. Program modules **42** generally carry out the functions and/or methodologies of embodiments of the invention as described herein.

**[0109]** Computer system/server **12** may also communicate with one or more external devices **14** such as a keyboard, a pointing device, a display **24**, etc.; one or more devices that enable a user to interact with computer system/server **12**; and/or any devices (e.g., network card, modem, etc.) that enable computer system/server **12** to communicate with one or more other computing devices. Such communication can occur via Input/output (I/O) interfaces **22**. Still yet, computer system/server **12** can communicate with one or more networks such as a local area network (LAN), a general wide area network (WAN), and/or a public network (e.g., the Internet) via network adapter **20**. As depicted, network adapter **20** communicates with the other components of computer system/server **12** via bus **18**. It should be understood that although not shown, other hardware and/or software components could be used in conjunction with computer system/server **12**. Examples, include, but are not limited to: microcode, device drivers, redundant processing units, external disk drive arrays, RAID systems, tape drives, and data archival storage systems, etc.

**[0110]** Referring now to FIG. **9**, illustrative cloud computing environment **50** is depicted. As shown, cloud computing environment **50** comprises one or more cloud computing nodes **10** with which local computing devices used by cloud consumers, such as, for example, personal digital assistant (PDA) or cellular telephone **54**A, desktop computer **54**B, laptop computer **54**C, and/or automobile computer system **54**N may communicate. Nodes **10** may communicate with one another. They may be grouped (not shown) physically or virtually, in one or more networks, such as Private, Community, Public, or Hybrid clouds as described hereinabove, or a combination thereof. This allows cloud computing environment **50** to offer infrastructure, platforms and/or software as services for which a cloud consumer does not need to maintain resources on a local computing device. It is understood that the types of computing devices **54**A-N shown in FIG. **9** are intended to be illustrative only and that computing nodes **10** and cloud computing environment **50** can communicate with any type of computerized device over any type of network and/or network addressable connection (e.g., using a web browser).

**[0111]** Referring now to FIG. **10**, a set of functional abstraction layers provided by cloud computing environment **50** (FIG. **9**) is shown. It should be understood in advance that the components, layers, and functions shown in FIG. **10** are intended to be illustrative only and embodiments of the invention are not limited thereto. As depicted, the following layers and corresponding functions are provided:

**[0112]** Hardware and software layer **60** includes hardware and software components. Examples of hardware components include: mainframes **61**; RISC (Reduced Instruction Set Computer) architecture based servers **62**; servers **63**; blade servers **64**; storage devices **65**; and networks and networking components **66**. In some embodiments, software components include network application server software **67** and database software **68**.

**[0113]** Virtualization layer **70** provides an abstraction layer from which the following examples of virtual entities may be provided: virtual servers **71**; virtual storage **72**; virtual networks **73**, including virtual private networks; virtual applications and operating systems **74**; and virtual clients **75**.

**[0114]** In one example, management layer **80** may provide the functions described below. Resource provisioning **81** provides dynamic procurement of computing resources and other resources that are utilized to perform tasks within the cloud computing environment. Metering and Pricing **82** provide cost tracking as resources are utilized within the cloud computing environment, and billing or invoicing for consumption of these resources. In one example, these resources may comprise application software licenses. Security provides identity verification for cloud consumers and tasks, as well as protection for data and other resources. User portal **83** provides access to the cloud computing environment for consumers and system administrators. Service level management **84** provides cloud computing resource allocation and management such that required service levels are met. Service Level Agreement (SLA) planning and fulfillment **85** provide pre-arrangement for, and procurement of, cloud computing resources for which a future requirement is anticipated in accordance with an SLA.

**[0115]** Workloads layer **90** provides examples of functionality for which the cloud computing environment may be utilized. Examples of workloads and functions which may be provided from this layer include: mapping and navigation **91**; software development and lifecycle management **92**; virtual classroom education delivery **93**; data analytics processing **94**; transaction processing **95**; and self-driving vehicle control processing **96** (for selectively setting/controlling physical spacing between SDVs as described herein).

**[0116]** The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

**[0117]** The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of various embodiments of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the present invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the present invention. The embodiment was chosen and described in order to best explain the principles of the present invention and the practical application, and to enable others of ordinary skill in the art to understand the present invention for various embodiments with various modifications as are suited to the particular use contemplated.

**[0118]** Any methods described in the present disclosure may be implemented through the use of a VHDL (VHSIC Hardware Description Language) program and a VHDL chip. VHDL is an exemplary design-entry language for Field Programmable Gate Arrays (FPGAs), Application Specific Integrated Circuits (ASICs), and other similar electronic devices. Thus, any software-implemented method described herein may be emulated by a hardware-based VHDL program, which is then applied to a VHDL chip, such as a FPGA.

**[0119]** Having thus described embodiments of the present invention of the present application in detail and by reference to illustrative embodiments thereof, it will be apparent that modifications and variations are possible without departing from the scope of the present invention defined in the appended claims.

What is claimed is:

**1**. A method for controlling a physical spacing between self-driving vehicles (SDVs), the method comprising:

receiving, by one or more processors, a social network node graph, wherein the social network node graph describes a graphical distance between a first node on the social network node graph and a second node on the social network node graph, wherein the first node represents a first passenger in a first SDV, wherein the second node represents a second passenger in a second SDV, and wherein the graphical distance between the first node and the second node describes a relationship level in a social network between the first passenger and the second passenger; and

adjusting, by an SDV on-board computer on at least one of the first SDV and the second SDV, a physical spacing between the first SDV and the second SDV proportional to the graphical distance between the first node and the second node.

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

altering, by the SDV on-board computer on said at least one of the first SDV and the second SDV, a route of travel based on the relationship level between the first passenger and the second passenger.

**3**. The method of claim **1**, wherein the social network node graph further describes a graphical distance between a third node on the social network node graph and the second node on the social network node graph, wherein the third node represents a third passenger in the first SDV, wherein the graphical distance between the third node and the second node describes a relationship level in the social network between the third passenger and the second passenger, and wherein the method further comprises:

weighting, by one or more processors, the first node and the third node based on the relationship level in the social network between the first passenger and the second passenger versus the relationship level in the social network between the third passenger and the second passenger; and

adjusting, by an SDV on-board computer on at least one of the first SDV and the second SDV, a physical spacing between the first SDV and the second SDV based on the weighted first and third nodes.

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

detecting, based on sensor readings from a roadway sensor, a current roadway condition of a roadway upon which the first SDV and the second SDV are traveling; and

further adjusting, by the SDV on-board computer on the first SDV, the physical spacing between the first SDV and the second SDV based on the current roadway condition of the roadway upon which the first SDV and the second SDV are traveling.

**5**. The method of claim **1**, wherein the first SDV is traveling on a roadway in manual mode and the second SDV is traveling on the roadway in autonomous mode, and wherein the method further comprises:

retrieving, by one or more processors, driver profile information about a human driver of the first SDV;

assigning, by one or more processors, the human driver of the first SDV to a cohort of drivers who have traveled on the roadway in other SDVs, wherein the human driver of the first SDV shares more than a predetermined quantity of traits with members of the cohort of drivers who have traveled on the roadway in the other SDVs;

retrieving, by one or more processors, traffic pattern data for the other SDVs as they traveled on the roadway;

examining, by one or more processors, the traffic pattern data to determine a first traffic flow of the other SDVs while operating in autonomous mode on the roadway;

examining, by one or more processors, the traffic pattern data to determine a second traffic flow of the other SDVs while operating in manual mode on the roadway; and

in response to determining that the first traffic flow has a lower accident rate than the second traffic flow, changing, by the operational mode device, the operational mode of the first SDV from manual mode to autonomous mode.

**6**. The method of claim **1**, wherein the first SDV and the second SDV are traveling on the roadway in autonomous mode, and wherein the method further comprises:

receiving, by one or more processors, sensor readings from multiple sensors, wherein each of the multiple sensors detects a different type of current condition of the roadway;

weighting, by one or more processors, each of the sensor readings for different current conditions of the roadway;

summing, by one or more processors, weighted sensor readings for the different current conditions of the roadway;

determining, by one or more processors, whether the summed weighted sensor readings exceed a predefined level; and

in response to determining that the summed weighted sensor readings exceed the predefined level, further adjusting, by an SDV on-board computer on at least one of the first SDV and the second SDV, the physical spacing between the first SDV and the second SDV.

**7**. The method of claim **1**, wherein the first SDV and the second SDV are traveling on the roadway in autonomous mode, and wherein the method further comprises:

receiving, by one or more processors, operational readings from one or more SDV operational sensors on the first SDV, wherein the SDV operational sensors detect a current state of mechanical equipment on the first SDV;

detecting, by the one or more processors and based on received operational readings, a mechanical fault with the mechanical equipment on the first SDV; and in response to detecting the mechanical fault with the mechanical equipment on the first SDV, further adjusting, by the SDV on-board computer on said at least one of the first SDV and the second SDV, the physical spacing between the first SDV and the second SDV.

**8**. A computer program product for controlling a physical spacing between self-driving vehicles (SDVs), the computer program product comprising a non-transitory computer readable storage medium having program code embodied therewith, the program code readable and executable by a processor to perform a method comprising:

receiving a social network node graph, wherein the social network node graph describes a graphical distance between a first node on the social network node graph and a second node on the social network node graph, wherein the first node represents a first passenger in a first SDV, wherein the second node represents a second passenger in a second SDV, and wherein the graphical distance between the first node and the second node describes a relationship level in a social network between the first passenger and the second passenger; and

adjusting, via an SDV on-board computer on at least one of the first SDV and the second SDV, a physical spacing between the first SDV and the second SDV proportional to the graphical distance between the first node and the second node.

**9**. The computer program product of claim **8**, wherein the method further comprises:

altering, via the SDV on-board computer on said at least one of the first SDV and the second SDV, a route of travel based on the relationship level between the first passenger and the second passenger.

**10**. The computer program product of claim **8**, wherein the social network node graph further describes a graphical distance between a third node on the social network node graph and the second node on the social network node graph, wherein the third node represents a third passenger in the first SDV, wherein the graphical distance between the third node and the second node describes a relationship level in the social network between the third passenger and the second passenger, and wherein the method further comprises:

weighting the first node and the third node based on the relationship level in the social network between the first passenger and the second passenger versus the relationship level in the social network between the third passenger and the second passenger; and

adjusting, via an SDV on-board computer on at least one of the first SDV and the second SDV, a physical spacing between the first SDV and the second SDV based on the weighted first and third nodes.

**11**. The computer program product of claim **8**, wherein the method further comprises:

detecting, based on sensor readings from a roadway sensor, a current roadway condition of a roadway upon which the first SDV and the second SDV are traveling; and

further adjusting the physical spacing between the first SDV and the second SDV based on the current roadway condition of the roadway upon which the first SDV and the second SDV are traveling.

**12**. The computer program product of claim **8**, wherein the first SDV is traveling on a roadway in manual mode and the second SDV is traveling on the roadway in autonomous mode, and wherein the method further comprises:

retrieving driver profile information about a human driver of the first SDV;

assigning the human driver of the first SDV to a cohort of drivers who have traveled on the roadway in other SDVs, wherein the human driver of the first SDV shares more than a predetermined quantity of traits with members of the cohort of drivers who have traveled on the roadway in the other SDVs;

retrieving traffic pattern data for the other SDVs as they traveled on the roadway;

examining the traffic pattern data to determine a first traffic flow of the other SDVs while operating in autonomous mode on the roadway;

examining the traffic pattern data to determine a second traffic flow of the other SDVs while operating in manual mode on the roadway; and

in response to determining that the first traffic flow has a lower accident rate than the second traffic flow, changing, via an operational mode device on the first SDV, an operational mode of the first SDV from manual mode to autonomous mode.

**13**. The computer program product of claim **8**, wherein the first SDV and the second SDV are traveling on the roadway in autonomous mode, and wherein the method further comprises:

receiving sensor readings from multiple sensors, wherein each of the multiple sensors detects a different type of current condition of the roadway;

weighting each of the sensor readings for different current conditions of the roadway;

summing weighted sensor readings for the different current conditions of the roadway;

determining whether the summed weighted sensor readings exceed a predefined level; and

in response to determining that the summed weighted sensor readings exceed the predefined level, further adjusting, via an SDV on-board computer on at least one of the first SDV and the second SDV, the physical spacing between the first SDV and the second SDV.

**14**. The computer program product of claim **8**, wherein the first SDV and the second SDV are traveling on the roadway in autonomous mode, and wherein the method further comprises:

receiving operational readings from one or more SDV operational sensors on the first SDV, wherein the SDV operational sensors detect a current state of mechanical equipment on the first SDV;

detecting, based on received operational readings, a mechanical fault with the mechanical equipment on the first SDV; and

in response to detecting the mechanical fault with the mechanical equipment on the first SDV, further adjusting, via the SDV on-board computer on said at least one of the first SDV and the second SDV, the physical spacing between the first SDV and the second SDV.

**15**. A self-driving vehicle comprising:

a processor, a computer readable memory, and a non-transitory computer readable storage medium;

first program instructions to receive a social network node graph, wherein the social network node graph describes a graphical distance between a first node on the social network node graph and a second node on the social network node graph, wherein the self-driving vehicle is a first self-driving vehicle (SDV), wherein the first node represents a first passenger in a first SDV, wherein the second node represents a second passenger in a second SDV, and wherein the graphical distance between the first node and the second node describes a relationship level in a social network between the first passenger and the second passenger; and

second program instructions to direct an SDV on-board computer on the first SDV to adjust a physical spacing between the first SDV and the second SDV proportional to the graphical distance between the first node and the second node; and wherein the first and second program instructions are stored on the non-transitory computer readable storage medium for execution by one or more processors via the computer readable memory.

**16**. The self-driving vehicle of claim **15**, further comprising:

third program instructions to alter a route of travel based on the relationship level between the first passenger and the second passenger; and wherein

the third program instructions are stored on the non-transitory computer readable storage medium for execution by one or more processors via the computer readable memory.

**17**. The self-driving vehicle of claim **15**, wherein the social network node graph further describes a graphical distance between a third node on the social network node graph and the second node on the social network node graph, wherein the third node represents a third passenger in the first SDV, wherein the graphical distance between the third node and the second node describes a relationship level in the social network between the third passenger and the second passenger, and wherein the self-driving vehicle further comprises:

third program instructions to weight the first node and the third node based on the relationship level in the social network between the first passenger and the second passenger versus the relationship level in the social network between the third passenger and the second passenger; and

fourth program instructions to adjust a physical spacing between the first SDV and the second SDV based on the weighted first and third nodes; and wherein

the third and fourth program instructions are stored on the non-transitory computer readable storage medium for execution by one or more processors via the computer readable memory.

**18**. The self-driving vehicle of claim **15**, further comprising:

a roadway sensor for detecting a current roadway condition of a roadway upon which the self-driving vehicle is traveling; and

an operational mode device for adjusting an operational mode of the self-driving vehicle based on the current roadway condition detected by the roadway sensor.

**19**. The self-driving vehicle of claim **15**, wherein the self-driving vehicle is a first SDV that is traveling on a roadway in manual mode and while a second SDV is traveling on the roadway in autonomous mode, and wherein the self-driving vehicle further comprises:

third program instructions to retrieve driver profile information about a human driver of the first SDV;

fourth program instructions to assign the human driver of the first SDV to a cohort of drivers who have traveled on the roadway in other SDVs, wherein the human driver of the first SDV shares more than a predetermined quantity of traits with members of the cohort of drivers who have traveled on the roadway in the other SDVs;

fifth program instructions to retrieve traffic pattern data for the other SDVs as they traveled on the roadway;

sixth program instructions to examine the traffic pattern data to determine a first traffic flow of the other SDVs while operating in autonomous mode on the roadway;

seventh program instructions to examine the traffic pattern data to determine a second traffic flow of the other SDVs while operating in manual mode on the roadway; and

eighth program instructions to, in response to determining that the first traffic flow has a lower accident rate than the second traffic flow, change, via an operational mode device on the first SDV, the operational mode of the first SDV from manual mode to autonomous mode; and wherein

the third, fourth, fifth, sixth, seventh, and eighth program instructions are stored on the non-transitory computer readable storage medium for execution by one or more processors via the computer readable memory.

**20**. The self-driving vehicle of claim **15**, wherein the self driving vehicle is traveling on a roadway while in autonomous mode, and wherein the self-driving vehicle further comprises:

one or more SDV operational sensors for generating operational readings based on a current state of mechanical equipment on the self-driving vehicle, wherein the one or more SDV operational sensors detect a mechanical fault with the mechanical equipment on the self-driving vehicle, and wherein the SDV on-board computer on the first SDV, in response to detecting the mechanical fault with the mechanical equipment on the first SDV, further adjusts the physical spacing between the first SDV and the second SDV.

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