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(54) **VISUALIZIING REAL-TIME INTERSECTION OCCUPANCY AND CALCULATED ANALYTICS IN 3D**

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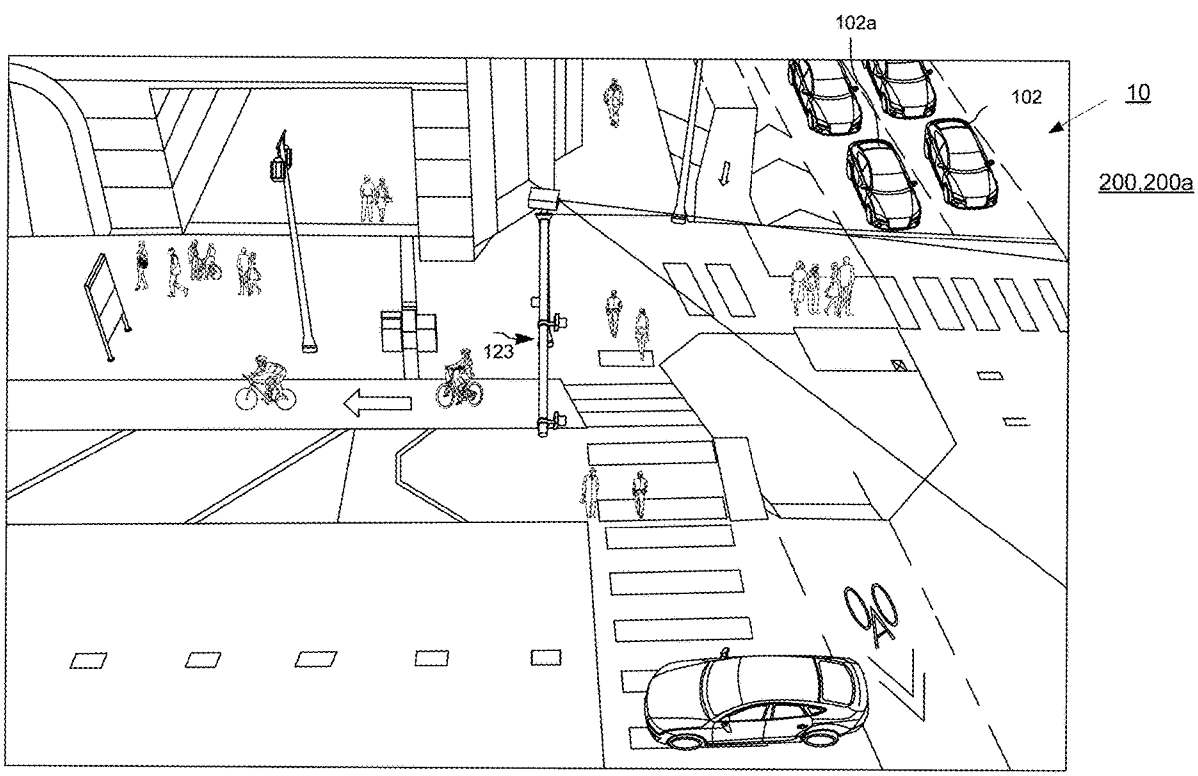
(57) **ABSTRACT**

A method for generating a heat map of a surface area includes receiving, at a hardware processor, sensor data from one or more sensors in communication with the hardware processor and positioned such that the surface area is within a field of view of the one or more sensors. Determining, at the hardware processor, the speed and location for each of the traffic participants. Generating, at the hardware processor, a 2D map based on the traffic participants. The method also includes generating, at the hardware processor, a 3D map based on the traffic participants.



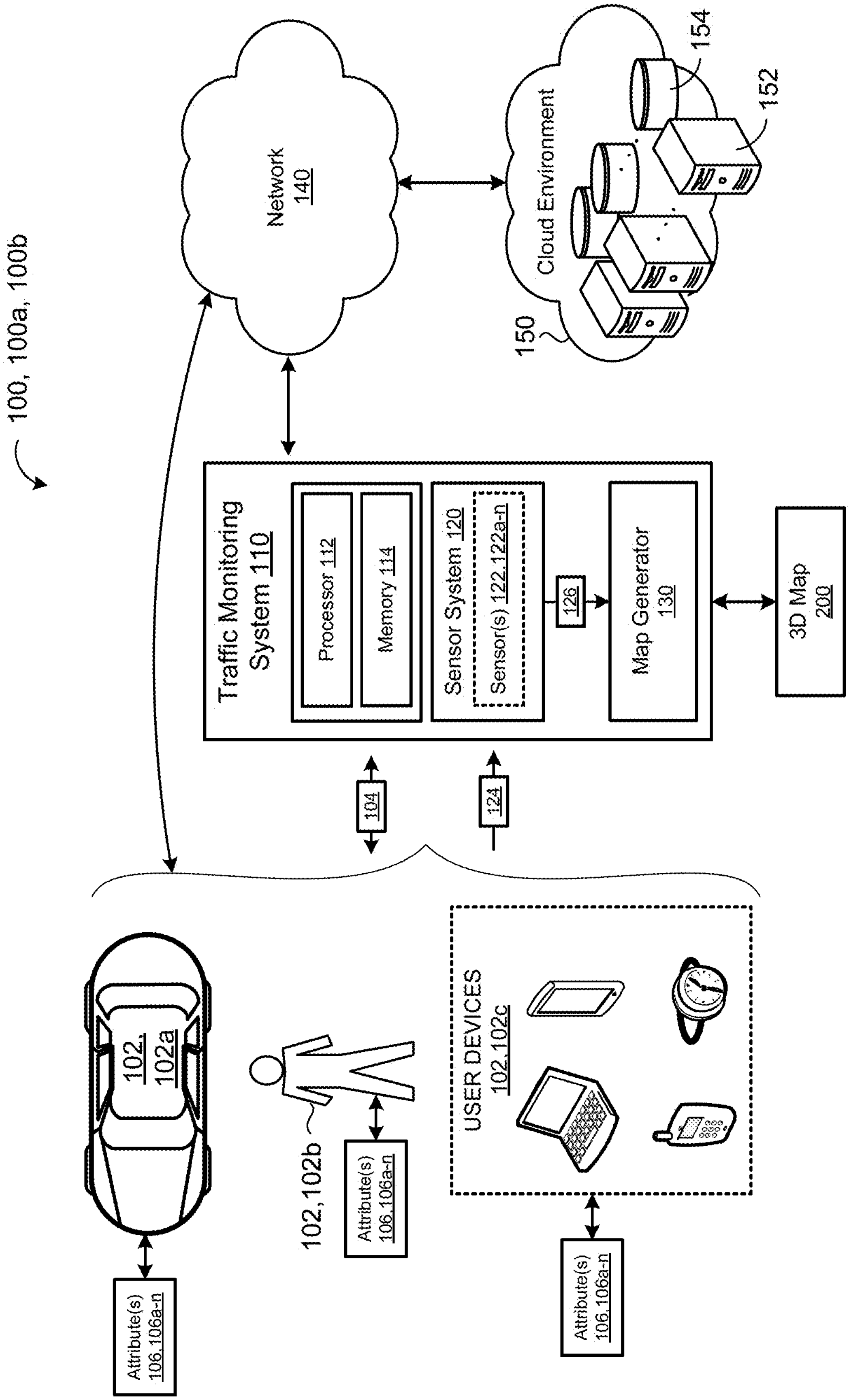

100, 100a, 100b
Network
140
Cloud Environment
150
152
154
Traffic Monitoring System 110
Processor 112
Memory 114
Sensor System 120
Sensor(s) 122,122a-n
126
Map Generator
130
3D Map
200
104
124
102,
102a
102,102b
Attribute(s)
106,106a-n
USER DEVICES
102,102c
Attribute(s)
106,106a-n
Attribute(s)
106,106a-n

FIG. 1

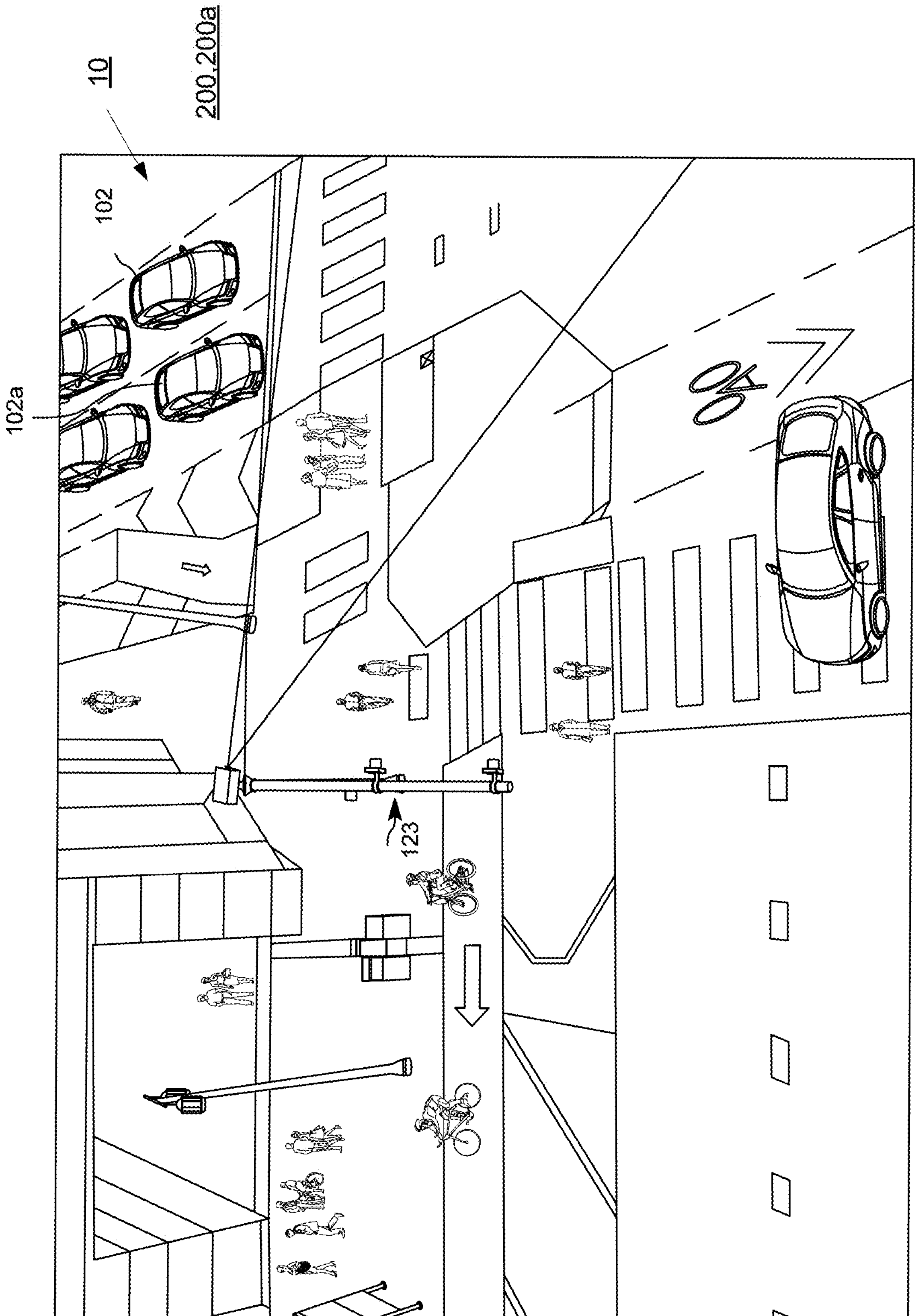


FIG. 2

200,200a, 220c

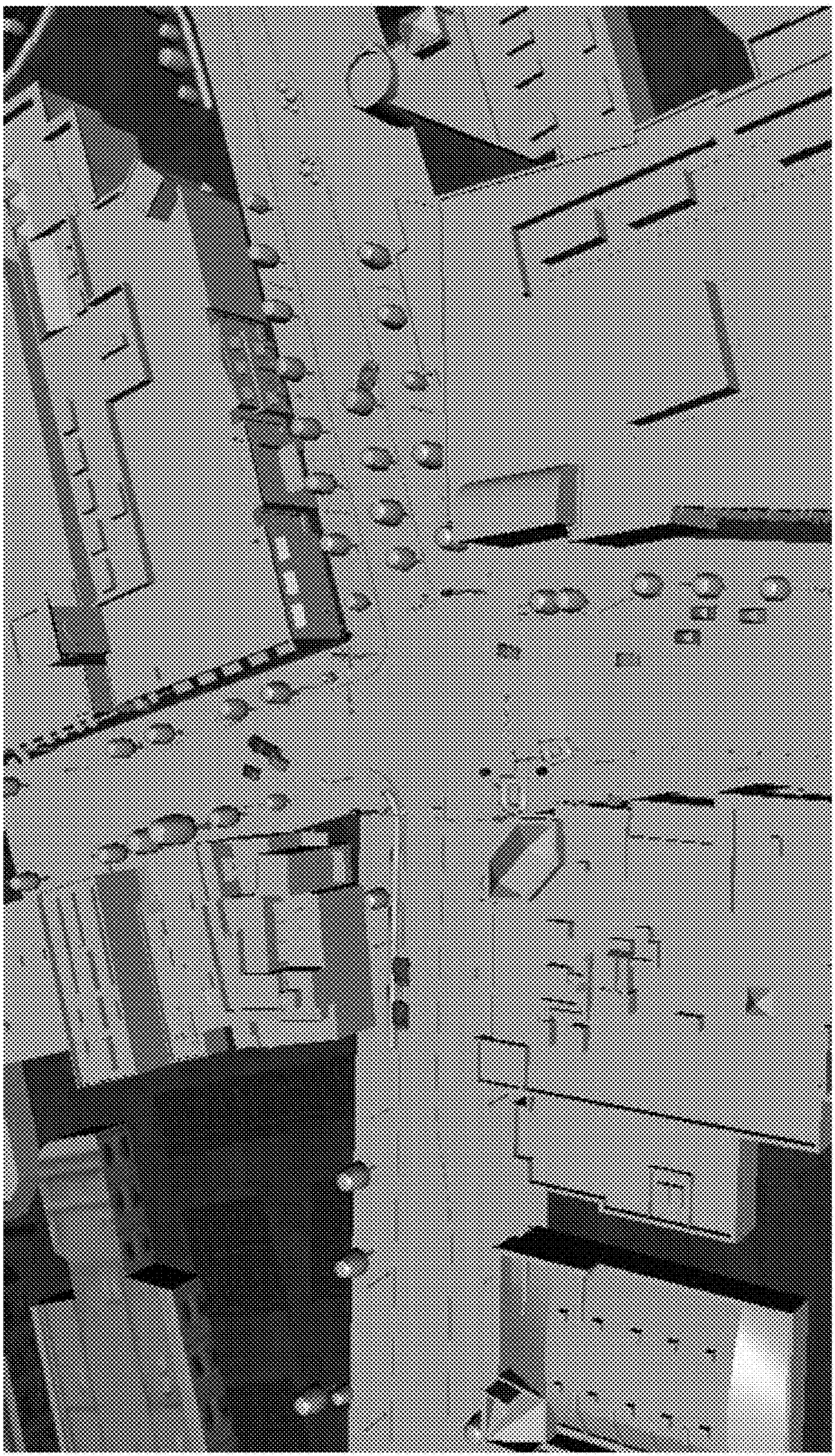


FIG. 3

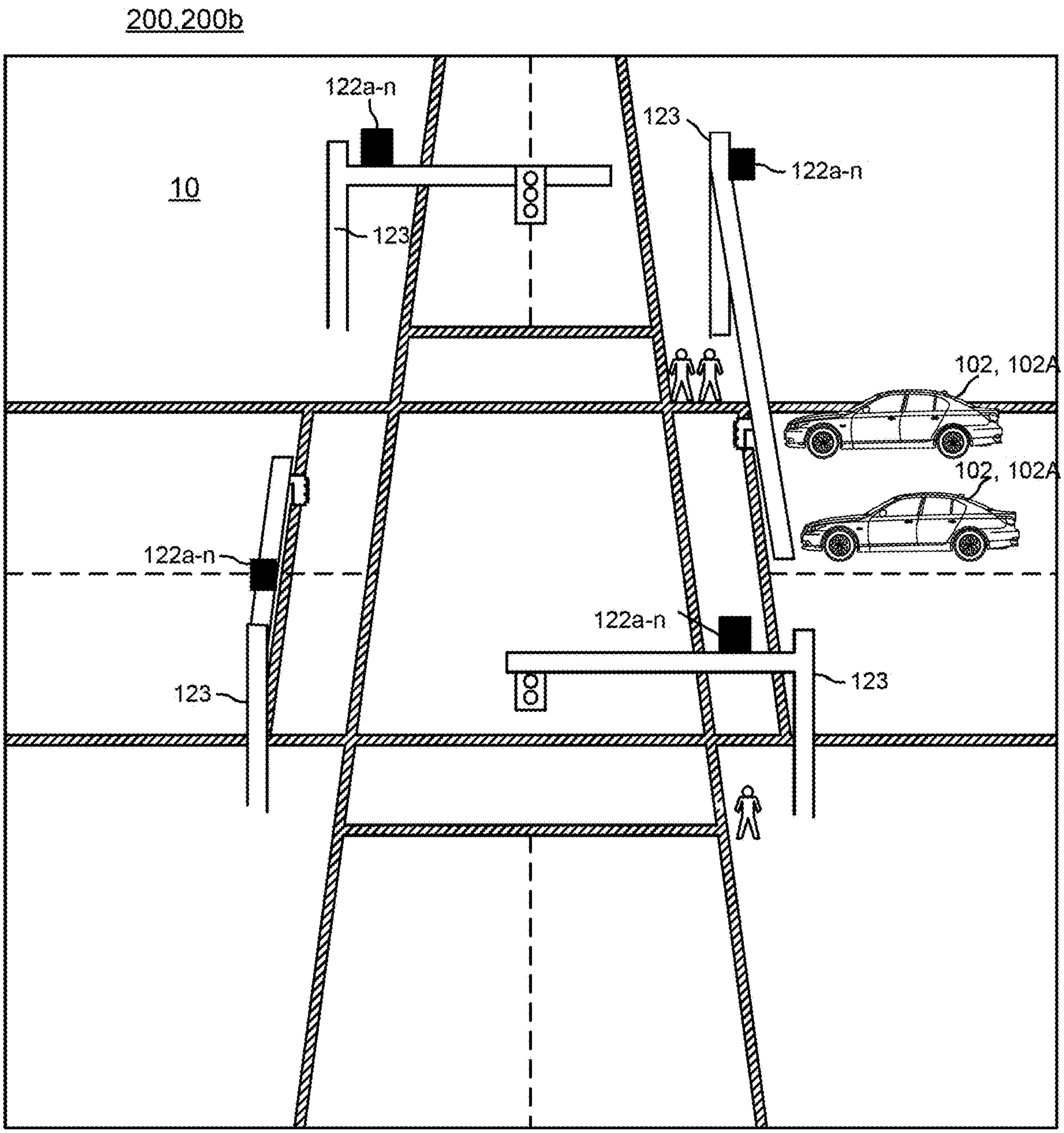

200,200b
10
122a-n
123
123
122a-n
102, 102A
102, 102A
122a-n
122a-n
123
123

FIG. 4

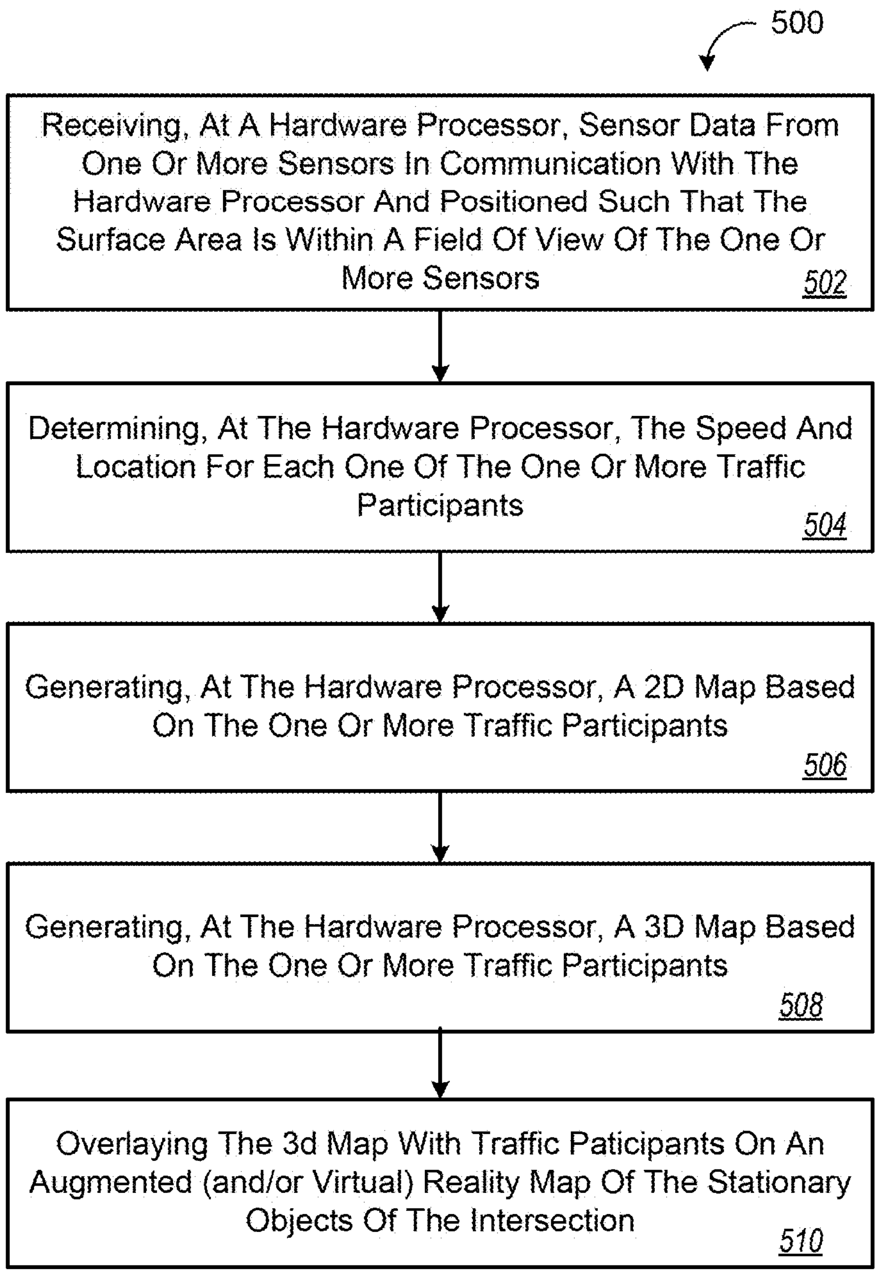

500
Receiving, At A Hardware Processor, Sensor Data From One Or More Sensors In Communication With The Hardware Processor And Positioned Such That The Surface Area Is Within A Field Of View Of The One Or More Sensors 502
Determining, At The Hardware Processor, The Speed And Location For Each One Of The One Or More Traffic Participants 504
Generating, At The Hardware Processor, A 2D Map Based On The One Or More Traffic Participants 506
Generating, At The Hardware Processor, A 3D Map Based On The One Or More Traffic Participants 508
Overlaying The 3d Map With Traffic Paticipants On An Augmented (and/or Virtual) Reality Map Of The Stationary Objects Of The Intersection 510

FIG. 5

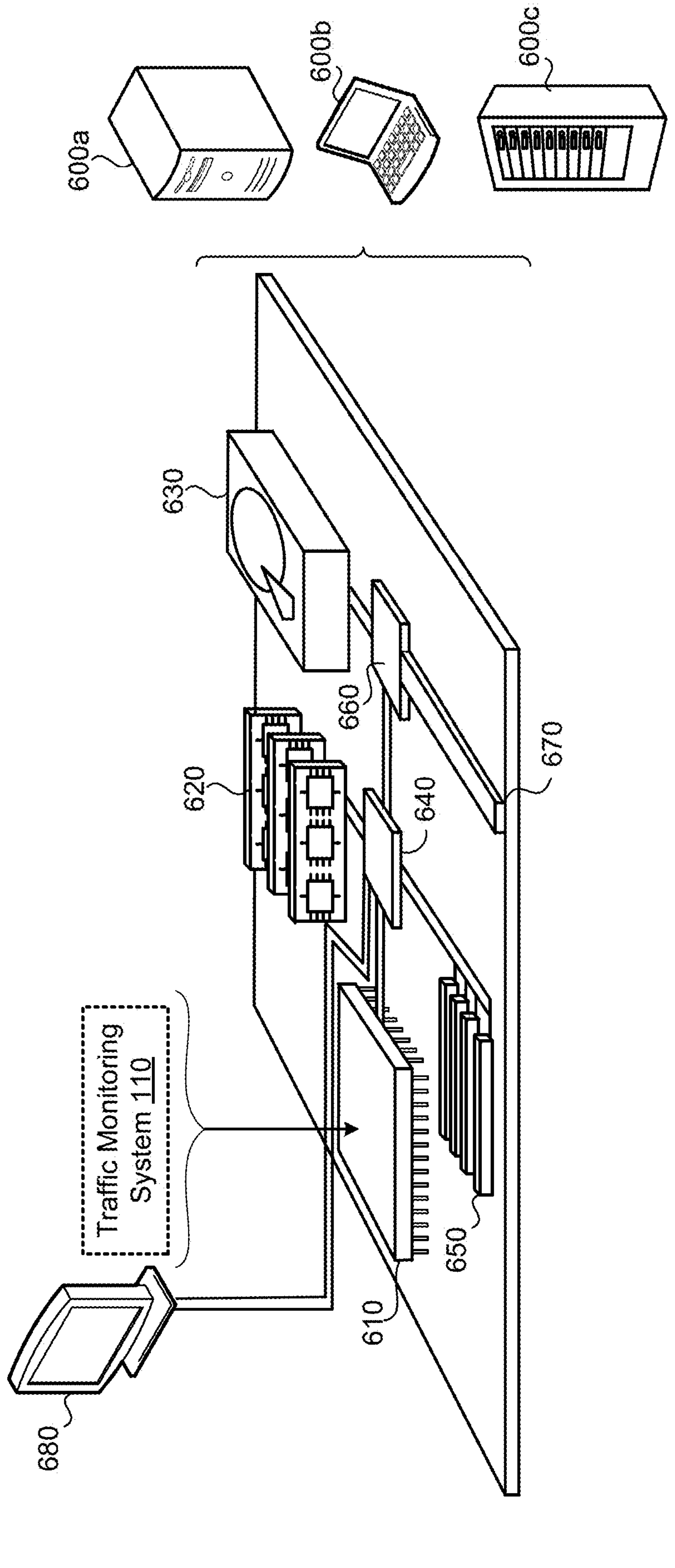

600
600a
600b
600c
630
620
660
640
670
Traffic Monitoring System 110
610
650
680

FIG. 6

VISUALIZIING REAL-TIME INTERSECTION OCCUPANCY AND CALCULATED ANALYTICS IN 3D

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This U.S. patent application claims the benefit of U.S. provisional patent application No. 62/789,799, filed Jan. 8, 2019, which is hereby incorporated by reference.

TECHNICAL FIELD

[0002] The invention relates generally to a system for detecting real time or near real time data of a traffic event, such as traffic proximate to an intersection. The system is able to be integrated into local infrastructure and is able to detect vehicles and objects which may not be readily visible to other drivers.

BACKGROUND

[0003] Currently, there are many types of systems in place, which are part of a vehicle, to make a driver of the vehicle aware of potential objects such as pedestrians, other vehicles, and other objects along the side of a road, or on a road. However, not all vehicles are equipped with these sensors and even with all of these advances in technology, blind spots for specific vehicles can still occur.

[0004] Traffic on roads includes traffic participants, such as, but not limited to, vehicles, streetcars, buses, pedestrians, and any other moving object using public roads and walkways or stationary objects such as benches and trash cans. Organized traffic generally has well established priorities, lanes, right-of-way, and traffic control intersections. It is desirable to have a system and method for monitoring the traffic to determine traffic patterns and view spots which may be blind to some vehicles proximate to an intersection.

[0005] Accordingly, there exists a need for a system for detecting traffic an intersection based on an automated nature, which presents the information to a driver and/or user in an understandable manner.

[0006] The background description provided herein is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

SUMMARY

[0007] One general aspect includes a method for generating a heat map of a surface area. The method also includes receiving, at a hardware processor, sensor data from one or more sensors in communication with the hardware processor and positioned such that the surface area is within a field of view of the one or more sensors. The method also includes determining, at the hardware processor, the speed and location for each one of the one or more traffic participants. The method also includes generating, at the hardware processor, a 2d map based on the one or more traffic participants. The method also includes generating, at the hardware processor, a 3d map based on the one or more traffic participants.

[0008] Implementations may include one or more of the following features. The method may include overlaying the 3d map with traffic participants on an augmented reality map of the stationary objects of the intersection.

[0009] The method may include overlaying the 3d map with traffic participants on a virtual reality map of the stationary objects of the intersection.

[0010] One general aspect includes a traffic monitoring system for generating a heat map of a surface area. The traffic monitoring system also includes a hardware processor. The system also includes hardware memory in communication with the hardware processor, the hardware memory storing instructions that when executed on the hardware processor cause the hardware processor to perform operations may include: receiving, at a hardware processor, sensor data from one or more sensors in communication with the hardware processor and positioned such that the surface area is within a field of view of the one or more sensors; determining, at the hardware processor, the speed and location for each one of the one or more traffic participants; generating, at the hardware processor, a 2d map based on the one or more traffic participants. The system also includes generating, at the hardware processor, a 3d map based on the one or more traffic participants. The system also includes a display to show the 3d map.

[0011] Implementations may include one or more of the following features. The system where the operations further may include overlaying the 3d map with traffic participants on an augmented reality map of the stationary objects of the intersection.

[0012] The operations further include determining traffic participant boundaries based on the heat map, each boundary identifies traffic lanes, crosswalks, and/or pedestrian lanes of the surface area.

[0013] The sensors further may include one of: a camera, a radar, a lidar, a ladar, ultrasound, and sonar.

[0014] The sensors are secured to at least one infrastructure component, and where the at least one infrastructure component being one selected from the group may include of a building, a bridge, a parking structure, and a support structure.

[0015] Other objects, features and characteristics of the present invention, as well as the methods of operation and the functions of the related elements of the structure, the combination of parts and economics of manufacture will become more apparent upon consideration of the following detailed description and appended claims with reference to the accompanying drawings, all of which form a part of this specification. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the disclosure, are intended for purposes of illustration only and are not intended to limit the scope of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0017] FIG. **1** is a schematic view of an exemplary overview of an intersection visualization system.

[0018] FIG. **2** is a diagram of a first example of an intersection having an intersection visualization system, according to embodiments of the present invention;

[0019] FIG. **3** is a diagram of a first example 3D visualization of intersection created using the intersection visualization system, according to embodiments of the present invention;

[0020] FIG. **4** is a diagram of a second example of an intersection having an intersection visualization system, according to embodiments of the present invention;

[0021] FIG. **5** is a flow diagram of an example method for implementing accident detection and warning system, according to embodiments of the present invention; and

[0022] FIG. **6** is a schematic view of an example computing device executing any system or methods described herein.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0023] The following description of the preferred embodiment(s) is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

[0024] Autonomous and semi-autonomous driving has been gaining interest in the past few years. To increase transportation safety of autonomous and semi-autonomous vehicles, it is important to have an accurate idea of the infrastructure (i.e., roads, lanes, traffic signs, crosswalks, sidewalks, etc.) that is being used by these vehicles, and know the active participants (e.g., vehicles, pedestrians, etc.) using the infrastructure. A vehicle-traffic system as described below quantifies this information as a map showing the moving flow of vehicles, pedestrians, and object in the intersection, which may be used by the autonomous and semi-autonomous vehicles to improve driving accuracy and thus transportation safety. Specifically, the map is shown as a 3D map.

[0025] Referring to FIGS. **1-4**, a vehicle-traffic system **100**, **100***a*, **100***b* includes a traffic monitoring system **110** that includes a computing device (or hardware processor) **112** (e.g., central processing unit having one or more computing processors) in communication with non-transitory memory or hardware memory **114** (e.g., a hard disk, flash memory, random-access memory) capable of storing instructions executable on the computing processor(s) **112**. The traffic monitoring system **110** includes a sensor system **120**. The sensor system **120** includes one or more sensors **122***a-n* positioned at one or more roads or road intersections **10** and configured to sense one or more traffic participants **102**, **102***a-c*. Traffic participants **102**, **102***a-c* may include, but are not limited to, vehicles **102***a*, pedestrians and bicyclists **102***b*, user devices **102***c*. In some implementations, the user device **102***c* is any computing device capable of communicating with the sensors **122**. The user device **102***c* may include, but is not limited to, a mobile computing device, such as a laptop, a tablet, a smart phone, and a wearable computing device (e.g., headsets and/or watches). The user device **102***c* may also include other computing devices having other form factors, such as a gaming device.

[0026] In some implementations, the one or more sensors **122***a-n* may be positioned to capture data **124** associated with a specific area **10**, where each sensor **122***a-n* captures data **124** associated with a portion of the area **10**. As a result, the sensor data **124** associated with each sensor **122***a-n* includes sensor data **124** associated with the entire area **10**. In some examples, the sensors **122***a-n* are positioned within the intersection **10**, for example, each sensor **122***a-n* is positioned on a corner of the intersection to view the traffic participants **102** or supported by a traffic light or other infrastructure proximate tot he intersection. In the embodiment, shown in FIGS. **2** and **4**, the sensors **122***a-n* are mounted on a light pole, **123** of the system **100**, **100***a*, **100***b*.

[0027] While in this embodiment, the infrastructure component is the post **123**, it is within the scope of the invention that the visualization system **100** may include any other type of infrastructure component, such as a building, bridge, parking structure, support structure, or the like. In this embodiment, the sensors **122***a-n*, are integrated into a single component but it is within the scope of the invention that the sensors **122***a-n* may be separate components in different locations located about the intersection each having differing fields of view. The sensors **122***a-n* in this embodiment are able to detect objects in a detection area, shown generally at **10**.

[0028] The sensors **122***a-n* may include, but are not limited to, Radar, Sonar, LIDAR (Light Detection and Ranging, which can entail optical remote sensing that measures properties of scattered light to find range and/or other information of a distant target), HFL (High Flash LIDAR), LADAR (Laser Detection and Ranging), cameras (e.g., monocular camera, binocular camera). Each sensor **120** is positioned at a location where the sensor **122** can capture sensor data **124** associated with the traffic participants **102**, **102***a-c* at the specific location. Therefore, the sensor system **120** analyses the sensor data **124** captured by the one or more sensors **122***a-n*. The analysis of the sensor data **124** includes the sensor system **120** identifying one or more traffic participants **102** and determining one or more attributes **106**, **106***a-n* associated with each traffic participant **102**. The traffic attributes **106**, **106***a-n*, may include, but are not limited to, the location of the traffic participant **102** (e.g., in a coordinate system), a speed associated with the traffic participant **102**, a type of the traffic participant **102** (e.g., vehicles **102***a*, pedestrians and bicyclists **102***b*, user devices **102***c*), and other attributes of each traffic participant **102** within the area **10**.

[0029] The traffic monitoring system **110** executes a map generator **130** that generates a map **200**, **200***a*, as shown in FIG. **3**, based on the analyzed sensor data **126** received from the sensor system **120**. Therefore, the sensors **122***a-n* capture sensor data **124** associated with an area **10**, such as a road or intersection, then the sensor system **120** analyses the received sensor data **124**. No a-priori information about the area **10** is needed by the traffic monitoring system **110** since all relevant information, such as sensor metadata (i.e., sensor location, for example, a relative position of each sensor **122**, **122***a-n* in a coordinate system and/or with respect to one another) associated with each sensor **122**, **122***a-n* are known and the received sensor data **124** is captured and collected. Therefore, the traffic monitoring system **110** generates the map **200***a* to understand the geometry and geography of the area based on the received sensor data **124** associated with each of the sensors **122***a-n*.

[0030] Vehicle-to-everything (V2X) communication is the flow of information from a vehicle to any other device, and vice versa. More specifically, V2X is a communication system that includes other types of communication such as, V2I (vehicle-to-infrastructure), V2V (vehicle-to-vehicle), V2P (vehicle-to-pedestrian), V2D (vehicle-to-device), and V2G (vehicle-to-grid). V2X is developed with the vision towards safety, mainly so that the vehicle is aware of its surroundings to help prevent collision of the vehicle with other vehicles or objects. In some implementations, the traffic monitoring system **110** communicates with the traffic participants **102** via V2X by way of a V2X communication **104**, and the traffic participant **102** sends one or more attributes of the traffic participant **102** to the traffic monitoring system **110** by way of the V2X communication **104**. Therefore, the traffic monitoring system **110** may analyze the V2X communication to determine one or more attributes **106** associated with the respective traffic participant **102**.

[0031] In some examples, the traffic monitoring system **110** is in communication with a remote system **150** via the network **140**. The remote system **150** may be a distributed system (e.g., a cloud environment) having scalable/elastic computing resources **152** and/or storage resources **154**. The network **140** may include various types of networks, such as a local area network (LAN), wide area network (WAN), and/or the Internet. In some examples, the traffic monitoring system **110** executes on the remote system **150** and communicates with the sensors **122** via the network **140**. In this case, the sensors **122** are positioned at the intersection to capture the sensor data **124**. Additionally, in this case, the traffic participants **102** may communicate with the traffic monitoring system **110** via the network **140**, such that the traffic participants **102** send the traffic monitoring system **110** one or more attributes **106** associated with the traffic participant **102**.

[0032] Further in regards to the embodiments described above, the communication device **24** is a DSRC device **24**, or may be a 5g communication device **24**, but it is within the scope of the invention that other types of communication devices maybe used.

[0033] Learning Intersection Attributes from Sensor Data

[0034] In some implementations, the map generator **130** learns patterns of traffic participants **102**, **102**a-c based on the analyzed sensor data **126** received from the sensor system **120** (including the attributes **106** associated with each traffic participant **102**). Additionally, in some examples, the map generator **130** determines a map of the area **10** based on the analyzed sensor data **126**.

[0035] The map generator **130** may divide the map **200**a into cells, and cell movement is indicative of a traffic participant **102** moving from one cell to another adjacent cell. The map generator **130** identifies one or more boundaries, such as a traffic lane **210** (e.g., left, straight, right), a pedestrian lane or a sidewalk **220**, a cycling lane (not shown), etc. based on the received sensor data **124**. For example, the traffic monitoring system **110** may determine a boundary to be a traffic lane **210** based on a speed of the traffic participant **102** (e.g., the speed of the traffic participant **102** determined based on the sensor data **124** as one of the participant attributes **106**). Moreover, the map generator **130** may identify a cycle lane based on the attributes **106** associated with each traffic participant **102**. In some examples, the map generator **130** identifies a sidewalk or a crosswalk **230** where the pedestrians walk the most. In some examples, the map generator **130** determines an overlap between a portion of the traffic lanes **210** at a first time and pedestrian boundaries at a second time.

[0036] In some examples, the map generator **130** generates the map **200**a and divides the map **200**a into cells (not shown). Some cells may be associated with cell attributes, such as crosswalk, pedestrian traffic light, cyclist lane, vehicle lane.

[0037] Overlaying the Map onto Other Maps

[0038] In some implementations, the map generator **130** generates the map **200** based on the sensor data **124** and overlays the map **200** on other types of maps, e.g., a geographic map, a street map, an intersection map, to name a few, to enhance sensor detection and representation of objects resulting in a geographic-map **200**c as shown in FIG. **2**C. The traffic monitoring system **110** may use extrinsic calibration parameters associated with the sensors **120** to generate a correspondence matrix between the generated map **200**a and the other types of map. For example, the extrinsic calibration parameters associated with the sensors **122** may include the location of each sensor **122** in a coordinate system which may be overlain on the geographic map. As such, the resulting map **200**c (i.e., the map and the other map overlaid) shown in FIG. **2**C, provides a better representation of the traffic participants **102**, objects (e.g., street lights, trash cans, mail boxes, etc.), vehicle lanes **210**, sidewalk **220**, and crosswalks **230**.

[0039] The system **100**, **100** utilizes the data from the sensors **122**a-n and the map generator **130** to turn the data into a 3D visualization of the intersection **10**, shown in FIG. **3** (Further 3D visualization examples can be seen in the Appendix A, attached). Therefore, the visualization system **100** provides a clear and concise way to visualize important data for the infrastructure system (intersection, parking, etc.) as well as a way to use data collected and generated by the system **100**. The visualization system **100** and software (in processor **112**, and memory **114**) utilizes data broadcast by the infrastructure (sensors **120**a-n). The sensor data **126** can be real time, or previously recorded and played back. Using the data the 3D map, **200**, **200**a,**200**b is generated, including all the detected traffic participants, **102**,**102**a,**102**b,**102**c. The system **100** is also capable of consuming generated analytics and overlaying them on the 3D map **200**, **200**s, **200**b to visually tie data that is otherwise difficult to picture. The 3D map **200**,**200**a,**200**b with overlays can be displayed on a screen, including via augmented reality displays or immersive virtual reality experience. The system **100** provides an comprehensive visualization with improved cohesiveness to the data and simplifies use of complex analytics and applications over using purely raw data.

[0040] FIG. **5** provides an example arrangement of operations for a method **500** for generating a heat map of a surface area using the system **100** of FIGS. **1**-**2**C. At block **502**, the method **500** includes receiving, at a hardware processor **112**, sensor data **124** from one or more sensors **122** in communication with the hardware processor **112** and positioned such that the surface area **10** is within a field of view of the one or more sensors **122**. At block **504**, the method **500** includes identifying, at the hardware processor **112**, one or more traffic participants **102** from the sensor data **124**. Additionally, at block **506**, the method **500** includes generating, at the hardware processor **112**, a 2D map based on the one or more traffic participants **102**, **102**a-c. Where the 2D map shows real time (or recorded and played back) motion of the traffic participants **102**, **102**a-c. Additionally, at block **508**, the method **500** includes generating, at the hardware processor **112**, a 3D map **200**, **200**a based on the one or more traffic participants **102**, **102**a-c as well as sensed stationary objects in the area, e.g. buildings, bushes or trees, mailboxes, etc. Where the 3D **200**c map also shows real time (or recorded and played back) motion of the traffic participants **102**, **102**a-c.

[0041] In some implementations, the method **300** further includes dividing, at the hardware processor **112**, the map **220***a* into a grid having one or more cells. The method **500** also includes determining, at the hardware processor **112**, a probability of one of the traffic participants **102**, **102***a-c* in a first cell moving to an adjacent second cell based on a pattern of motion of similar traffic participants.

[0042] The method may further include overlaying the map **220***a* over a 3D geographic map, photo, augmented reality and/or virtual reality map of the surface area **10** resulting from the sensor data, shown at block **510**. The augmented reality and/or virtual reality map may be generated using the sensor data **126** as well as photos and/or geographic maps.

[0043] In some examples, overlaying the map **220***a* over a map of the surface area **10** includes: receiving, at the hardware processor **112**, a sensor geographic location associated with each one of the one or more sensors **122**, **122***a-n* from the one or more sensors **122**, **122***a-n*; and identifying, at the hardware processor **112**, the sensor geographic location of each one of the one or more sensors **122**, **122***a-n* on the map **20***a* based on the sensor geographic location as a first set of reference points. The method **300** also includes identifying, at the hardware processor **112**, the sensor geographic location of each one of the one or more sensors **122**, **122***a-n* on the geographic map as a second set of reference points; and overlaying, at the hardware processor **112**, the first set of reference points over the second set of reference points resulting in the geographic-map **220***c*. In some examples, the method also includes determining, at the hardware processor **112**, traffic participant boundaries **210**, **220**, **230** based on the map **230***a*, where each boundary **210**, **220**, **230** identifies traffic lanes **210**, crosswalks **230**, and/or pedestrian lanes **220** of the surface area.

[0044] FIG. **6** is schematic view of an example computing device **400** that may be used to implement the systems and methods described in this document. The computing device **600** is intended to represent various forms of digital computers, such as laptops, desktops, workstations, personal digital assistants, servers, blade servers, mainframes, and other appropriate computers. The components shown here, their connections and relationships, and their functions, are meant to be exemplary only, and are not meant to limit implementations of the inventions described and/or claimed in this document.

[0045] The computing device **600** includes a processor **610**, memory **620**, a storage device **630**, a high-speed interface/controller **640** connecting to the memory **620** and high-speed expansion ports **650**, and a low speed interface/controller **660** connecting to low speed bus **670** and storage device **630**. Each of the components **610**, **620**, **630**, **640**, **650**, and **660**, are interconnected using various busses, and may be mounted on a common motherboard or in other manners as appropriate. The processor **610** can process instructions for execution within the computing device **600**, including instructions stored in the memory **620** or on the storage device **630** to display graphical information for a graphical user interface (GUI) on an external input/output device, such as display **680** coupled to high speed interface **640**. In other implementations, multiple processors and/or multiple buses may be used, as appropriate, along with multiple memories and types of memory. Also, multiple computing devices **600** may be connected, with each device providing portions of the necessary operations (e.g., as a server bank, a group of blade servers, or a multi-processor system).

[0046] The memory **620** stores information non-transitorily within the computing device **600**. The memory **620** may be a computer-readable medium, a volatile memory unit(s), or non-volatile memory unit(s). The non-transitory memory **620** may be physical devices used to store programs (e.g., sequences of instructions) or data (e.g., program state information) on a temporary or permanent basis for use by the computing device **600**. Examples of non-volatile memory include, but are not limited to, flash memory and read-only memory (ROM)/programmable read-only memory (PROM)/erasable programmable read-only memory (EPROM)/electronically erasable programmable read-only memory (EEPROM) (e.g., typically used for firmware, such as boot programs). Examples of volatile memory include, but are not limited to, random access memory (RAM), dynamic random access memory (DRAM), static random access memory (SRAM), phase change memory (PCM) as well as disks or tapes.

[0047] The storage device **630** is capable of providing mass storage for the computing device **600**. In some implementations, the storage device **630** is a computer-readable medium. In various different implementations, the storage device **630** may be a floppy disk device, a hard disk device, an optical disk device, or a tape device, a flash memory or other similar solid state memory device, or an array of devices, including devices in a storage area network or other configurations. In additional implementations, a computer program product is tangibly embodied in an information carrier. The computer program product contains instructions that, when executed, perform one or more methods, such as those described above. The information carrier is a computer- or machine-readable medium, such as the memory **620**, the storage device **630**, or memory on processor **610**.

[0048] The high-speed controller **640** manages bandwidth-intensive operations for the computing device **600**, while the low speed controller **660** manages lower bandwidth-intensive operations. Such allocation of duties is exemplary only. In some implementations, the high-speed controller **640** is coupled to the memory **620**, the display **680** (e.g., through a graphics processor or accelerator), and to the high-speed expansion ports **650**, which may accept various expansion cards (not shown). In some implementations, the low-speed controller **660** is coupled to the storage device **630** and low-speed expansion port **670**. The low-speed expansion port **670**, which may include various communication ports (e.g., USB, Bluetooth, Ethernet, wireless Ethernet), may be coupled to one or more input/output devices, such as a keyboard, a pointing device, a scanner, or a networking device such as a switch or router, e.g., through a network adapter.

[0049] The computing device **600** may be implemented in a number of different forms, as shown in the figure. For example, it may be implemented as a standard server **600***a* or multiple times in a group of such servers **600***a*, as a laptop computer **600***b*, or as part of a rack server system **600***c*.

[0050] Various implementations of the systems and techniques described here can be realized in digital electronic and/or optical circuitry, integrated circuitry, specially designed ASICs (application specific integrated circuits), computer hardware, firmware, software, and/or combinations thereof. These various implementations can include implementation in one or more computer programs that are executable and/or interpretable on a programmable system including at least one programmable processor, which may be special or general purpose, coupled to receive data and instructions from, and to transmit data and instructions to, a storage system, at least one input device, and at least one output device.

[0051] These computer programs (also known as programs, software, software applications or code) include machine instructions for a programmable processor, and can be implemented in a high-level procedural and/or object-oriented programming language, and/or in assembly/machine language. As used herein, the terms "machine-readable medium" and "computer-readable medium" refer to any computer program product, non-transitory computer readable medium, apparatus and/or device (e.g., magnetic discs, optical disks, memory, Programmable Logic Devices (PLDs)) used to provide machine instructions and/or data to a programmable processor, including a machine-readable medium that receives machine instructions as a machine-readable signal. The term "machine-readable signal" refers to any signal used to provide machine instructions and/or data to a programmable processor.

[0052] Implementations of the subject matter and the functional operations described in this specification can be implemented in digital electronic circuitry, or in computer software, firmware, or hardware, including the structures disclosed in this specification and their structural equivalents, or in combinations of one or more of them. Moreover, subject matter described in this specification can be implemented as one or more computer program products, i.e., one or more modules of computer program instructions encoded on a computer readable medium for execution by, or to control the operation of, data processing apparatus. The computer readable medium can be a machine-readable storage device, a machine-readable storage substrate, a memory device, a composition of matter effecting a machine-readable propagated signal, or a combination of one or more of them. The terms "data processing apparatus", "computing device" and "computing processor" encompass all apparatus, devices, and machines for processing data, including by way of example a programmable processor, a computer, or multiple processors or computers. The apparatus can include, in addition to hardware, code that creates an execution environment for the computer program in question, e.g., code that constitutes processor firmware, a protocol stack, a database management system, an operating system, or a combination of one or more of them. A propagated signal is an artificially generated signal, e.g., a machine-generated electrical, optical, or electromagnetic signal, that is generated to encode information for transmission to suitable receiver apparatus.

[0053] A computer program (also known as an application, program, software, software application, script, or code) can be written in any form of programming language, including compiled or interpreted languages, and it can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A computer program does not necessarily correspond to a file in a file system. A program can be stored in a portion of a file that holds other programs or data (e.g., one or more scripts stored in a markup language document), in a single file dedicated to the program in question, or in multiple coordinated files (e.g., files that store one or more modules, sub programs, or portions of code). A computer program can be deployed to be executed on one computer or on multiple computers that are located at one site or distributed across multiple sites and interconnected by a communication network.

[0054] The processes and logic flows described in this specification can be performed by one or more programmable processors executing one or more computer programs to perform functions by operating on input data and generating output. The processes and logic flows can also be performed by, and apparatus can also be implemented as, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application specific integrated circuit).

[0055] Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer. Generally, a processor will receive instructions and data from a read only memory or a random access memory or both. The essential elements of a computer are a processor for performing instructions and one or more memory devices for storing instructions and data. Generally, a computer will also include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data, e.g., magnetic, magneto optical disks, or optical disks. However, a computer need not have such devices. Moreover, a computer can be embedded in another device, e.g., a mobile telephone, a personal digital assistant (PDA), a mobile audio player, a Global Positioning System (GPS) receiver, to name just a few. Computer readable media suitable for storing computer program instructions and data include all forms of non-volatile memory, media and memory devices, including by way of example semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks, e.g., internal hard disks or removable disks; magneto optical disks; and CD ROM and DVD-ROM disks. The processor and the memory can be supplemented by, or incorporated in, special purpose logic circuitry.

[0056] To provide for interaction with a user, one or more aspects of the disclosure can be implemented on a computer having a display device, e.g., a CRT (cathode ray tube), LCD (liquid crystal display) monitor, or touch screen for displaying information to the user and optionally a keyboard and a pointing device, e.g., a mouse or a trackball, by which the user can provide input to the computer. Other kinds of devices can be used to provide interaction with a user as well; for example, feedback provided to the user can be any form of sensory feedback, e.g., visual feedback, auditory feedback, or tactile feedback; and input from the user can be received in any form, including acoustic, speech, or tactile input. In addition, a computer can interact with a user by sending documents to and receiving documents from a device that is used by the user; for example, by sending web pages to a web browser on a user's client device in response to requests received from the web browser.

[0057] One or more aspects of the disclosure can be implemented in a computing system that includes a backend component, e.g., as a data server, or that includes a middleware component, e.g., an application server, or that includes a frontend component, e.g., a client computer having a graphical user interface or a Web browser through which a user can interact with an implementation of the subject matter described in this specification, or any combination of one or more such backend, middleware, or frontend components. The components of the system can be interconnected by any form or medium of digital data communication, e.g., a communication network. Examples of communication networks include a local area network ("LAN") and a wide area network ("WAN"), an inter-network (e.g., the Internet), and peer-to-peer networks (e.g., ad hoc peer-to-peer networks).

[0058] The computing system can include clients and servers. A client and server are generally remote from each other and typically interact through a communication network. The relationship of client and server arises by virtue of computer programs running on the respective computers and having a client-server relationship to each other. In some implementations, a server transmits data (e.g., an HTML page) to a client device (e.g., for purposes of displaying data to and receiving user input from a user interacting with the client device). Data generated at the client device (e.g., a result of the user interaction) can be received from the client device at the server.

[0059] While this specification contains many specifics, these should not be construed as limitations on the scope of the disclosure or of what may be claimed, but rather as descriptions of features specific to particular implementations of the disclosure. Certain features that are described in this specification in the context of separate implementations can also be implemented in combination in a single implementation. Conversely, various features that are described in the context of a single implementation can also be implemented in multiple implementations separately or in any suitable sub-combination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a sub-combination or variation of a sub-combination.

[0060] Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain circumstances, multi-tasking and parallel processing may be advantageous. Moreover, the separation of various system components in the embodiments described above should not be understood as requiring such separation in all embodiments, and it should be understood that the described program components and systems can generally be integrated together in a single software product or packaged into multiple software products.

[0061] A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the disclosure. Accordingly, other implementations are within the scope of the following claims. For example, the actions recited in the claims can be performed in a different order and still achieve desirable results.

What is claimed is:

1. A method for generating a heat map of a surface area, the method comprising:

receiving, at a hardware processor, sensor data from one or more sensors in communication with the hardware processor and positioned such that the surface area is within a field of view of the one or more sensors;

determining, at the hardware processor, the speed and location for each one of the one or more traffic participants;

generating, at the hardware processor, a 2D map based on the one or more traffic participants;

generating, at the hardware processor, a 3D map based on the one or more traffic participants.

2. The method of claim **1**, further comprising overlaying the 3D map with traffic participants on an augmented reality map of the stationary objects of the intersection.

3. The method of claim **1**, further comprising overlaying the 3D map with traffic participants on a virtual reality map of the stationary objects of the intersection.

4. A traffic monitoring system for generating a heat map of a surface area, the system comprising:

a hardware processor; and

hardware memory in communication with the hardware processor, the hardware memory storing instructions that when executed on the hardware processor cause the hardware processor to perform operations comprising:

receiving, at a hardware processor, sensor data from one or more sensors in communication with the hardware processor and positioned such that the surface area is within a field of view of the one or more sensors;

determining, at the hardware processor, the speed and location for each one of the one or more traffic participants;

generating, at the hardware processor, a 2D map based on the one or more traffic participants; and

generating, at the hardware processor, a 3D map based on the one or more traffic participants; and

a display to show the 3D map.

5. The system of claim **4**, wherein the operations further comprise overlaying the 3D map with traffic participants on an augmented reality map of the stationary objects of the intersection.

5. The system of claim **4**, wherein the operations further comprise overlaying the 3D map with traffic participants on a virtual reality map of the stationary objects of the intersection.

6. The system of claim **4**, wherein the operations further include determining traffic participant boundaries based on the heat map, each boundary identifies traffic lanes, crosswalks, and/or pedestrian lanes of the surface area.

7. The system of claim **4**, wherein the sensors further comprises one of: a camera, a radar, a LIDAR, a LADAR, ultrasound, and sonar.

8. The system of claim **4**, wherein the sensors are secured to at least one infrastructure component, and wherein the at least one infrastructure component being one selected from the group consisting of a building, a bridge, a parking structure, and a support structure.

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