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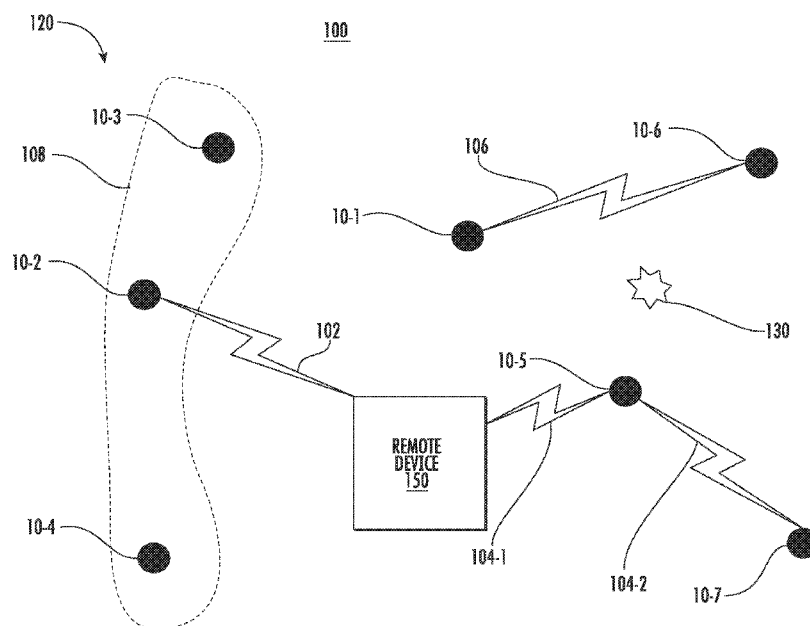


FIG. 2

(57) Abstract: Aspects of the present disclosure provide a decentralized network of processors and processing technologies that are co-located with smart poles. Each smart pole has a respective processor therein or thereon. The processor of the smart pole is configured to receive signals from one or more electronic sensors located at the smart pole, analyze the signals to detect an incident in a vicinity of the smart pole, and perform one or more actions responsive to the detection, such as reporting data to a remote device. By performing the one or more actions only responsive to the detection of the incident, the present disclosure provides a technical advantage in that network performance is improved.



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SMART POLE BASED INCIDENT DETECTION AND ALERTING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] The present application claims the benefit of priority to U.S. Provisional Application No. 62/986,948, filed on March 9, 2020, the entire contents of which are incorporated by reference as if set forth herein.

TECHNICAL FIELD

[0002] The present disclosure relates to a smart pole based detection and alerting system.

BACKGROUND

[0003] In recent years, the telecommunications industry has experienced rapid growth by offering a variety of new and improved services to customers. This growth has been particularly notable in the area of wireless communications, e.g., cellular, personal communication services (PCS) and other mobile radio systems. The technology is continually evolving as consumer needs change and new ideas are developed.

[0004] Cellular communications systems are well known in the art. In a typical cellular communications system, a geographic area may be divided into a series of regions that are referred to as "cells," and each cell is served by a base station. Typically, a cell may serve users who are within a distance of, for example, 2-20 kilometers from the base station, although smaller cells are typically used in urban areas to increase capacity. The base station may include baseband equipment, radios and antennas that are configured to provide two-way radio frequency ("RF") communications with mobile subscribers that are positioned throughout the cell. In many cases, the cell may be divided into a plurality of "sectors," and separate antennas may provide coverage to each of the sectors. The antennas are often mounted on a tower or other raised structure, with the radiation beam ("antenna beam") that is generated by each antenna directed outwardly to serve a respective sector. Typically, a base station antenna includes one or more phase-controlled arrays of radiating elements, with the radiating elements arranged in one or more vertical columns when the antenna is mounted for use. Herein, "vertical" refers to a direction that is perpendicular relative to the plane defined by the horizon.

[0005] In order to increase capacity, cellular operators have, in recent years, been deploying so-called "small cell" cellular base stations. A small cell base station refers to a low-power base station that may operate in the licensed and/or unlicensed spectrum that has a much smaller range than a typical "macrocell" base station. A small cell base station may be designed to serve users who are within short distances from the small cell base station (e.g., tens or hundreds of meters). Small cells may be used, for example, to provide cellular coverage to high traffic areas within a macrocell, which allows the macrocell base station to offload much or all of the traffic in the vicinity of the small cell to the small cell base station. Small cells may be particularly effective in Long Term Evolution ("LTE") cellular networks in efficiently using the available frequency spectrum to maximize network capacity at a reasonable cost. Small cell base stations typically employ an antenna that provides full 360 degree coverage in the azimuth plane and a suitable beamwidth in the elevation plane to cover the designed area of the small cell. In many cases, the small cell antenna will be designed to have a small downtilt in the elevation plane to reduce spill-over of the antenna beam of the small cell antenna into regions that are outside the small cell and also for reducing interference between the small cell and the overlaid macro cell.

[0006] Alongside the development and deployment of small cell cellular base stations, there has been increasing development and deployment of "smart pole" designs. Smart poles stem in part from the increasing efforts within communities to reduce or minimize visual clutter arising from numerous utility poles and other vertical structures, such as base station antenna towers, each supporting only a limited number of electronic devices. Instead, smart poles typically have at their core a monopole structure configured to support one or more street lights, which illuminate street and path surfaces below. As these poles are already supplied with power, they provide a convenient location at which other electronic devices can be located. Such electronic devices can include, for example, small cell base stations, weather stations or weather sensors, microphones, cameras, motion detectors, RFID sensors, infrared sensors, particle detectors (e.g., smoke detectors, radiation detectors), and so on. Such electronic devices can assist law enforcement and other officials within a community to identify and respond to threats, emergencies, accidents, traffic incidents, or other situations.

SUMMARY

[0007] Aspects of the present disclosure include methods, systems, and apparatuses which may include and/or may utilize processors and processing technologies that are co-located with smart poles. For example, some aspects of the present disclosure provides methods, such as a method in which a processor co-located with a smart pole: receives data from at least a first sensor of the smart pole; determines that the data indicates an incident occurring in a vicinity of the smart pole; and communicates an indication of the incident to a remote device.

[0008] Some aspects of the present disclosure other methods, such as: receiving, by a processor co-located with a first smart pole, data from a sensor of the first smart pole; determining, by the processor, that the data indicates an incident occurring in a vicinity of the smart pole; and transmitting, by the processor co-located with the first smart pole, a request for data from a sensor of a second smart pole and for data from a sensor of a third smart pole.

[0009] Some aspects of the present disclosure provide apparatuses and/or systems, such as a smart pole that may include: at least one sensor; a processor positioned within the smart pole and communicatively coupled to the at least one sensor; and memory storing non-transitory computer readable instructions that, when executed by the processor cause the processor to perform operations. These operations may include: receiving data from the at least one sensor; determining that the data indicates an incident occurring in a vicinity of the smart pole; and communicating an indication of the incident to a remote device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] **FIG. 1** is a block diagram illustrating components of a smart pole assembly used in a smart pole based incident detection and alerting system.

[0011] **FIG. 2** is a block diagram illustrating a smart pole based incident detection and alerting system comprising a plurality of smart pole assemblies of **FIG. 1**.

[0012] **FIGS. 3** and **4** are flowcharts illustrating example methods of detecting an incident using the assembly of **FIG. 1** and/or the system of **FIG. 2**, according to some of the inventive concepts of the present disclosure.

[0013] **FIG. 5** is a schematic block diagram of various components of a computing device, which may be used in the implementation of the processing unit of **FIG. 1**, as well as other devices discussed herein.

DETAILED DESCRIPTION

[0014] Typically, data from the electronic devices that are mounted on smart poles is delivered either by wire or wirelessly to a central command location, where it is acted upon. For example, an explosion or a discharging firearm may create observable sounds and/or may be visible by camera. Public safety officials may respond to the observed explosion or gunfire using police, fire, and medical first responders, and may coordinate their response based on identification of the type, location, and severity of the emergency; an act of terrorism or violence requires a different response than a gas leak or vehicle fire.

[0015] As the number of electronic devices on smart poles proliferate, there is a corresponding increase of data communicated to the central command location. This has potentially undesirable effects. First, there is increasing concern with respect to individual rights and civil liberties. Cameras and microphones that can observe the public may be susceptible to abuse and voyeurism, even if deployed for legitimate public safety concerns. Second, an increase in data creates challenges for officials (e.g., law enforcement) to maintain vigilant observation of an observed area (e.g., neighborhood, city, county, community, street, premises, factory, or the like). For example, if staffing levels are not adjusted, an increase in the number of cameras may actually reduce the efficacy of the surveillance, because of the greater amount of image data that must be studied per unit of time. Third, an increased amount of data creates constraints on the network delivering such data, requiring a greater number and/or size (in terms of bandwidth or throughput) of communication links between the network of smart poles and the central command location.

[0016] Aspects of the present disclosure address these undesirable effects by providing a decentralized network of processors and processing technologies that are co-located with the smart poles. In other words, each smart pole has a respective processor therein or thereon. The processor of the smart pole is configured to receive signals from one or more electronic devices located at the smart pole, analyze the signals to detect an incident in a vicinity of the smart pole, and perform one or more actions responsive to the detection, such as reporting data to a remote device. By performing the one or more actions only responsive to the detection of the incident, the present disclosure provides a technical advantage in that network performance is improved, as in "normal" situations (i.e., when no incident is occurring) transmitting data may be reduced or eliminated

entirely, reducing network congestion. Furthermore, by performing the one or more actions only responsive to the detection of the incident, civil liberties may be preserved while still enabling public safety to perform legitimate functions, in that only when the co-located processor detects an incident is an indication of the incident transmitted to the remote device, thus reducing voyeurism.

[0017] Referring to **FIG. 1**, a smart pole assembly **10** is shown. In one aspect, the smart pole assembly **10** can include a pole structure **12** having a hollow interior supported by a base **14**. A lamp or light fixture **16** can be supported by the pole structure **12** and can be powered by a power line **20** extending through the base **14** and pole structure **12**. Although a cylindrical smart pole assembly is shown in **FIG. 1**, the present disclosure is not limited to pole structures **12** having circular or near-circular cross-sections, and square, rectangular, or other cross-sections may be implemented.

[0018] The smart pole assembly includes a processing unit **23**, which is communicatively coupled to the sensors of an upper sensor array **19** and/or a lower sensor array **21**, which will be discussed in greater detail below. The processing unit **23** may include at least one processor **23-1** which may be any general purpose processor that is specifically or specially programmed to implement at least one of the one or more algorithms and/or functions described herein, or may be a specifically or specially constructed processor that is programmed to implement at least one of such algorithms and/or functions. For example, the processor **23** may be an application-specific integrated circuit (ASIC), a system on chip (SoC), a field programmable gate array (FPGA), a micro-processor, or the like, although the present disclosure is not limited to such examples. Further, the processing unit may include at least one memory **23-2** storing instructions that, when executed by the at least one processor **23-1**, cause the at least one processor **23-1** to perform at least one of the algorithms and/or functions described herein. Further aspects and/or components of the processing unit **23** will be described in greater detail below with reference to **FIG. 6**.

[0019] The upper sensor array **19** and/or lower sensor array **21** may each include one or more sensors, such as a photo-cell for sensing ambient light, a microphone and/or other sensors configured to detect sound, an imaging device (e.g., thermal cameras, infrared cameras, still cameras, motion cameras, and so on), a radio frequency identification (RFID) sensor, moisture sensor, temperature sensor, and/or a particulate sensor (e.g., a smoke detector, a radiation sensor,

a volatile organic compound (VOC) sensor, or the like). The listed sensors are merely provided as examples, and the present disclosure is not limited thereto.

[0020] The number, type, and position of the sensors may be selected based on conditions or characteristics of the vicinity of the installation site of the smart pole assembly **10**. For example, it may be more practical as a matter of early detection and/or warning to place a greater number of radiation sensors (e.g., a greater number of smart pole assemblies **10** having at least one radiation sensor) near a known radiation source, such as a power plant, and/or near a known or expected site for potential aberrant and/or terrorist activity, such as more densely populated areas and/or central business areas (e.g., downtown). Conversely, some of the sensors may be optional or omitted as local conditions warrant. Further, some sensors may be located at either the upper sensor array **19** and/or the lower sensor array **21**.

[0021] Although data from the upper sensor array **19** and/or the lower sensor array **21** is described as being provided to the processing unit **23** for processing according to the algorithms and/or methods described herein, in some embodiments, data from at least some of the sensors of the upper sensor array **19** and/or lower sensor array **21** may also be communicated to one or more remote sources. For example, a lidar sensor may be provided at the lower sensor array **21** to obtain information pertaining to vehicular traffic in the vicinity of the smart pole assembly **10**. This information may be communicated to the processing unit **23** in accordance with the present disclosure, but may also be communicated to one or more vehicles (e.g., “smart” vehicles) or traffic lights (e.g., “smart” traffic lights) to enable and/or enhance operation thereof.

[0022] In some embodiments, a plurality of a same type of sensor may be provided in a circumferential arrangement to provide omni-directional or near-omni-directional coverage of an environment in the vicinity of the smart pole assembly **10**. For example, two, three, four, or more than four RFID sensors may be provided in the upper sensor array **19** and/or the lower sensor array **21**, to ensure that RFID tags passing within range of the smart pole assembly **10** are detected. In some embodiments, a single sensor, such as an image sensor, may be provided along with a mechanism for moving, the sensor in one or more ways. For example, an image sensor may have a field of view that is limited to only a portion of the three-hundred-sixty degrees (360) of azimuth about the smart pole assembly **10**. One or more assemblies may be provided to aim and/or rotate the image sensor from receiving data from a first portion of the azimuth plane (e.g., 0-45 degrees) to receiving data from a second portion of the azimuth plane (e.g., 180-215 degrees). Herein, for

convenience of description, 0 degrees in the azimuth direction of a smart pole assembly **10** may be considered North 0 degrees, although the present disclosure is not limited thereto.

[0023] The smart pole assembly **10** is also provided with a data communications module **18** supported by the pole structure **12**. The data communications module **18** can be provided to support and/or house a variety of data- communications equipment components. For example, the data-communications module **18** can be provided with a small cell base station including one or more radio heads and antennas, a wireless transceiver configured to communicate in one or more frequency bands (e.g., microwave bands, radio frequency bands allocated to telecommunications, radio frequency bands, or the like). The data communications module **18** may be configured to support one-way or two-way communications between components of the smart pole assembly **10** (e.g., the sensors of the upper sensor array **19** and/or the lower sensor array **21**, the processing unit **23**) with a remote device. The data communications module **18** may be configured to provide telecommunications services to consumers of data, such as mobile devices, laptop and desktop computers, and tablets and smartphones, within a service area in a vicinity of the smart pole assembly **10**. The data communications module **18** may be configured with a wired backhaul link **22**, although in some embodiments this backhaul link may be wireless (e.g., microwave).

[0024] Turning now to **FIG. 2**, a system **100** may include a plurality of smart pole assemblies **10** (seven pole assemblies **10-1** to **10-7** are shown) arranged at various locations in an environment **120**. For example, smart pole assemblies **10** may be located along streets or pathways and/or at street intersections, at places of public gatherings, at sites of importance (e.g., shrines, temples, churches, tourist locations, or the like), or as appropriate for local conditions. Smart pole assemblies **10** may be spaced apart from each other at relatively uniform intervals (e.g., every 10 meters, every 100 feet, every mile), or the smart pole assemblies may be placed at non-uniform intervals. Also located within the system **100** is a remote device **150**. The remote device **150** may be located at a central command facility, such as an emergency operations center or police station, or may be located elsewhere. In some embodiments the remote device **150** may be a mobile device configured with telecommunications capabilities. In its simplest form, remote device **150** may even be an electronic pager or a telephone hardwired to a telephone network. Although the remote device **150** is shown as relatively proximate to the plurality of smart pole assemblies **10** and relatively centrally located among the plurality of smart pole assemblies **10**, the present disclosure is not limited thereto.

[0025] The smart pole assemblies **10** may communicate with each other and with the remote device **150**. In some embodiments, the communication between smart pole assemblies **10** may be a direct communication link **102**, and in some embodiments the communication may be an indirect communication link **104** in which a first smart pole assembly **10** (in this case, smart pole assembly **10-5**) may act as a relay for a communication from a second smart pole assembly **10** (in this case, smart pole assembly **10-7**). In such embodiments, first and second communication links **104-1** and **104-2** may be created or used.

[0026] Further, two or more devices may communicate using a device-to-device communication link or network **106**. Although communication network **106** is shown as a device-to-device link, in some embodiments the smart pole assemblies **10** may engage in point-to-multipoint communications (e.g., via multicast or unicast) and may communicate on a network created specifically for smart pole assemblies **10**, or may communicate via other networks (including the Internet). Each of the smart pole assemblies **10** may be individually identifiable and/or addressable, and/or each of the smart pole assemblies **10** may register with one or more multicast groups based on properties and/or characteristics thereof. For example, each of smart pole assemblies **10-2**, **10-3**, and **10-4** may register with a multicast group **108**, which may be configured as a multicast group for a certain area or portion of environment **120**. Not all communication links are shown in **FIG. 2**, in order to simplify the drawing.

[0027] As discussed above, aspects of the present disclosure permit the processing unit **23** of each smart pole assembly **10** to receive signals from one or more sensors thereof (e.g., at the upper sensor array **19** and/or lower sensor array **21**), analyze the signals to detect an incident (such as incident **130** of **FIG. 2**) in a vicinity of the smart pole, and perform one or more actions responsive to the detection, such as reporting data to a remote device (such as remote device **150** of **FIG. 2**). In some embodiments, the one or more actions include communicating with processing units **23** of other smart pole assemblies **10** in order to determine a location of the incident **130**. For example, data from three smart pole assemblies **10** may be used to triangulate an approximate location of the incident **130**, and the nearest smart pole assembly **10** may then obtain an image of the approximate location and communicate the image to the remote device **150**.

[0028] **FIG. 3** is a flowchart illustrating a first example method of detecting an incident using the assembly of **FIG. 1** and/or the system of **FIG. 2**. In a first operation **S310** of method **300**, the processing unit **23** of a smart pole assembly **10** may receive data from at least one sensor thereof.

For example, the processing unit **23** may receive audio data from an audio sensor, and/or the processing unit **23** may receive image data from an image sensor, such as a camera device.

[0029] In a second operation **S320**, the data may be analyzed using one or more analytical methods programmed into the processor **23-1** of the processing unit **23**. For example, the processing unit **23** may be programmed with a recurrent neural network (RNN) in which a waveform in the audio data is classified as a type of incident. The RNN may be trained using audio waveforms corresponding to gunfire or explosions, for example. Additionally or alternatively, the processing unit **23** may be programmed with a convoluted neural network (CNN) which is trained to classify objects in image data, such as firearms, bombs (e.g., improvised explosive devices) face masks, or other objects.

[0030] In a third operation **S330**, the data and/or the output of the one or more analytical methods may be used to determine whether an incident is occurring in a vicinity of the smart pole assembly **10**. For example, data from some sensors may be compared with a threshold. If the data is at or above a threshold, then it may be determined that an incident is occurring. Conversely, if the data is below the threshold, then it may be determined that the incident is not occurring. As another example, an output in the form of a classification score and/or confidence level from one or more analytical methods may be compared with a threshold. If the output is at or above a threshold, then it may be determined that an incident is occurring. Conversely, if the output is below the threshold, then it may be determined that the incident is not occurring.

[0031] If no incident is occurring ("No" branch from operation **S330**), then in operation **S335** the data may be discarded, although in some embodiments the data may be stored for a finite duration of time in a storage device local to the smart pole assembly **10** prior to being discarded. Storage of such data may be required for regulatory reasons, and stored data may be useful to the processing unit **23** in the future. For example, an isolated event may not rise to the level of an actionable incident (e.g., a sound of a car honking), but repeated events may collectively give rise to an incident (e.g. heavy traffic in an area).

[0032] If, however, it is determined that an incident is occurring ("Yes" branch from operation **S330**), then in operation **S340** one or more actions may be performed responsive to the determination. For example, a camera or image device may be rotated or moved to capture an approximate location of the incident. The location may be determined, for example, from a plurality of audio sensors arranged around the circumference or perimeter of the smart pole

assembly **10**, as discussed previously. Data from each of the plurality of audio sensors may be analyzed for loudness (e.g., amplitude), with the understanding the loudest audio is likely originating from the source of the incident. Another method for approximating the position or location of an incident is discussed below with respect to **FIG. 4**, which may be used in conjunction with this method.

[0033] As discussed, the one or more actions performed may include reporting or communicating the occurrence of the event to a remote device. This may include, for example, transmitting data indicative of the event, such as time, location, type of event, confidence in the determination, captured data from the one or more sensors. In some embodiments, a telecommunications session in which "real-time" information is transmitted to the remote device **150** may be instantiated. For example, a session in which audio and/or video data is streamed to the remote device may be begun.

[0034] **FIG. 4** is a flowchart illustrating a second example method of detecting an incident using the assembly of **FIG. 1** and/or the system of **FIG. 2**. As with operation **310** of **FIG. 3**, in a first operation **S410** of method **400**, the processing unit **23** of a first smart pole assembly **10-1** may receive data from at least one sensor thereof. For example, the processing unit **23** may receive audio data from an audio sensor, and/or the processing unit **23** may receive image data from an image sensor, such as a camera device.

[0035] In a second operation **S420**, the data may be analyzed using one or more analytical methods programmed into the processor **23-1** of the processing unit **23** of the first smart pole assembly **10-1**. For example, the processing unit **23** may be programmed with a recurrent neural network (RNN) in which a waveform in the audio data is classified as a type of incident. The RNN may be trained using audio waveforms corresponding to gunfire or explosions, for example. Additionally or alternatively, the processing unit **23** may be programmed with a convoluted neural network (CNN) which is trained to classify objects in image data, such as firearms, bombs (e.g., improvised explosive devices) face masks, or other objects.

[0036] In a third operation **S430**, the data and/or the output of the one or more analytical methods may be used to determine whether the first smart pole assembly **10-1** should request data from one or more other smart pole assemblies, such as second smart pole assembly **10-2** and/or third smart pole assembly **10-3**. For example, data from some sensors may be compared with a threshold. If the data is at or above a threshold ("Yes" branch from operation **S430**), then it may

be determined that data should be requested, and the data is requested in operation **S440**. Conversely, if the data is below the threshold ("No" branch from operation **S430**), then it may be determined that the data should not be requested and may be stored in operation **S435**. As another example, an output in the form of a classification score and/or confidence level from one or more analytical methods may be compared with a threshold. If the output is at or above a threshold, then it may be determined that the data should be requested. Conversely, if the output is below the threshold, then it may be determined that the data should not be requested.

[0037] In some embodiments, requesting data by a first smart pole assembly **10-1** from one or more other smart pole assemblies, such as second smart pole assembly **10-2** and/or third smart pole assembly **10-3**, may be an action performed responsive to detecting an incident has occurred; however, the threshold for requesting data from other smart pole assemblies may be different than the threshold for determining that an incident has occurred in operation **S330** of **FIG. 3**.

[0038] The data requested in operation **S440** may be received by the first smart pole assembly **10-1**. In some embodiments, if an event occurs, it is to be expected that multiple smart pole assemblies **10** may determine that the data is at or exceeds the threshold at which data from other smart pole assemblies **10** of the system **100** should be requested. To avoid network flooding where each smart pole assembly **10** is requesting and responding to data requests, in some embodiments the request for data may include an identifier by which a request collision mechanism may be implemented. For example, a maximum loudness level of an audio signal associated with the event may be included in a request transmitted from first smart pole assembly **10-1** to second smart pole assembly **10-2**. If the maximum loudness level of an audio signal associated with the event (e.g., at the same timestamp or a substantially similar timestamp) recorded by the second smart pole assembly **10-2** exceeds that of the first smart pole assembly **10-1**, then it may be presumed that the second smart pole assembly **10-2** is closer to the event than the first smart pole assembly **10-1**. Accordingly, the second smart pole assembly **10-2** may elect not to respond to the request for data received from the first smart pole assembly **10-1**.

[0039] Accordingly, a request for data may be valid for a period of time. If data is received from the other smart pole assemblies **10-2**, **10-3** ("Yes" branch from operation **S445**), then the method **400** of **FIG. 4** may continue with operations **S450**, **S435**, and **S460** which may be similar to operations **S330**, **S335**, and **S340** of **FIG. 3**. If data is not received from the other smart pole assemblies **10-2**, **10-3** ("No" branch from operation **S445**), then the data may be stored and/or

discarded in operation **S435**. In some embodiments, the one or more actions performed in operation **S460** may include determining a location of the incident using triangulation.

[0040] **FIG. 5** illustrates various components of a computing device **600** which may be used to implement one or more of the devices, components, and/or modules herein, such as the processing unit **23** of **FIG. 1**. **FIG. 5** illustrates hardware elements that can be used in implementing any of the various computing devices discussed herein. In some aspects, general hardware elements may be used to implement the various devices discussed herein, and those general hardware elements may be specially programmed with instructions that execute the algorithms discussed herein. In special aspects, hardware of a special and non-general design may be employed (e.g., ASIC or the like). Various algorithms and components provided herein may be implemented in hardware, software, firmware, or a combination of the same.

[0041] A computing device **600** may include one or more processors **601**, which may execute instructions of a computer program to perform any of the features described herein. The instructions may be stored in any type of computer-readable medium or memory, to configure the operation of the processor **601**. For example, instructions may be stored in a read-only memory (ROM) **602**, random access memory (RAM) **603**, removable media **604**, such as a Universal Serial Bus (USB) drive, compact disk (CD) or digital versatile disk (DVD), floppy disk drive, or any other desired electronic storage medium. Instructions may also be stored in an attached (or internal) hard drive **605**. The computing device **600** may be configured to provide output to one or more output devices (not shown) such as printers, monitors, display devices, and so on, and receive inputs, including user inputs, via input devices (not shown), such as a remote control, keyboard, mouse, touch screen, microphone, or the like. The computing device **600** may also include input/output interfaces **607** which may include circuits and/or devices configured to enable the computing device **600** to communicate with external input and/or output devices on a unidirectional or bidirectional basis. The components illustrated in **FIG. 5** (e.g., processor **601**, ROM storage **602**) may be implemented using basic computing devices and components, and the same or similar basic components may be used to implement any of the other computing devices and components described herein. For example, the various components herein may be implemented using computing devices having components such as a processor executing computer-executable instructions stored on a computer-readable medium, as illustrated in **FIG. 5**.

[0042] The inventive concepts provided by the present disclosure have been described above with reference to the accompanying drawings and examples, in which examples of embodiments of the inventive concepts are shown. The inventive concepts provided herein may be embodied in many different forms than those explicitly disclosed herein, and the present disclosure should not be construed as limited to the embodiments set forth herein. Rather, the examples of embodiments disclosed herein are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the inventive concepts to those skilled in the art. Like numbers refer to like elements throughout.

[0043] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the specification and relevant art and should not be interpreted in an idealized or overly formal sense unless expressly so defined herein. Well-known functions or constructions may not be described in detail for brevity and/or clarity.

[0044] Some of the inventive concepts are described herein with reference to block diagrams and/or flowchart illustrations of methods, apparatus (systems) and/or computer program products, according to embodiments of the inventive concepts. It is understood that one or more blocks of the block diagrams and/or flowchart illustrations, and combinations of blocks in the block diagrams and/or flowchart illustrations, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, and/or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer and/or other programmable data processing apparatus, create means for implementing the functions/acts specified in the block diagrams and/or flowchart block or blocks.

[0045] These computer program instructions may also be stored in a computer-readable memory that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable memory produce an article of manufacture including instructions which implement the function/act specified in the block diagrams and/or flowchart block or blocks.

[0046] The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer-implemented process such that the instructions which execute on the computer or other programmable apparatus provide steps for implementing the functions/acts specified in the block diagrams and/or flowchart block or blocks.

[0047] Accordingly, the inventive concepts may be embodied in hardware and/or in software (including firmware, resident software, micro-code, etc.). Furthermore, embodiments of the present inventive concepts may take the form of a computer program product on a computer-usable or computer-readable non-transient storage medium having computer-usable or computer-readable program code embodied in the medium for use by or in connection with an instruction execution system.

[0048] The computer-usable or computer-readable medium may be, for example but not limited to, an electronic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device. More specific examples (a non-exhaustive list) of the computer-readable medium would include the following: an electrical connection having one or more wires, a portable computer diskette, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory such as an SD card), an optical fiber, and a portable compact disc read-only memory (CD-ROM).

[0049] The terms first, second, etc. may be used herein to describe various elements, but these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element, without departing from the scope of the present inventive concepts. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. 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 should be further understood that the terms "comprises," "comprising," "includes," and/or "including" when used herein, specify the presence of stated features, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, operations, elements, components, and/or groups thereof.

[0050] When an element is referred to as being "on" another element, it can be directly on the other element or intervening elements may also be present. In contrast, when an element is referred to as being "directly on" another element, there are no intervening elements present. When an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present. Other words used to describe the relationship between elements should be interpreted in a like fashion (i.e., "between" versus "directly between", "adjacent" versus "directly adjacent", etc.).

[0051] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure.

[0052] Aspects and elements of all of the embodiments disclosed above can be combined in any way and/or combination with aspects or elements of other embodiments to provide a plurality of additional embodiments. Although a few exemplary embodiments of the inventive concepts have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of the inventive concepts provided herein. Accordingly, all such modifications are intended to be included within the scope of the present application as defined in the claims.

What is claimed is:

1. A method comprising:
receiving, by a processor co-located with a smart pole, data from at least a first sensor of the smart pole;
determining, by the processor, that the data indicates an incident occurring in a vicinity of the smart pole; and
communicating, by the processor, an indication of the incident to a remote device.
2. The method of Claim 1, wherein the first sensor is an image sensor, wherein the data is image data, and wherein determining that the data indicates an incident comprises identifying an object in the image data.
3. The method of Claim 2, wherein the image is identified using a convoluted neural network.
4. The method of Claim 1, wherein the first sensor is an acoustic sensor, wherein the data is audio data, and wherein determining that the data indicates an incident comprises identifying an acoustic signature in the audio data.
5. The method of Claim 4, wherein the acoustic signature is identified using a recurrent neural network.
6. The method of Claim 4, further comprising:
determining a location of a source of the audio data.
7. The method of Claim 6, wherein the location is determined by triangulating the location of the source.
8. The method of Claim 7, wherein the smart pole is a first smart pole, and wherein triangulating the location of the source comprises:

receiving, by the processor co-located with the first smart pole, data from at least one sensor of a second smart pole different from the first smart pole; and

receiving, by the processor co-located with the first smart pole, data from at least one sensor of a third smart pole different from the first and second smart poles.

9. The method of Claim 8, wherein the first smart pole comprises an image sensor, and wherein the method further comprises:

positioning an aperture of an image sensor toward the determined location.

10. A smart pole comprising:

at least one sensor;

a processor positioned within the smart pole and communicatively coupled to the at least one sensor; and

memory storing non-transitory computer readable instructions that, when executed by the processor cause the processor to perform operations comprising:

receiving data from the at least one sensor;

determining that the data indicates an incident occurring in a vicinity of the smart pole; and

communicating an indication of the incident to a remote device.

11. The smart pole of Claim 10, wherein the at least one sensor includes an image sensor, wherein the data is image data, and wherein determining that the data indicates an incident comprises identifying an object in the image data.

12. The smart pole of Claim 11, wherein the image is identified using a convoluted neural network.

13. The smart pole of Claim 10, wherein the at least one sensor includes an acoustic sensor, wherein the data is audio data, and wherein determining that the data indicates an incident comprises identifying an acoustic signature in the audio data.

14. The smart pole of Claim 13, wherein the acoustic signature is identified using a recurrent neural network.
15. A method comprising:
 - receiving, by a processor co-located with a first smart pole, data from a sensor of the first smart pole;
 - determining, by the processor, that the data indicates an incident occurring in a vicinity of the smart pole; and
 - transmitting, by the processor co-located with the first smart pole, a request for data from a sensor of a second smart pole and for data from a sensor of a third smart pole.
16. The method of Claim 15, wherein the request indicates a timestamp associated with the incident.
17. The method of Claim 15, further comprising receiving, responsive to the request, data from the sensor of the second smart pole and data from the sensor of the third smart pole.
18. The method of Claim 17, further comprising determining a location of the incident relative to the first smart pole.
19. The method of Claim 18, wherein the location is determined based on a triangulation using the data from the sensors of the first, second, and third smart poles.
20. The method of Claim 19, further comprising pointing an image sensor of the first smart pole toward the determined location.

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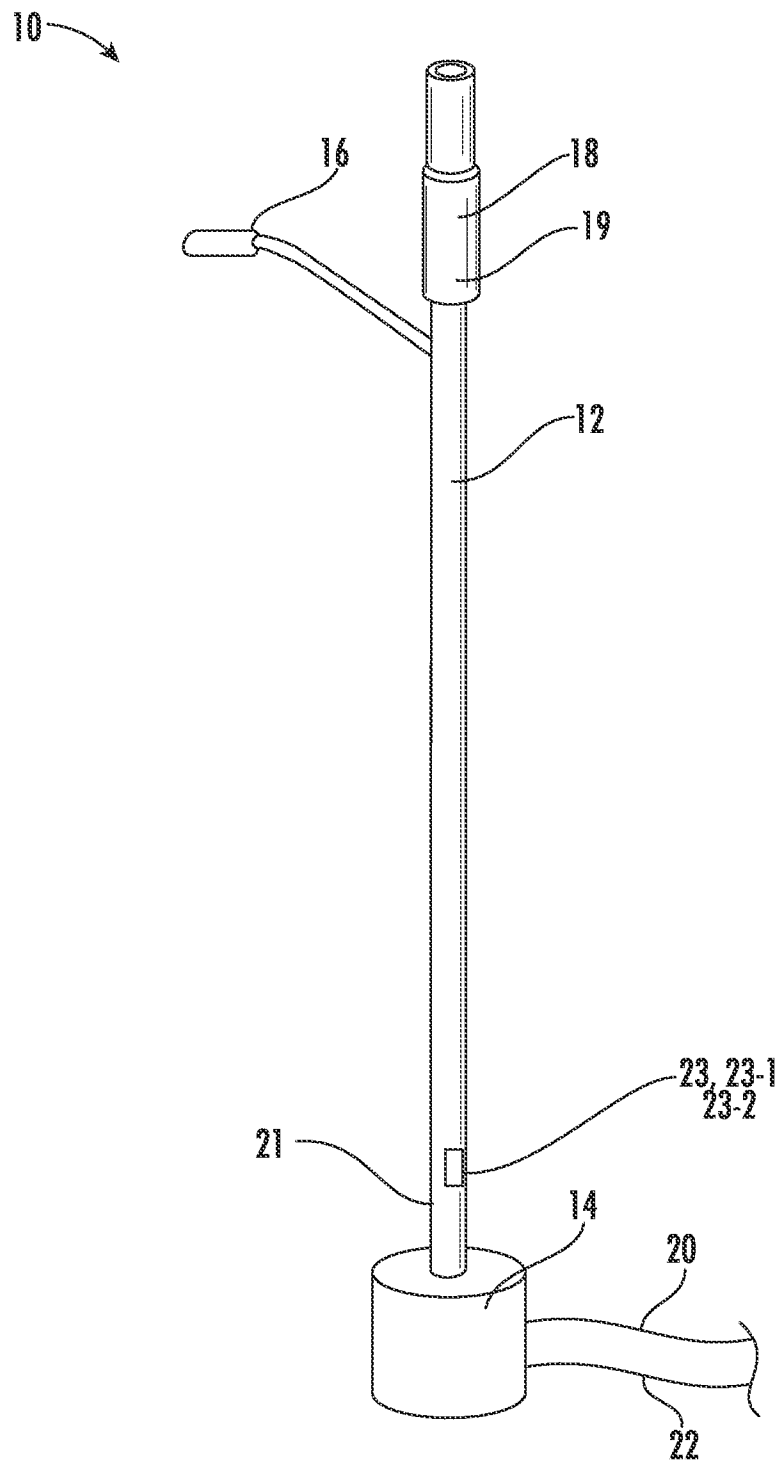


FIG. 1

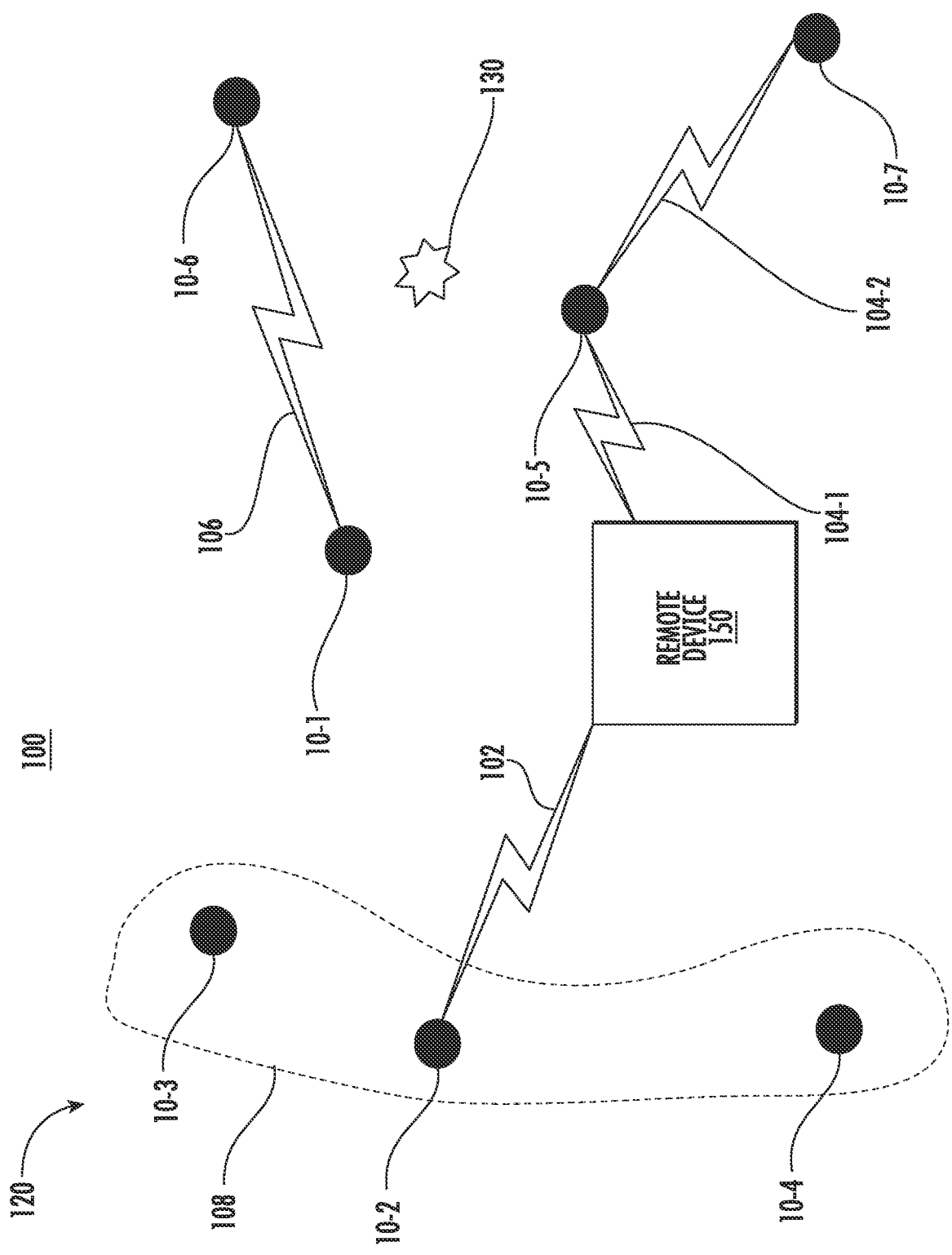


FIG. 2

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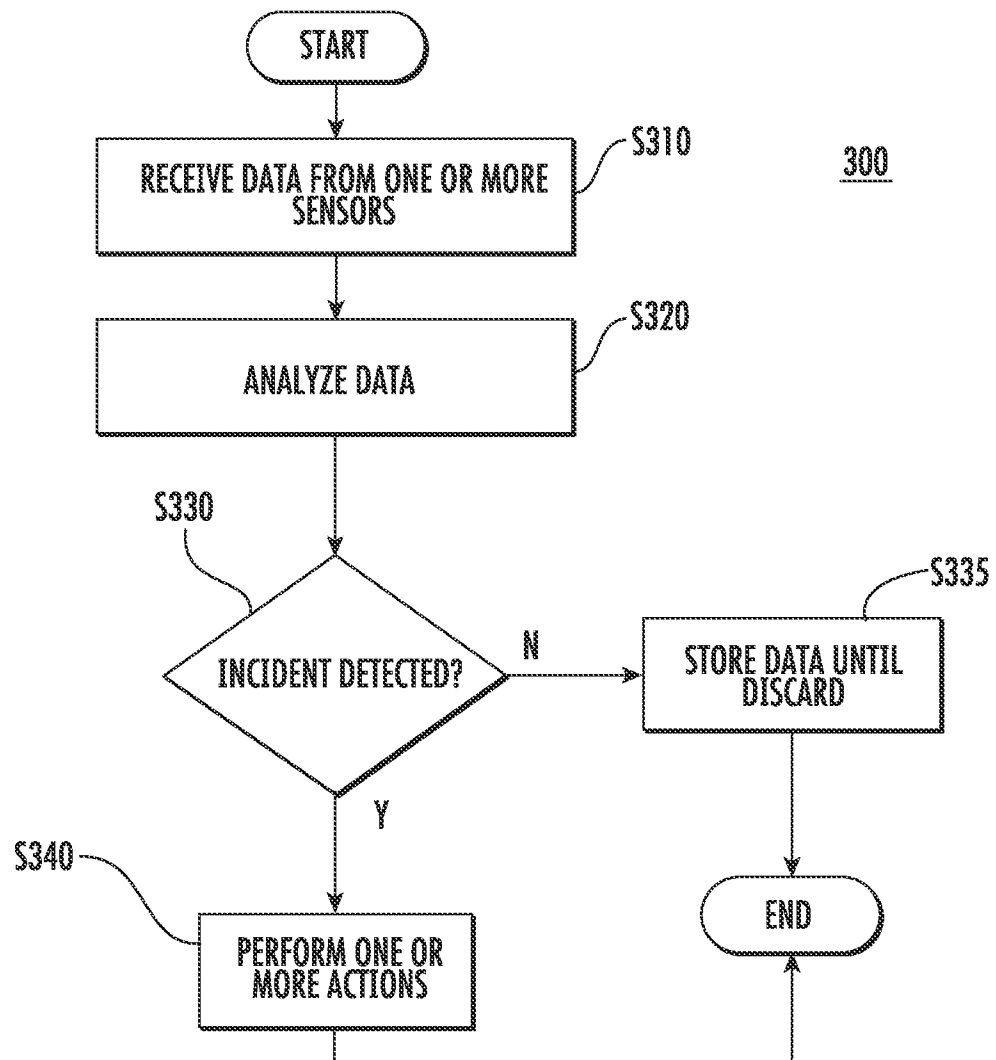


FIG. 3

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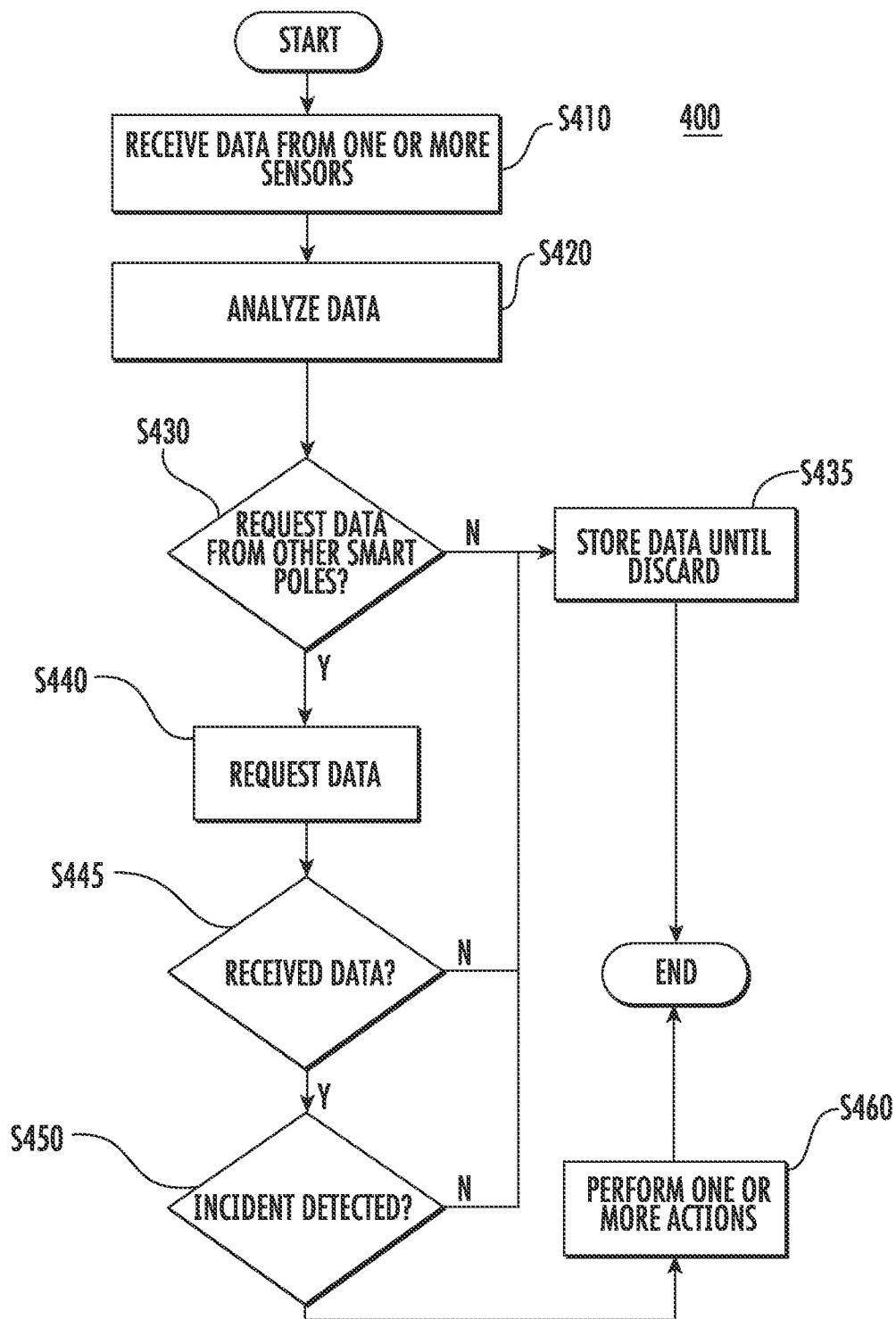


FIG. 4

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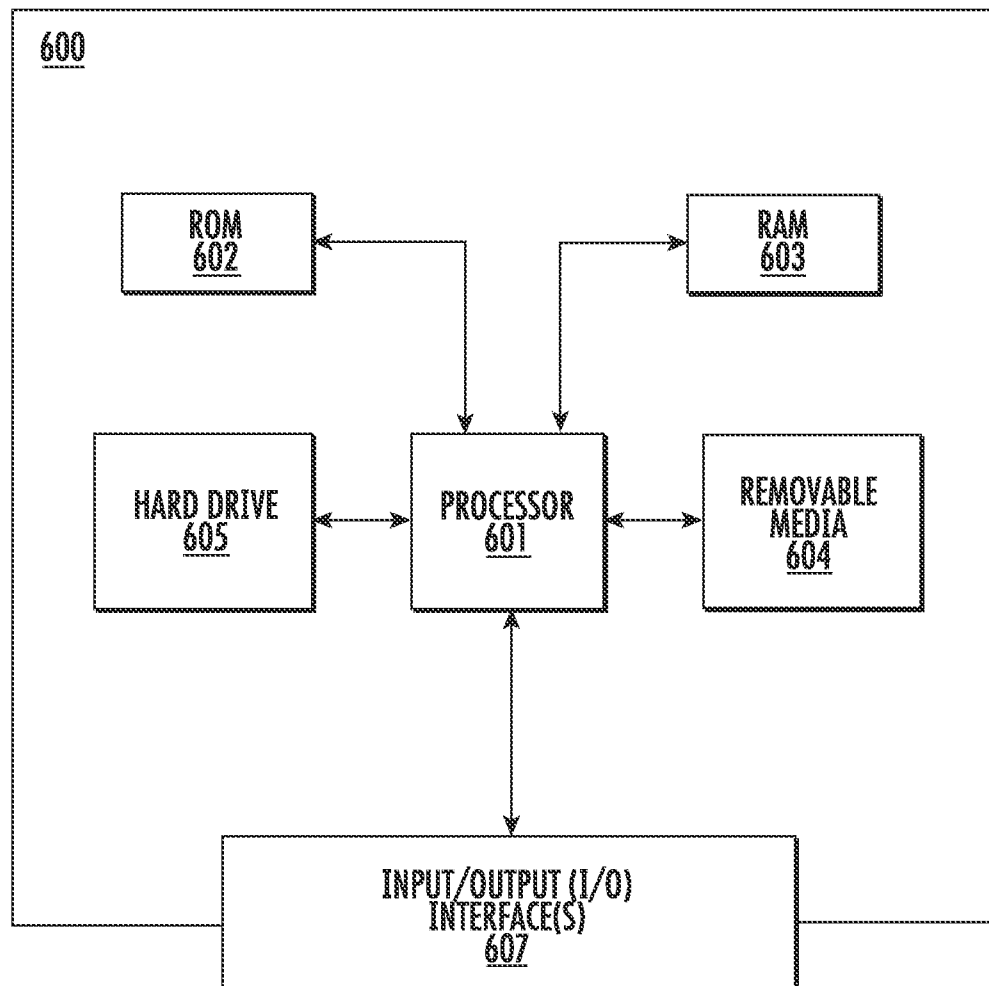


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2021/020627

A. CLASSIFICATION OF SUBJECT MATTER**G08B 21/02**(2006.01)i; **G06K 9/00**(2006.01)i; **G10L 17/26**(2013.01)i; **G06N 3/04**(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G08B 21/02(2006.01); B60W 50/00(2006.01); G05D 1/02(2006.01); G06K 9/00(2006.01); G06K 9/46(2006.01);
G06K 9/62(2006.01); G08B 21/10(2006.01); G08G 5/00(2006.01); H04W 84/18(2009.01)

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

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: smart pole, incident, sensor, neural network

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2017-0324936 A1 (BAO TRAN) 09 November 2017 (2017-11-09) paragraphs [0036]-[0078], claims 1-7 and figures 1A-3	1-2,4,6-11,13,15-20 3,5,12,14
Y	US 2018-0330183 A1 (CANON KABUSHIKI KAISHA) 15 November 2018 (2018-11-15) paragraph [0005], claims 1-5 and figures 1A-3	3,5,12,14
A	US 2019-0188493 A1 (MICRON TECHNOLOGY, INC.) 20 June 2019 (2019-06-20) the entire document	1-20
A	US 2018-0253980 A1 (FARROKH MOHAMADI) 06 September 2018 (2018-09-06) the entire document	1-20
A	KR 10-2019-0063729 A (NECTOMINING) 10 June 2019 (2019-06-10) the entire document	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

24 June 2021

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/US2021/020627

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KR	10-2019-0063729	A	10 June 2019	None		