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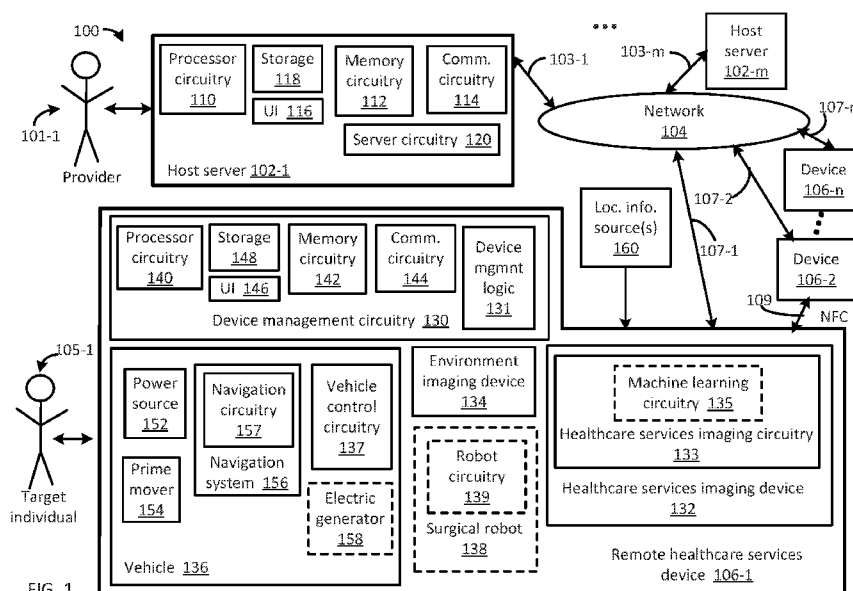


FIG. 1

(57) Abstract: Generally, there is provided a device for providing remote healthcare services. The remote healthcare services device includes a healthcare services imaging device, a vehicle and a healthcare services imaging circuitry. The healthcare services imaging device is configured to capture healthcare services image data associated with at least a portion of a target individual. The target individual is located at or near a target destination. The vehicle is configured to transport the healthcare services imaging device to the target destination semiautonomously or autonomously. The healthcare services imaging circuitry is configured to generate a healthcare services result based, at least in part, on the captured healthcare services image data.



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AUTONOMOUS VEHICLE-BASED AFFORDABLE TOMOGRAPHY ANALYTICS ROBOT (AVATAR)

CROSS REFERENCE TO RELATED APPLICATION(S)

This application claims the benefit of U.S. Provisional Application No. 62/717922, filed August 13, 2018, which is incorporated by reference as if disclosed herein in its entirety.

FIELD

The present disclosure is related to a device for providing remote healthcare services, in particular to, an autonomous vehicle-based affordable tomography analytics robot (AVATAR).

BACKGROUND

A number of human activities may occur at centralized locations, including, but not limited to, watching movies at a cinema, shopping for groceries in a supermarket, shopping for clothes at a department store and/or mall, performing research in a library and receiving healthcare services in clinics, physicians' offices and hospitals. Healthcare services may include, for example, diagnostic imaging and/or image-guided surgery.

More recently, movies may be watched away from cinemas, for example, in home theaters, on televisions, on computing devices, on smartphones and/or other personal electronic devices via, for example, streaming video. Grocery shopping and/or clothes shopping may be performed outside of supermarkets, department stores and/or malls using computing devices and/or smart phones with access to the Internet. Applications executing on such devices are configured to provide users access to sellers' web sites remotely, with the purchased items delivered to the user at a location designated by the user. Research may be performed outside of the library at any location that has access to a network and the Internet using a user electronic device (e.g., computing device, smart phone). Such distributed activities are facilitated by the connectivity of the Internet and networks of providers of content and/or goods ("sellers"). The Internet and the networks thus provide to users remote access to a wide range of content and/or sellers. The Internet and the networks further provide a wide range of remote consumers of content and/or potential buyers to content providers and/or sellers.

Healthcare services, including for example, diagnostic imaging and/or surgery may not be generally available remotely, away from the centralized locations. Individuals located

in rural areas (e.g., in third world countries), on battlefields, at sites of terrorist attacks, at sites of natural disasters and similar environments may be unwilling and/or unable to travel to the centralized locations to receive healthcare services. Thus, these individuals may not receive healthcare services that they may need.

SUMMARY

In some embodiments, there is provided a device for providing remote healthcare services. The remote healthcare services device includes a healthcare services imaging device, a vehicle and a healthcare services imaging circuitry. The healthcare services imaging device is configured to capture healthcare services image data associated with at least a portion of a target individual. The target individual is located at or near a target destination. The vehicle is configured to transport the healthcare services imaging device to the target destination semiautonomously or autonomously. The healthcare services imaging circuitry is configured to generate a healthcare services result based, at least in part, on the captured healthcare services image data.

In some embodiments, the remote healthcare services device corresponds to an autonomous vehicle-based affordable tomography analytics robot (“AVATAR”). In some embodiments of the remote healthcare services device, the healthcare services imaging circuitry includes a machine learning circuitry configured to facilitate generating the healthcare services result.

In some embodiments of the remote healthcare services device, the vehicle is selected from the group including a terrestrial vehicle, an aircraft and a watercraft. In some embodiments of the remote healthcare services device, the healthcare services imaging device is selected from the group including an ultrasound probe, a diagnostic ultrasound machine, an optical scanner, an x-ray scanner, a computed tomography (CT) scanner, a magnetic resonance imaging (MRI) scanner and a nuclear imaging device.

In some embodiments, the remote healthcare services device further includes a surgical robot and a robot circuitry. The surgical robot is configured to perform a surgical procedure. The robot circuitry is configured to adjust a position of a selected element of the surgical robot in response to a command from a provider. The provider is situated at a location remote from the target destination.

In some embodiments, the remote healthcare services device further includes a navigation system configured to receive vehicle location data from a selected location

information source and to determine a vehicle heading based, at least in part, on the vehicle location data.

In some embodiments, there is provided a method for providing remote healthcare services. The method includes transporting, by a vehicle, a healthcare services imaging device to a target destination semiautonomously or autonomously. The method further includes capturing, by the healthcare services imaging device, healthcare services image data associated with at least a portion of a target individual. The target individual is located at or near the target destination. The method further includes generating, by a healthcare services imaging circuitry, a healthcare services result based, at least in part, on the captured healthcare services image data.

In some embodiments of the method, the healthcare services imaging device, the vehicle and the healthcare services imaging circuitry correspond to an autonomous vehicle-based affordable tomography analytics robot (“AVATAR”).

In some embodiments of the method, the healthcare services imaging circuitry includes a machine learning circuitry configured to facilitate generating the healthcare services result. In some embodiments of the method, the vehicle is selected from the group including a terrestrial vehicle, an aircraft and a watercraft. In some embodiments of the method, the healthcare services imaging device is selected from the group including an ultrasound probe, a diagnostic ultrasound machine, an optical scanner, an x-ray scanner, a computed tomography (CT) scanner, a magnetic resonance imaging (MRI) scanner and a nuclear imaging device.

In some embodiments, the method further includes performing, by a surgical robot, a surgical procedure. In some embodiments, the method further includes adjusting, by a robot circuitry, a position of a selected element of the surgical robot in response to a command from a provider. The provider is situated at a location remote from the target destination.

In some embodiments, the method further includes receiving, by a navigation system, vehicle location data from a selected location information source. In some embodiments, the method further includes determining, by the navigation system, a vehicle heading based, at least in part, on the vehicle location data.

In some embodiments, there is provided a remote healthcare services provider system. The system includes a device for providing remote healthcare services and a host server. The remote healthcare services device includes a healthcare services imaging device, a vehicle and a healthcare services imaging circuitry. The healthcare services imaging device is configured to capture healthcare services image data associated with at least a portion of a

target individual. The target individual is located at or near a target destination. The vehicle is configured to transport the healthcare services imaging device to the target destination semiautonomously or autonomously. The healthcare services imaging circuitry is configured to generate a healthcare services result based, at least in part, on the captured healthcare services image data. The host server is configured to couple to the remote healthcare services device via a network. The host server includes a user interface configured to receive input from a provider. The input is related to the remote healthcare services.

In some embodiments of the system, the remote healthcare services device corresponds to an autonomous vehicle-based affordable tomography analytics robot (“AVATAR”).

In some embodiments, the system includes a plurality of remote healthcare services devices. Each remote healthcare services device is configured to communicate with one or more other remote healthcare services devices when in proximity, via near field communication.

In some embodiments of the system, the healthcare services imaging circuitry includes a machine learning circuitry configured to facilitate generating the healthcare services result.

In some embodiments of the system, the remote healthcare services device further includes a surgical robot and a robot circuitry. The surgical robot is configured to perform a surgical procedure. The robot circuitry is configured to adjust a position of a selected element of the surgical robot in response to a command from the provider. The provider is situated at a location remote from the target destination.

In some embodiments of the system, the remote healthcare services device further includes a navigation system. The navigation system is configured to receive vehicle location data from a selected location information source and to determine a vehicle heading based, at least in part, on the vehicle location data.

In some embodiments, a remote healthcare services provider system includes at least one device arranged to perform any one of the embodiments of the method.

In some embodiments, a remote healthcare services provider system includes means to perform any one of the embodiments of the method.

In some embodiments, a computer readable storage device having stored thereon instructions that when executed by one or more processors result in the following operations including any one of the embodiments of the method.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings show embodiments of the disclosed subject matter for the purpose of illustrating features and advantages of the disclosed subject matter. However, it should be understood that the present application is not limited to the precise arrangements and instrumentalities shown in the drawings, wherein:

FIG. 1 illustrates a functional block diagram of a remote healthcare services system consistent with several embodiments of the present disclosure;

FIG. 2 is a flowchart of example host server operations consistent with several embodiments of the present disclosure; and

FIG. 3 is a flowchart of example remote healthcare services device operations consistent with several embodiments of the present disclosure.

DETAILED DESCRIPTION

Generally, this disclosure relates to a system for providing remote healthcare services. The system may include a host server coupled via a network to a device configured to provide remote healthcare services. Healthcare services may include, but are not limited to, diagnostic and/or interventional imaging (e.g., ultrasound, x-ray, computed tomography (CT), magnetic resonance imaging (MRI), nuclear, optical scanning, etc.), remote diagnostic and/or interventional procedures (e.g., semiautonomously with a provider participating remotely or autonomously), selected surgical procedures, etc. An apparatus, method and/or system may be configured to provide remote healthcare services, at least semiautonomously, to a target individual located at or near a target destination that is remote from the host server. In an embodiment, the remote healthcare services device may correspond to an autonomous vehicle-based affordable tomography analytics robot (“AVATAR”).

The remote healthcare services device is configured to travel, autonomously or semiautonomously, to the target destination. In an embodiment, the remote healthcare services device may be configured to provide diagnostic and/or interventional imaging services to the target individual at least semiautonomously. In another embodiment, the remote healthcare services device may be configured to provide selected surgical services semiautonomously to the target individual. In this embodiment, selected operations of the remote healthcare services device may be controlled remotely by a provider via the host server. Thus, travel by the target individual to a centralized location in order to receive healthcare services may be avoided. In other words, remote healthcare services, as described herein, may be provided to target individuals located in rural areas (e.g., in third world

countries), on battlefields, at sites of terrorist attacks, at sites of natural disasters and similar environments.

In an embodiment, image processing techniques, including for example machine learning, may facilitate provision of healthcare services using relatively less complex, and thus relatively less expensive, imaging devices. For example, the relatively less complex image device may be portable. The image processing techniques may be configured to enhance a healthcare services result based, at least in part, on possibly lower quality image data captured by the relatively less complex imaging device. Thus, the image processing techniques combined with the relatively less complex imaging devices (as well as network connectivity) may support provision of healthcare services to target individuals away from centralized locations.

In one nonlimiting example, a relatively less complex imaging device may include an example relatively lower cost CT scanner. The relatively lower cost scanner may be configured to utilize compressive sensing and/or interior tomography techniques. In these techniques, the data acquisition system may be configured to target a region of interest (ROI) to acquire relatively limited and truncated data. Similar to linear tomosynthesis, the source and detector may be translated in opposite directions. ROI image reconstruction may then be performed utilizing one or more localized linear scans or utilizing a global reconstruction technique that includes combining multiple ROI reconstructions. In other words, in this relatively lower cost CT scanner, a slip ring may be replaced by a translation based setup. The instrumentation cost may then be reduced by a relaxation of the imaging speed constraint. Numerical simulation results from different numbers of linear scans support the feasibility of such an approach. A first system may be configured to capture images with a target individual positioned vertically (e.g., sitting). A second system may be configured to capture images with the target individual positioned horizontally. Thus, relatively low cost CT scanning may be feasible utilizing a combination of linear scanning, compressive sensing, and interior tomography. Such an architecture may be implemented in a movable (i.e., portable) and/or reconfigurable systems. It is contemplated that relatively advanced image registration and/or spectral imaging features may be included.

In an embodiment, a device for providing remote healthcare services is provided. The remote healthcare services device includes a healthcare services imaging device, a vehicle and a healthcare services imaging circuitry. The healthcare services imaging device is configured to capture healthcare services image data associated with at least a portion of a target individual. The target individual is located at or near a target destination. The vehicle is

configured to transport the healthcare services imaging device to the target destination semiautonomously or autonomously. The healthcare services imaging circuitry is configured to generate a healthcare services result based, at least in part, on the captured healthcare services image data.

FIG. 1 illustrates a functional block diagram of a remote healthcare services system 100 consistent with several embodiments of the present disclosure. System 100 includes at least one host server 102-1,..., and/or 102-m, a network 104 and at least one remote healthcare services device, e.g., an autonomous vehicle-based affordable tomography analytics robot (AVATAR) 106-1,..., and/or 106-n. Network 104 is coupled to each host server 102-1,..., and/or 102-m by a respective link 103-1,..., and/or 103-m and to one or more of remote healthcare services devices 106-1,..., and/or 106-n by respective links 107-1,..., and/or 107-n. Each remote healthcare services device, e.g., remote healthcare services device 106-1, may be configured to communicate with one or more host servers, e.g., host server 102-1, via network 104 and links 107-1 and 103-1.

Network 104 may include, but is not limited to, one or more of a mobile (e.g., cellular) telephone network, a cable television system configured to provide internet, telephone and/or television service, a local area network (LAN), a wide area network (WAN), etc. Network 104 may include wired and/or wireless networks and/or a combination thereof. Links 103-1,..., and 103-m may include wired and/or wireless links. Links 107-1,..., and/or 107-n may generally include one or more wireless links that may comply and/or be compatible with one or more of a 3G, 4G and/or 5G cellular communication protocol and/or an IEEE 802.11 (e.g., Wi-Fi®) wireless communication protocol, as described herein. In some embodiments, a plurality of remote healthcare services devices, e.g., devices 106-1 and 106-2, may be configured to communicate using near field communication (NFC) when the devices 106-1 and 106-2 are in proximity to each other.

Each host server, e.g., host server 102-1, includes a processor circuitry 110, a memory circuitry 112, a communication circuitry 114, a user interface (UI) 116 and server circuitry 120. Host server 102-1 may further include, and/or be coupled to, storage 118.

Processor circuitry 110 may be configured to perform one or more operations of host server 102-1. Memory circuitry 112 may include one or more types of memory, as described herein. Memory circuitry 112 and/or storage 118 may be configured to store information and/or data associated with processor circuitry 110, communication circuitry 114, UI 116 and/or server circuitry 120.

UI 116 may include a user input device (e.g., keyboard, keypad, mouse, touchpad, one or more joysticks, robotic (e.g., surgical robot) control input devices, etc.) and a user output device (e.g., one or more displays). UI 116 may be configured to receive inputs from a provider, e.g., provider 101-1, and/or to provide output to the provider 101-1, as will be described in more detail below.

Each remote healthcare services device, e.g., remote healthcare services device 106-1 includes a device management circuitry 130, a healthcare services imaging device 132, an environment imaging device 134 and a vehicle 136. In some embodiments, remote healthcare services device 106-1 may include a surgical robot 138.

Device management circuitry 130 is configured to control and/or manage operations of remote healthcare services device 106-1, including, but not limited to, communication with host server 102 – 1 and providing an interface between healthcare services imaging device 132, environment imaging device 134, vehicle 136 and/or surgical robot 138. Operations of remote healthcare services device 106-1 may include, but are not limited to, semiautonomous or autonomous travel (including navigation) to a destination location, identification of a target individual, image capture of at least a portion of an environment, healthcare services image data capture, generation of a healthcare services result based, at least in part, on the healthcare services image data, healthcare services data acquisition and analysis related to the target individual, operations related to surgical activities (if any), communication with, for example, host server 102-1, and/or communication with another remote healthcare services device, e.g., remote healthcare services device 106-2, as will be described in more detail below. As used herein, “healthcare services data” corresponds to diagnostic and/or interventional data. As used herein, “healthcare services image data” corresponds to diagnostic and/or interventional image data.

Device management circuitry 130 includes a processor circuitry 140, a memory circuitry 142, a communication circuitry 144, a user interface (UI) 146 and device management logic 131. Device management circuitry 130 may further include and/or be coupled to storage 148.

Processor circuitry 140 may be configured to perform one or more operations of device management circuitry 130 and/or other components of remote healthcare services device 106-1. Memory circuitry 142 may include one or more types of memory, as described herein. Memory circuitry 142 and/or storage 148 may be configured to store information and/or data associated with processor circuitry 140, communication circuitry 144, UI 146,

device management logic 131, healthcare services imaging device 132, environment imaging device 134, vehicle 136 and/or surgical robot 138 and/or their operations thereof.

User interface 146 may include a user input device (e.g., keyboard, keypad, mouse, touchpad, touch sensitive display, a microphone, one or more joysticks, etc.) and a user output device (e.g., a display, a loudspeaker, a visual indicator (e.g., light bulb, light emitting diode (LED), etc.). As used herein, “user input” means received from a user and “user output” means provided to the user. User interface 146 may be configured to receive inputs from a target individual, e.g., target individual 105-1, and/or to provide output to the target individual 105-1, as will be described in more detail below.

Healthcare services imaging device 132 may be configured to perform healthcare services imaging services. As used herein, “healthcare services imaging” corresponds to diagnostic and/or interventional imaging. Thus, healthcare services imaging device may be configured to perform diagnostic and/or interventional imaging. Healthcare services imaging device 132 may include, but is not limited to, an ultrasound probe configured to couple to a user device (e.g., smart phone, tablet computer, laptop computer, etc.), a diagnostic ultrasound machine, an optical scanner, an x-ray scanner, a computed tomography (CT) scanner, a magnetic resonance imaging (MRI) scanner, a nuclear imaging device, etc. Healthcare services imaging device 132 may include or be coupled to healthcare services imaging circuitry 133. Healthcare services imaging circuitry 133 is configured to manage operation of healthcare services imaging device 132, capture healthcare services image data (i.e., diagnostic and/or interventional image data) and generate a healthcare services result based, at least in part, on the captured healthcare services image data. In an embodiment, healthcare services imaging circuitry 133 may include a machine learning circuitry 135 and may thus be configured to implement machine learning. Machine learning circuitry 135 may include, but is not limited to, an artificial neural network, a deep neural network, a convolutional neural network, a multilayer perceptron, etc. Environment imaging device 134 may include, but is not limited to, a camera configured to capture still images, a camera configured to record moving images, an infrared camera, a night vision camera, etc.

Surgical robot 138 may include a robotic arm, one or more sensors (e.g., force sensor, pressure sensor, temperature sensor, etc.), grasping features, etc. In an embodiment, surgical robot 138 may be configured to perform one or more surgical procedures semiautonomously. The surgical procedures may be performed under control of a provider, e.g., provider 101-1, via host server 102-1 and UI 116, as will be described in more detail below. Surgical procedures may include, for example, laparoscopic procedures, arthroscopic procedures, etc.

Vehicle 136 may be autonomous or semiautonomous. As used herein, an autonomous vehicle is configured to travel and/or navigate without active human control. As used herein, a semiautonomous vehicle is configured to travel with remote human control. Vehicle 136 may include, but is not limited to, a terrestrial vehicle (e.g., wheeled (two, three, four or more wheels), on tracks, on foot (e.g., biped, quadruped, etc.), a rolling sphere, tandem (e.g., road tractor and semi trailer) or single frame, etc.), an aircraft (e.g., drone, uncrewed aerial vehicle (UAV), etc.) and/or a watercraft (e.g., a boat, a hydroplane, etc.).

Vehicle 136 includes a power source (e.g., fuel, batteries, solar cells, etc.) 152, a prime mover (e.g., internal combustion engine, Stirling engine, electric motor, etc.) 154, a navigation system 156 and vehicle control circuitry 137. The vehicle control circuitry 137 is configured to manage operation of vehicle 136 and vehicle elements 152, 154 and 158. Vehicle control circuitry 137 may be further configured to provide an interface between navigation system 156 and vehicle elements 152, 154, 158.

The power source 152 is configured to provide energy or an energy source to the prime mover 154. The prime mover 154 is configured to drive motion, i.e., travel, of vehicle 136. In one nonlimiting example, the power source 152 may correspond to batteries and/or solar cells configured to provide electrical energy to the electric motor. The electric motor may then correspond to the prime mover 154. In another nonlimiting example, the power source 152 may correspond to fuel provided to the internal combustion engine or the Stirling engine. The engine, i.e., prime mover, may then drive motion of the vehicle 136. In some embodiments, vehicle 136 may include an electric generator 158 configured to provide electrical energy to, for example, imaging devices 132, 134. The electric generator 158 may be powered by, for example, the internal combustion engine or the Stirling engine, thus, in this example, the prime mover 154 is configured to drive the electric generator 158.

Navigation system 156 is configured to guide travel of vehicle 136 and thus travel of remote healthcare services device 106-1. Navigation system 156 includes navigation circuitry 157. Navigation circuitry 157 is configured to manage operation of navigation system 156 and may be configured to communicate with vehicle control circuitry 137. Navigation system 156 may be configured to receive a target destination from host server 102-1, as will be described in more detail below. Navigation system 156 is configured to determine and/or monitor a current location of the remote healthcare services device 106-1. Navigation system 156 may be further configured to adjust a heading, i.e., travel direction of the remote healthcare services device 106-1, based, at least in part, on the current location and based, at least in part, on the target destination. Navigation system 156 may include one or more of a

global positioning system (GPS) receiver, a radio direction finder, a radar navigation system, an inertial navigation system, a Wi-Fi® based positioning system based on wireless access points, etc. Navigation system 156 (and navigation circuitry 157) may utilize one or more location information source(s) 160 to determine the current location. Location information source(s) 160 may thus include GPS satellites, radio transmitters with known locations, wireless access points with location identifiers, cellular telephone transmitters, predefined waypoints, etc.

In operation, remote healthcare services device system 100 may be configured to provide decentralized, distributed, remote healthcare services to one or more target individuals, e.g., target individual 105-1. The healthcare services may be provided autonomously or semiautonomously. As used herein, an autonomous healthcare service may be performed without active participation by a provider, e.g., provider 101 – 1. As used herein, a semiautonomous healthcare service may be performed under active control by a provider that is remote from the target individual that is receiving the healthcare service. In other words, semiautonomous healthcare services include active participation by a provider located remote from the target individual. Whether the healthcare services are provided autonomously or semiautonomously is related to characteristics of the particular healthcare service. For example, a diagnostic imaging procedure may be performed autonomously. In another example, a surgical procedure may be performed semiautonomously.

Thus, remote healthcare services device 106 – 1 is configured to provide selected healthcare services at one or more locations remote from the centralized clinic, provider office and/or hospital. Transport of a (e.g., portable) healthcare services imaging device and/or a surgical robot may be accomplished by vehicle 136. Healthcare services imaging device 132 may be relatively less complex than a similar healthcare services imaging device that is not portable. The relatively lesser complexity may be associated with a relatively lower cost and possibly relatively lower quality image data. An associated relatively lower image quality may be at least partially compensated for by image data processing techniques that include machine learning. Machine learning may be performed by machine learning circuitry, e.g., machine learning circuitry 135.

The machine learning may include deep learning. Deep learning is a type of machine learning technique that uses a cascade of a plurality of layers of nonlinear processing units for feature extraction and transformation. Each successive layer uses the output from the previous layer as input. Deep learning techniques learn in supervised (e.g., classification) and/or unsupervised (e.g., pattern analysis) manners. Deep learning algorithms learn multiple

levels of representations that correspond to different levels of abstraction. In other words, deep learning methods are representation-learning methods with multiple levels of representation, obtained by composing simple but non-linear modules that each transform the representation at one level into a representation at a higher, slightly more abstract level. With the composition of enough such transformations, very complex functions can be learned.

Deep learning may be utilized in image analysis including, for example, image classification, identification and segmentation. For example, convolutional neural network (CNN) techniques may be utilized for image denoising in low-dose CT. The deep learning CT denoising methods may be configured to learn a function between a low-dose image patch and the corresponding patch of high quality from a large training dataset. After this training process, CNN is used to transform a low-dose CT image to a relatively higher quality counterpart. In another example, deep learning for image reconstruction may be utilized to enhance image quality. The deep learning method may be configured to learn a regularization transformation and parameters from big data for iterative reconstruction, complying with natural structures of medical images. In another example, a deep residual network may be configured to suppress artifacts for limited-angle CT image reconstruction.

Selected healthcare services may thus be provided to target individuals at distributed locations remote from a clinic, a provider's office or a hospital. Individuals that are unwilling or unable to travel to the centralized location may then receive the selected healthcare services. Selected illustrative examples of provision of remote healthcare services are described below. It should be noted that the teachings of this disclosure are not limited to these specific illustrative examples.

Provision of the distributed healthcare services may be initiated in response to a request for a healthcare service from an authorized requester. Authorized requesters may include, but are not limited to, providers, selected military personnel and/or selected other individuals. The healthcare service request may be received by a host server, e.g., host server 102 – 1. The request may include a requester identifier, location data, environment characteristic identifier, a healthcare service identifier and/or a target date and time of service. The location data is configured to identify a target destination where the requested healthcare services will be provided. In one nonlimiting example, location data may include GPS coordinates. The environment characteristic identifier may correspond to characteristics of the target destination including, for example, whether the destination is on land or on water, whether the environment is a battlefield, site of a natural disaster, a rural location, etc.

One or more remote healthcare services device(s) may then be identified that include vehicles possessing appropriate elements able to travel to the target destination.

The healthcare service identifier may correspond to one or more healthcare services. Thus, each healthcare service identifier may be associated with a respective group of one or more specific healthcare services selected from the groups of diagnostic imaging procedures, remote real-time semiautonomous or autonomous diagnostic procedures and/or selected surgical procedures. One or more remote healthcare services device(s) may then be identified that possess appropriate components able to provide the requested healthcare service and able to travel to the target destination. In a first nonlimiting example, the appropriate component may correspond to a CT scanner. Continuing with this example, an AVATAR, as described herein, is one example of a remote healthcare services device that includes the CT scanner. In a second nonlimiting example, an appropriate component may correspond to a surgical robot. Continuing with this second example, an appropriate vehicle may include a terrestrial vehicle with capacity for carrying a surgical robot and a sterile environment.

Whether a remote healthcare services device includes appropriate components may be determined based, at least in part, on the requested healthcare service and based, at least in part, on the environment associated with the target destination. Whether a remote healthcare services device includes appropriate components is related to the particular components, i.e., equipment, included in or on the remote healthcare services device as well as characteristics of the vehicle. An appropriately equipped remote healthcare services device, e.g., remote healthcare services device 106 – 1, of the identified remote healthcare services devices may then be selected. The selected remote healthcare services device 106 – 1 may then be dispatched. Selection and/or dispatch of the remote healthcare services device may be performed, for example, by host server 102 – 1 and server circuitry 120. Dispatching the remote healthcare services device 106 – 1 may include providing a dispatch request to, for example, the device management logic 131 of the selected remote healthcare services device. The dispatch request may be provided from communication circuitry 114 to communication circuitry 144 via network 104.

The dispatch request may include the location data, the healthcare service identifier, the environment characteristics identifier, the target date and time of service, the requester identifier, a target individual identifier and a security code. In some situations, the requester identifier and the target individual identifier may be a same identifier corresponding to a same person. In other situations, the requester and the target individual may not be the same person. The requester and/or target individual may then be notified of the dispatch of the

remote healthcare services device 106 – 1. In some situations, the target individual may be provided the security code.

The selected remote healthcare services device, in response to receiving the dispatch request, may be configured to determine a route to a target service destination identified by the location data. The route and the target destination identifier may be determined by navigation circuitry 157. The power source 152 and prime mover 154 may then be engaged by vehicle control circuitry 137 and the remote healthcare services device may travel to the target service destination. The navigation circuitry 157 and vehicle control circuitry 137 may coordinate their operations to manage travel of the remote healthcare services device 106-1. The navigation system 156 may be configured to acquire intermediate location data from one or more of the location information sources 160 during travel. The navigation circuitry 157 may be configured to adjust a direction of travel, e.g., a heading, of the remote healthcare services device based, at least in part, on the intermediate location data. The adjusted heading may then be communicated to vehicle control circuitry 137 to control prime mover 154 to implement a heading change.

Upon arrival at the target service destination, the remote healthcare services device 106 – 1 may be configured to identify the target individual. In one nonlimiting example, the target individual may be identified based, at least in part, on the security code. Thus, the security code may be utilized to confirm that an interested individual is the target individual. The remote healthcare services device may then be configured to provide the healthcare service(s) corresponding to the healthcare service identifier, as described herein. If the remote healthcare services device 106 – 1 is unable to reach the service destination after a predefined number of tries or is unable to identify the target individual, the remote healthcare services device may be configured to notify the host server and provision of the healthcare service may fail.

In an embodiment, the healthcare services associated with the healthcare service identifier may include a diagnostic imaging procedure. In one nonlimiting example, the healthcare services may correspond to cancer screening that includes a CT scan of a body portion and analysis of CT scan image data. The body portion may correspond to a region of interest (ROI). In this example, the healthcare services imaging device 132 may correspond to a CT scanner and remote healthcare services device 106-1 may correspond to an AVATAR. Healthcare services imaging circuitry 133 may then be configured to manage positioning of the target individual, acquisition of CT scan image data and analysis of the CT scan image data. The target individual may be directed to a location in or on the CT scanner

132 and may be instructed to obtain and maintain a specific body position. The direction and instruction may be provided via UI 146 verbally (e.g., via a microphone) and/or visually (e.g., via markings in the CT scanner and/or selected indicators, e.g., LEDs). The target individual's location and body position may be confirmed through imaging, e.g., environment imaging device 134. CT scan image data may then be acquired by CT scanner 132 and captured by healthcare services imaging circuitry 133. The CT scan image data may then be analyzed by healthcare services imaging circuitry 133, for example, by machine learning circuitry 135 using machine learning techniques, and presence or absence of a cancerous lesion may be evaluated. Such cancer screening may be facilitated by the machine learning techniques, as described herein. In other words, a relatively less complex and thus relatively lower cost CT scanner may be used for cancer screening with CT scan image data analysis enhanced by the machine learning techniques.

In an embodiment, the healthcare services associated with the healthcare service identifier may include a surgical procedure. In one nonlimiting example, a laparoscopic surgical procedure may be performed. In this example, the healthcare service is configured to be semiautonomous, thus, a provider, e.g., provider 101-1, may be present and coupled to a host server, e.g., host server 102-1, via UI 116. UI 116 may then include, at least, robot control input devices (e.g., graspers, joysticks, etc.). Remote health care device 106-1 may then include surgical robot 138. The surgical robot 138 may include robot circuitry 139 configured to adjust a position of a selected element of the surgical robot 138 in response to a command from the provider 101-1. The provider 101-1 is configured to be situated at a location remote from the target destination (and the target individual 105-1).

The target individual 105-1 may be directed to a location within reach of the surgical robot 138 (i.e., within an operational volume of the surgical robot) and may be instructed to obtain and maintain a specific body position. The direction and instruction may be provided via UI 146 verbally (e.g., via a microphone) and/or visually (e.g., via markings in the CT scanner and/or selected indicators, e.g., LEDs). The target individual's location and body position may be confirmed through imaging, e.g., environment imaging device 134. In this example, the environment imaging data from environment imaging device 134 may be transmitted to host server 102-1 via network 104 and displayed to provider 101-1 via UI 116. The surgical robot 138 may then be configured, under control of provider 101-1, via at least robot circuitry 139, to prepare the target individual for surgery, provide anesthesia and perform the surgical procedure. Thus, a surgical service, including a surgical procedure, may be provided to a target individual away from the centralized location.

It is contemplated that a remote healthcare services device and/or system may be configured to provide a variety of remote diagnostic and/or surgical services. For example, a neurological function evaluation may be performed semiautonomously or autonomously with the surgical robot 138, for example, configured with a robotic arm and one or more force sensors. Instructions may be provided to the target individual by the provider 101-1 and/or device management logic 131, verbally and/or visually via UI 146, as described herein, related to squeezing the force sensors. Hemisphere-specific functionality may then be evaluated by, for example, robot circuitry 139. Thus, selected remote diagnostic procedures may be performed semiautonomously or autonomously using an appropriately equipped remote healthcare services device.

FIG. 2 is a flowchart 200 of example host server operations consistent with several embodiments of the present disclosure. In particular, the flowchart 200 illustrates selection and dispatch of a remote healthcare services device configured to provide a remote healthcare service. The operations of flowchart 200 may be performed by, for example, host server 102-1 (e.g., UI 116 and/or server circuitry 120) of FIG. 1.

Operations of flowchart 200 may begin with receiving a request for a healthcare service at operation 202. One or more appropriately equipped remote healthcare services device(s) may be identified at operation 204. Operation 206 may include selecting an appropriately equipped remote healthcare services device. The identifying and/or selecting may be performed based, at least in part, on the requested healthcare service and based, at least in part, on characteristics of a target destination. The selected appropriately equipped remote healthcare services device may then be dispatched to the target destination at operation 208.

Thus, an appropriately equipped remote healthcare services device may be identified, selected and dispatched in response to a request for healthcare service.

FIG. 3 is a flowchart 300 of example remote healthcare services device operations consistent with several embodiments of the present disclosure. In particular, the flowchart 300 illustrates travel to a target destination and provision of remote healthcare services. The operations of flowchart 300 may be performed by, for example, remote healthcare services device 106-1 (e.g., vehicle 136, healthcare services imaging device 132, environment imaging device 134 and/or surgical robot 138) of FIG. 1.

Operations of flowchart 300 may begin with receiving a dispatch request at operation 302. For example, the dispatch request may be received from a host server and may include location data corresponding to a target destination. A route to the target destination may be

determined at operation 304. Operation 306 may include managing travel to the target destination, including navigation activities. Operation 308 may include identifying a target individual, after arriving at or near the target destination. Selected remote healthcare services may then be provided to the target individual at operation 310. The selected remote healthcare services may include, but are not limited to, diagnostic imaging, selected surgical procedures and selected diagnostic procedures.

Thus, selected remote healthcare services may be provided to a target individual at or near a target destination by a remote healthcare services device.

Thus, an apparatus, system and/or method consistent with the present disclosure may be configured to provide healthcare services away from a centralized location. A system may include a host server coupled via a network to a device configured to provide remote healthcare services. An apparatus, method and/or system may be configured to provide remote healthcare services, at least semiautonomously, to a target individual located at or near a target destination that is remote from the host server. In an embodiment, the remote healthcare services device may correspond to an AVATAR. The remote healthcare services device is configured to travel, autonomously or semiautonomously, to the target destination. In an embodiment, the remote healthcare services device may be configured to provide diagnostic and/or interventional imaging services to the target individual at least semiautonomously. In another embodiment, the remote healthcare services device may be configured to provide selected surgical services semiautonomously to the target individual. In this embodiment, selected operations of the remote healthcare services device may be controlled remotely by a provider via the host server. Thus, travel by the target individual to a centralized location in order to receive healthcare services may be avoided.

In an embodiment, image processing techniques, including for example machine learning, may facilitate provision of healthcare services using relatively less complex, and thus relatively less expensive, imaging devices. For example, the relatively less complex image device may be portable. The image processing techniques may be configured to enhance a healthcare services result based, at least in part, on possibly lower quality image data captured by the relatively less complex imaging device. Thus, the image processing techniques combined with the relatively less complex imaging devices (as well as network connectivity) may support provision of healthcare services to target individuals away from centralized locations.

As used in any embodiment herein, the term "logic" may refer to an app, software, firmware and/or circuitry configured to perform any of the aforementioned operations.

Software may be embodied as a software package, code, instructions, instruction sets and/or data recorded on non-transitory computer readable storage medium. Firmware may be embodied as code, instructions or instruction sets and/or data that are hard-coded (e.g., nonvolatile) in memory devices.

"Circuitry", as used in any embodiment herein, may include, for example, singly or in any combination, hardwired circuitry, programmable circuitry such as computer processors including one or more individual instruction processing cores, state machine circuitry, and/or firmware that stores instructions executed by programmable circuitry. The logic may, collectively or individually, be embodied as circuitry that forms part of a larger system, for example, an integrated circuit (IC), an application-specific integrated circuit (ASIC), a system on-chip (SoC), desktop computers, laptop computers, tablet computers, servers, smart phones, a field-programmable gate array (FPGA), a programmable logic device (PLD), a complex programmable logic device (CPLD), etc.

Processor circuitry 110 and/or 140 may each include, but are not limited to, a single core processing unit, a multicore processor, a graphics processing unit, a microcontroller, an application-specific integrated circuit (ASIC), a field programmable gate array (FPGA), a programmable logic device (PLD), etc.

Memory 112 and/or 142 may each include one or more of the following types of memory: semiconductor firmware memory, programmable memory, non-volatile memory, read only memory, electrically programmable memory, random access memory, flash memory, magnetic disk memory, and/or optical disk memory. Either additionally or alternatively memory 112 and/or 142 may include other and/or later-developed types of computer-readable memory.

Storage 118, 148 may include one or more storage devices, including, but not limited to, hard disk drives, removable storage media (e.g., digital versatile disk (DVD), CD-ROM (compact disk read only memory), etc.). In one nonlimiting example, storage 118 and/or 148 may include so called "cloud" storage. Thus, storage 118, 148 may be configured to store relatively more information than memory circuitry 112, 142.

Embodiments of the operations described herein may be implemented in a computer-readable storage device having stored thereon instructions that when executed by one or more processors perform the methods. The processor may include, for example, a processing unit and/or programmable circuitry. The storage device may include a machine readable storage device including any type of tangible, non-transitory storage device, for example, any type of disk including floppy disks, optical disks, compact disk read-only memories (CD-ROMs),

compact disk rewritables (CD-RWs), and magneto-optical disks, semiconductor devices such as read-only memories (ROMs), random access memories (RAMs) such as dynamic and static RAMs, erasable programmable read-only memories (EPROMs), electrically erasable programmable read-only memories (EEPROMs), flash memories, magnetic or optical cards, or any type of storage devices suitable for storing electronic instructions.

CLAIMS

What is claimed is:

1. A device for providing remote healthcare services, the remote healthcare services device comprising:
 - a healthcare services imaging device configured to capture healthcare services image data associated with at least a portion of a target individual, the target individual located at or near a target destination;
 - a vehicle configured to transport the healthcare services imaging device to the target destination semiautonomously or autonomously; and
 - a healthcare services imaging circuitry configured to generate a healthcare services result based, at least in part, on the captured healthcare services image data.
2. The remote healthcare services device of claim 1, wherein the remote healthcare services device corresponds to an autonomous vehicle-based affordable tomography analytics robot ("AVATAR").
3. The remote healthcare services device of claim 1, wherein the healthcare services imaging circuitry comprises a machine learning circuitry configured to facilitate generating the healthcare services result.
4. The remote healthcare services device according to any one of claims 1 to 3, wherein the vehicle is selected from the group comprising a terrestrial vehicle, an aircraft and a watercraft.
5. The remote healthcare services device according to any one of claims 1 to 3, wherein the healthcare services imaging device is selected from the group comprising an ultrasound probe, a diagnostic ultrasound machine, an optical scanner, an x-ray scanner, a computed tomography (CT) scanner, a magnetic resonance imaging (MRI) scanner and a nuclear imaging device.
6. The remote healthcare services device according to any one of claims 1 to 3, further comprising a surgical robot configured to perform a surgical procedure and a robot circuitry configured to adjust a position of a selected element of the surgical robot in response to a

command from a provider, the provider situated at a location remote from the target destination.

7. The remote healthcare services device according to any one of claims 1 to 3, further comprising a navigation system configured to receive vehicle location data from a selected location information source and to determine a vehicle heading based, at least in part, on the vehicle location data.

8. A method for providing remote healthcare services, the method comprising:
transporting, by a vehicle, a healthcare services imaging device to a target destination semiautonomously or autonomously;

capturing, by the healthcare services imaging device, healthcare services image data associated with at least a portion of a target individual, the target individual located at or near the target destination; and

generating, by a healthcare services imaging circuitry, a healthcare services result based, at least in part, on the captured healthcare services image data.

9. The method of claim 8, wherein the healthcare services imaging device, the vehicle and the healthcare services imaging circuitry correspond to an autonomous vehicle-based affordable tomography analytics robot (“AVATAR”).

10. The method of claim 8, wherein the healthcare services imaging circuitry comprises a machine learning circuitry configured to facilitate generating the healthcare services result.

11. The method of claim 8, wherein the vehicle is selected from the group comprising a terrestrial vehicle, an aircraft and a watercraft.

12. The method of claim 8, wherein the healthcare services imaging device is selected from the group comprising an ultrasound probe, a diagnostic ultrasound machine, an optical scanner, an x-ray scanner, a computed tomography (CT) scanner, a magnetic resonance imaging (MRI) scanner and a nuclear imaging device.

13. The method of claim 8, further comprising performing, by a surgical robot, a surgical procedure; and adjusting, by a robot circuitry, a position of a selected element of the surgical robot in response to a command from a provider, the provider situated at a location remote from the target destination.

14. The method of claim 8, further comprising receiving, by a navigation system, vehicle location data from a selected location information source and determining, by the navigation system, a vehicle heading based, at least in part, on the vehicle location data.

15. A remote healthcare services provider system, the system comprising:
a device for providing remote healthcare services, the remote healthcare services device comprising:

a healthcare services imaging device configured to capture healthcare services image data associated with at least a portion of a target individual, the target individual located at or near a target destination,

a vehicle configured to transport the healthcare services imaging device to the target destination semiautonomously or autonomously, and

a healthcare services imaging circuitry configured to generate a healthcare services result based, at least in part, on the captured healthcare services image data; and

a host server configured to couple to the remote healthcare services device via a network, the host server comprising a user interface configured to receive input from a provider, the input related to the remote healthcare services.

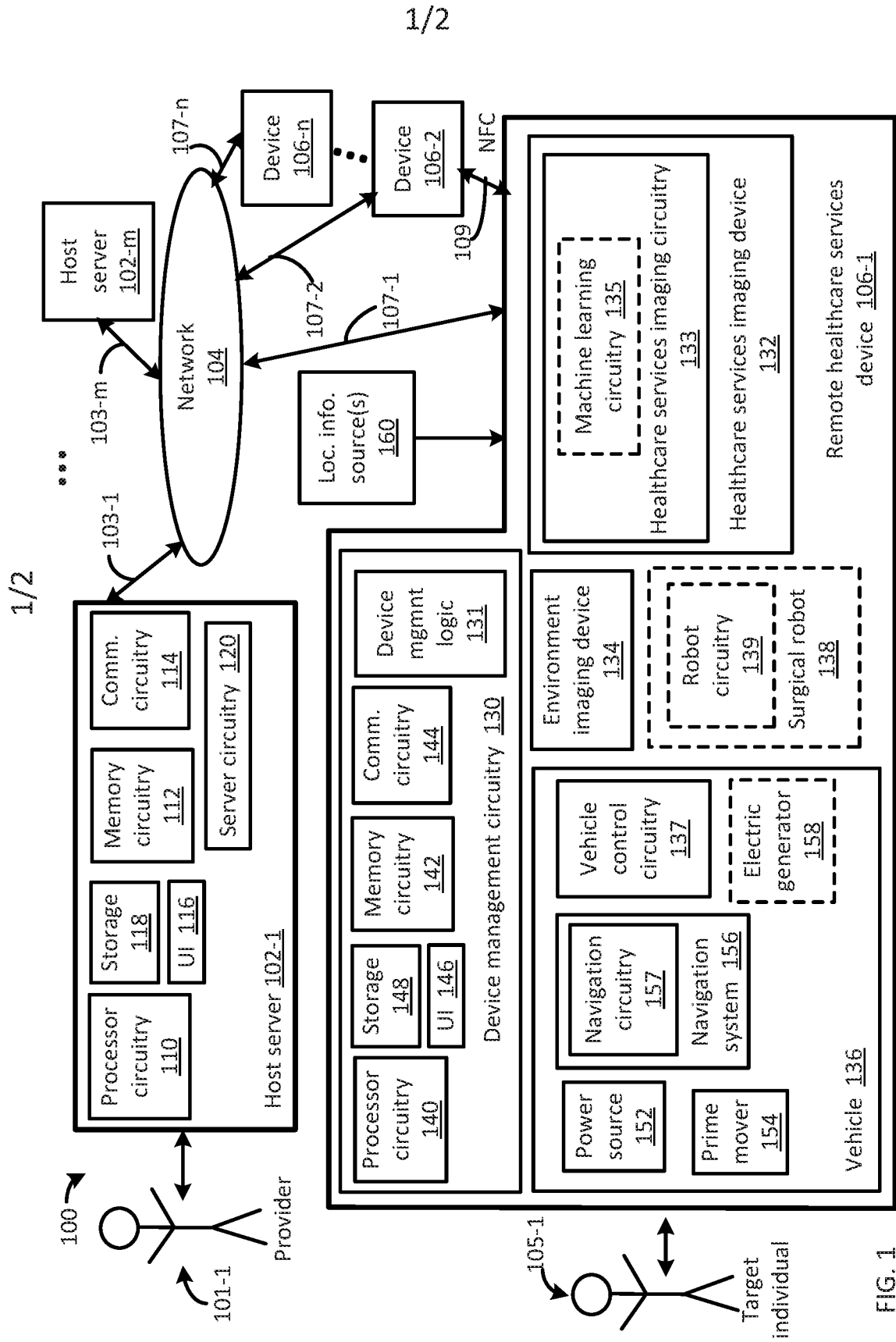
16. The system of claim 15, wherein the remote healthcare services device corresponds to an autonomous vehicle-based affordable tomography analytics robot (“AVATAR”).

17. The system of claim 15, wherein the system comprises a plurality of remote healthcare services devices, each remote healthcare services device configured to communicate with one or more other remote healthcare services devices when in proximity, via near field communication.

18. The system according to any one of claims 15 to 17, wherein the healthcare services imaging circuitry comprises a machine learning circuitry configured to facilitate generating the healthcare services result.

19. The system according to any one of claims 15 to 17, wherein the remote healthcare services device further comprises a surgical robot configured to perform a surgical procedure and a robot circuitry configured to adjust a position of a selected element of the surgical robot in response to a command from the provider, the provider situated at a location remote from the target destination.

20. The system according to any one of claims 15 to 17, wherein the remote healthcare services device further comprises a navigation system configured to receive vehicle location data from a selected location information source and to determine a vehicle heading based, at least in part, on the vehicle location data.



2/2

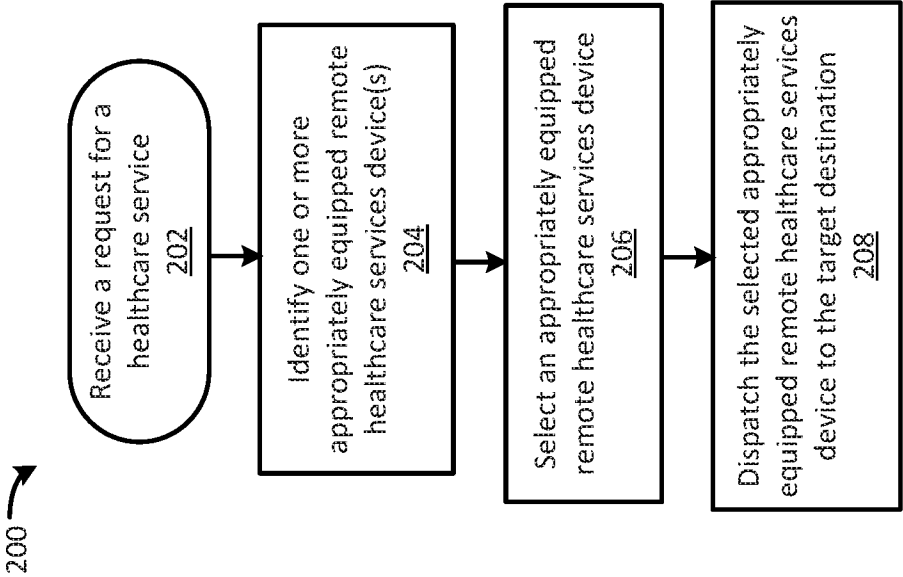


FIG. 2

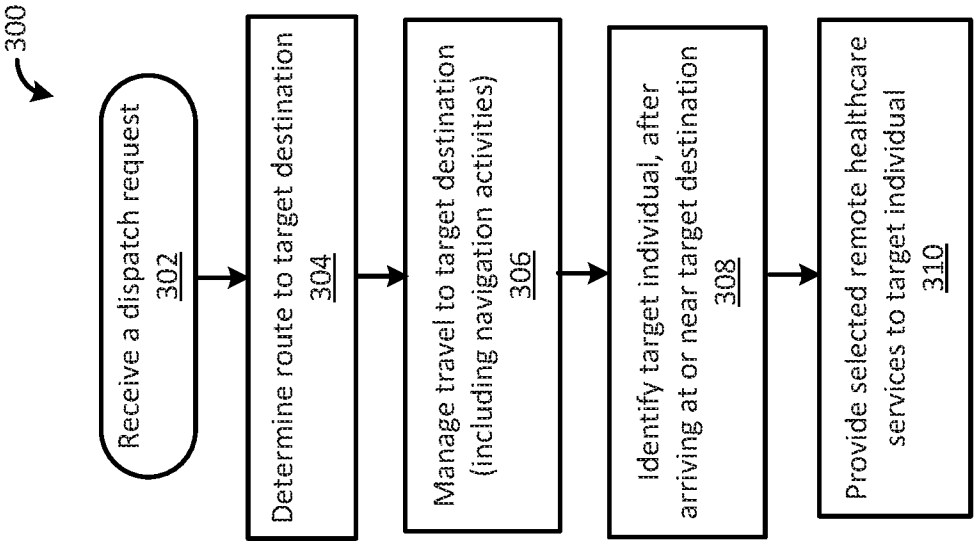


FIG. 3

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 104248-101	FOR FURTHER ACTION		see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2019/046126	International filing date (<i>day/month/year</i>) 12 August 2019	(Earliest) Priority Date (<i>day/month/year</i>) 13 August 2018	
Applicant RENSSELAER POLYTECHNIC INSTITUTE			

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 2 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

a. With regard to the **language**, the international search was carried out on the basis of:

- ☒ the international application in the language in which it was filed.
☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6bis(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

- ☒ the text is approved as submitted by the applicant.
☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

- ☒ the text is approved as submitted by the applicant.
☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

- a. the figure of the **drawings** to be published with the abstract is Figure No. 1
☒ as suggested by the applicant.
☐ as selected by this Authority, because the applicant failed to suggest a figure.
☐ as selected by this Authority, because this figure better characterizes the invention.
- b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2019/046126

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H04N 5/232; H04N 7/18 (2019.01)

CPC - G16H 40/67; G06T 7/0012; G06T 2207/10132; G16H 40/40; G16H 40/60; H04N 7/18; H04N 7/185 (2019.08)

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)

See Search History document

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

USPC - 700/245; 700/264; 705/2 (keyword delimited)

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2017/0084027 A1 (AURIS SURGICAL ROBOTICS, INC.) 23 March 2017 (23.03.2017) entire document	1-20
A	US 2015/0158182 A1 (IROBOT CORPORATION) 11 June 2015 (11.06.2015) entire document	1-20
A	US 2017/0303886 A1 (MERGE HEALTHCARE INCORPORATED) 26 October 2017 (26.10.2017) entire document	1-20
A	US 2017/0012929 A1 (NETSPECTIVE COMMUNICATIONS LLC) 12 January 2017 (12.01.2017) entire document	1-20
A	US 2009/0125147 A1 (WANG et al) 14 May 2009 (14.05.2009) entire document	1-20

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

02 October 2019

Date of mailing of the international search report

18 OCT 2019

Name and mailing address of the ISA/US

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