LOCATION-BASED AUTONOMOUS NAVIGATION USING A VIRTUAL WORLD SYSTEM

FIELD

The present disclosure generally relates to computer systems, and more specifically to a system, method, autonomous mobile robot and computer-readable media enabling location-based autonomous navigation using a virtual world system.

BACKGROUND

Autonomous mobile robots, including drones, autonomous vehicles, and other computing devices configured to move and autonomously perform a plurality of tasks, are becoming more widespread in recent years due to improvements, amongst others, in robotics, artificial intelligence, localization technologies and networks.

One challenge that is present in current autonomous mobile robots is the movement in certain complex structures such as rooms comprising a plurality of obstacles, or climbing structures such as stairs. Solutions so far has been, apart from a gradual improvement in artificial intelligence and machine learning algorithms, to use sensors, such as optical sensors (e.g., cameras, simultaneous localization and mapping (SLAM) sensors, acoustic sensors, and the like) to locate any obstacles in the room for avoiding any danger for the autonomous mobile robot.

In some occasions, a lot of involvement from human operators may be necessary to ensure a smoother displacement of the (semi)autonomous mobile robots from one area to another one. Furthermore, the extra processing required to both locate the path within an area using the sensors and/or real-time generated maps through SLAM can be cumbersome and heavy for the processor of the autonomous mobile robots.

SUMMARY

This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This summary is not intended to identify key features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

The current disclosure provides a system enabling location-based autonomous navigation using a virtual world system. The system comprises at least one server computer of a server computer system comprising at least one processor and memory storing a virtual world system comprising at least one virtual object being spatially defined by virtual three-

dimensional geolocation coordinates matching the three-dimensional geolocation coordinates of a corresponding real world object; and a navigation engine configured to compute the navigation route of at least one autonomous mobile robot based on the navigation destination data and considering the three-dimensional geolocation coordinates of the at least one virtual object. The navigation engine enables the at least one autonomous mobile robot to autonomously navigate the real world through a virtual replica of the at least one autonomous mobile robot comprised in the virtual world system connected to one or more corresponding motion mechanisms and circuitry.

In some embodiments, some of the virtual objects in the virtual world system are navigational virtual objects representing navigable structures of the real world, the navigational virtual objects comprising navigation data and instructions defining one or more possible navigation paths for the at least one autonomous mobile robot. The navigation data and instructions may comprise a plurality of navigation paths including three-dimensional coordinates and a directional vector that may be used by the navigation engine to calculate the navigation route. The plurality of navigation paths may take into consideration other navigational virtual objects close to the autonomous mobile robot for determining the optimum path to be used in the computation of the navigation route. In further embodiments, the at least one navigational virtual object is transmitted on demand to the at least one autonomous mobile robot via the network as the autonomous mobile robot approaches the real world object.

In some embodiments, the navigation route is further calculated and dynamically updated by the navigation engine in view of the navigation data of the navigational virtual objects. In other embodiments, the at least one autonomous mobile robot further comprises at least one sensor. The navigation engine may further utilize the data captured by the at least one sensor to update the navigation route in real-time. Thus, the navigation engine may obtain a plurality of data from various sources to calculate, update and enhance the navigation route of the autonomous mobile robot without being limited to the functioning of sensors in real-time or generated maps (e.g., simultaneous localization and mapping (SLAM) maps), as may be typically the case. Furthermore, providing the navigational virtual objects with navigation data for the navigation engine to enhance the navigation route may provide an alternative, computing-efficient way as each of the navigational virtual objects may support the at least one server computer and autonomous mobile robot in the calculation of the navigation route.

In some embodiments, the virtual objects comprise the virtual replicas of real world elements, or purely virtual objects, or combinations thereof. In these embodiments, at least some of the purely virtual objects are virtual corridors defining the navigation route of the at least one autonomous mobile robot by virtually coupling at least two real world objects via a connection between the virtual corridor and the corresponding virtual replicas of the at least two real world objects. The virtual corridors may thus provide further navigation route computing alternatives for the autonomous mobile robot to navigate.

In another aspect of the current disclosure, a method enabling location-based autonomous navigation using a virtual world is disclosed. The method comprises defining, in a virtual world system provided in memory of at least one server computer, virtual three-dimensional geolocation coordinates of at least one virtual object matching the three-dimensional geolocation coordinates of at least one corresponding real world object. The method continues by inputting navigation destination data of an autonomous mobile robot through a navigation engine stored in memory of the at least one server computing, The method ends by computing, by the navigation engine, the navigation route of at least one autonomous mobile robot based on the navigation destination data and considering the three-dimensional geolocation coordinates of the at least one virtual object, enabling the at least one autonomous mobile robot to autonomously navigate the real world through a virtual replica of the at least one autonomous mobile robot comprised in the virtual world system connected to one or more corresponding motion mechanisms and circuitry.

In some embodiments, the method further comprises providing, to some of the virtual objects, navigation data and instructions defining one or more possible navigation paths for the at least one autonomous mobile robot, creating navigational virtual objects representing navigable structures of the real world. In further embodiments, the method comprises, by the navigation engine, calculating and dynamically updating the navigation route, in view of the navigation data of the navigational virtual objects.

In some embodiments, the method comprises transmitting the at least one navigational virtual object on demand to the at least one autonomous mobile robot via the network as the autonomous mobile robot approaches the real world object.

In some embodiments, the method further comprises updating the navigation route in real-time using data captured by at least one sensor mounted on the autonomous mobile robot in conjunction with the data of the navigational virtual objects.

In some embodiments, the virtual objects comprise the virtual replicas of real world elements, or purely virtual objects, or combinations thereof. In these embodiments, at least some of the purely virtual objects are virtual corridors defining the navigation path of the at least one autonomous mobile robot. In further embodiments, the method comprises virtually coupling at least two real world objects via a connection between the virtual corridor and the corresponding virtual replicas of the at least two real world objects.

In another aspect of the current disclosure, an autonomous mobile robot is provided, comprising a drive unit converting signals from a control unit into a movement of the autonomous mobile robot; a communication unit connecting the autonomous mobile vehicle to a network enabling connection to at least one server computer storing a navigation engine and virtual world system in memory; and a control unit comprising at least one processor and memory. The at least one processor receives a navigation route computed by the navigation engine of the at least one server computer considering three-dimensional geolocation coordinates of virtual objects in the virtual world system matching three-dimensional geolocation coordinates of a corresponding real world objects and navigation destination data, prompting the autonomous mobile robot to autonomously navigate the real world through a virtual replica of the at least one autonomous mobile robot comprised in the virtual world system.

In some embodiments, some of the virtual objects in the virtual world system are navigational virtual objects representing navigable structures of the real world, the navigational virtual objects comprising navigation data and instructions defining one or more possible navigation paths for the at least one autonomous mobile robot. In further embodiments, the navigation route is further calculated and dynamically updated by the navigation engine in view of the navigation data of the navigational virtual objects. In further embodiments, the at least one navigational virtual object is transmitted on demand to the at least one autonomous mobile robot via the network as the autonomous mobile robot approaches the real world object.

In some embodiments, the at least one autonomous mobile robot further comprises at least one sensor, wherein the navigation engine further utilizes the data captured by the at least one sensor to update the navigation route in real-time.

In some embodiments, the virtual objects comprise the virtual replicas of real world elements, or purely virtual objects, or combinations thereof. In these embodiments, at least some of the purely virtual objects are virtual corridors defining the navigation route of the

at least one autonomous mobile robot by virtually coupling at least two real world objects via a connection between the virtual corridor and the corresponding virtual replicas of the at least two real world objects.

In another aspect of the current disclosure, computer readable media are provided comprising at least one computer readable medium having stored thereon instructions configured to cause at least one server computer comprising a processor and memory to perform a plurality of steps. The steps may comprise providing, in a virtual world system provided in memory of at least one server computer, virtual three-dimensional geolocation coordinates of a at least one virtual object matching the three-dimensional geolocation coordinates of at least one corresponding real world object; inputting navigation destination data of an autonomous mobile robot through a navigation engine stored in memory of the at least one server computing; and computing, by the navigation engine, the navigation route of at least one autonomous mobile robot based on the navigation destination data and considering the three-dimensional geolocation coordinates of the at least one virtual object, enabling the at least one autonomous mobile robot to autonomously navigate the real world through a virtual replica of the at least one autonomous mobile robot comprised in the virtual world system connected to one or more corresponding motion mechanisms and circuitry.

The above summary does not include an exhaustive list of all aspects of the present disclosure. It is contemplated that the disclosure includes all systems and methods that can be practiced from all suitable combinations of the various aspects summarized above, as well as those disclosed in the Detailed Description below, and particularly pointed out in the claims filed with the application. Such combinations have advantages not specifically recited in the above summary. Other features and advantages of the present invention will be apparent from the accompanying drawings and from the detailed description that follows below.

BRIEF DESCRIPTION OF THE DRAWINGS

Specific features, aspects and advantages of the present disclosure will be better understood with regard to the following description and accompanying drawings, where:

FIG. 1 depicts a schematic representation of a system enabling location-based autonomous navigation, according to an embodiment.

FIG. 2 depicts a schematic representation of a robot using the location-based autonomous navigation of the current disclosure, according to an embodiment.

FIG. 3 depicts a schematic representation of virtual corridors connecting two buildings, used by a drone to move between the two buildings, according to an embodiment.

FIG. 4 depicts a schematic representation of an autonomous mobile robot using location-based autonomous navigation, according to an embodiment.

FIG. 5 depicts a schematic representation of a method enabling location-based autonomous navigation, according to an embodiment.

DETAILED DESCRIPTION

In the following description, reference is made to drawings which show by way of illustration various embodiments. Also, various embodiments will be described below by referring to several examples. It is to be understood that the embodiments may include changes in design and structure without departing from the scope of the claimed subject matter.

Some of the technical problems disclosed in the background may be solved by one or more aspects of the current disclosure, where a system, method, autonomous mobile robot and computer-readable media enabling location-based autonomous navigation using a virtual world system. In the current disclosure, alternative sources for calculating a navigation route may be enabled, which may provide further data to a navigation engine to compute, update and enhance the navigation route to enable the autonomous mobile robot to navigate within indoor or outdoor spaces. The navigation engine may obtain at least a navigation destination data and three-dimensional coordinates of at least one virtual object representing real-world objects in the navigation space of the at least one autonomous mobile robot. This data may be used by the navigation engine to compute the navigation route. Furthermore, the navigation engine may further utilize data from at least one navigational virtual object representing navigable structures of the real world, the navigational virtual objects comprising navigation data and instructions defining one or more possible navigation paths for the at least one autonomous mobile robot. The navigation engine may further update and enhance the navigation route by utilizing sensor data from the at least one autonomous mobile robot. The navigation engine may further utilize virtual corridors connecting one area or virtual object to another one, providing a navigation path for the at least one autonomous mobile robot. Thus, with the plurality of navigation sources, the navigation route of the current disclosure may assist in a smoother navigation by the at least one autonomous mobile robot, decreasing chances of collision or

damages to structures of the internal or external environment, people or the autonomous mobile robot itself.

FIG. 1 depicts a schematic representation of a system **100** enabling location-based autonomous navigation, according to an embodiment.

The system **100** comprises at least one server computer **102** of a server computer system comprising at least one processor **104** and memory **106** storing a virtual world system **108** comprising at least one virtual object **110** being spatially defined by virtual three-dimensional geolocation coordinates **112** matching the three-dimensional geolocation coordinates **114** of a corresponding real world object **116** in the real world **118**. The memory further stores a navigation engine **120** configured to compute the navigation route **122** of at least one autonomous mobile robot **124** based on navigation destination data **126** and considering the three-dimensional geolocation coordinates **112** of the at least one virtual object **110**, enabling the at least one autonomous mobile robot **124** to autonomously navigate the real world through a virtual replica of the at least one autonomous mobile robot **124** comprised in the virtual world system **108** connected to one or more corresponding motion mechanisms and circuitry. The at least one server computer **102** connects to the at least one autonomous mobile robot **122** via a network **128**.

The system **100** of the current disclosure may implement distributed computing capabilities employing public or private cloud servers, fog servers, and systems, such as enterprise systems, mobile platforms, machinery, robots, sensors or user devices, all of which may connect through a network **128**. This way, resources including physical servers and network equipment enable a shared storage and computing that may be dynamically allocated depending on factors such as the distance of the user to the resources and the network and computational demand from the users.

According to an embodiment, tracking of devices is performed by one or more of time of arrival (TOA), angle of arrival (AOA), and visual imaging techniques. The tracking may be performed by one or more of radar technology, antennas, Wi-Fi, inertia measuring units, gyroscopes, and accelerometers.

In some embodiments, in order to reduce hardware and network demands, contribute to the reduction of network latency, and improve the general merged reality experience, the system may connect through a network 128 including millimeter-wave (mmW) or combinations of mmW and sub 6GHz communication systems, such as through 5^{th} generation wireless systems communication (5G). In other embodiments, the system

may connect through wireless local area networking (Wi-Fi) providing data preferably at 60GHz. Provided communication systems may allow for about low end-to-end (E2E) latency and high downlink speeds to end points in the field. This results in high-quality, low latency, real-time digital application content streaming. In other embodiments, the system may communicatively connect through 4th generation wireless systems communication (4G), may be supported by 4G communication systems, or may include other wired or wireless communication systems.

In an exemplary embodiment, the autonomous mobile robot **124** may refer to a machine, such as a computer-programmable machine, capable of carrying complex actions automatically. In the current disclosure, the autonomous mobile robot **124** receives navigation instructions from the navigation engine **120** through the at least one server computer **102**, and processes the instructions for navigation. For example, the autonomous mobile robot **124** may be a factory machine, such as one or more robots used for a plurality of tasks, such as painting, welding, assembling, packaging, labeling, pick and place (e.g., for printed circuit boards), etc. In another exemplary embodiment, the autonomous mobile robot **124** may refer to aerial vehicles (e.g., planes, drones, helicopters, etc.), land vehicles (e.g., autonomous cars, motor bikes, trucks, etc.), and sea vehicles (e.g., autonomous boats, cargo ships, submarines, etc.).

In some embodiments, some of the virtual objects **110** in the virtual world system **108** are navigational virtual objects **130** representing navigable structures of the real world **118**, the navigational virtual objects **130** comprising navigation data **132** and instructions defining one or more possible navigation paths for the at least one autonomous mobile robot.

In some embodiments, the navigation data **132** includes comprises a plurality of navigation paths including three-dimensional coordinates and a directional vector that may be used by the navigation engine to calculate the navigation route. The plurality of navigation paths may take into consideration other navigational virtual objects **130** close to the autonomous mobile robot **124** for determining the optimum path to be used in the computation of the navigation route. For example, an autonomous mobile robot **124** navigating towards a kitchen because of an initial input navigation destination data faces a table between the kitchen and the current location of the autonomous mobile robot **124**. The navigation route calculated and updated in real-time by the navigation engine **120** may prompt the autonomous mobile robot **124** to skip the table because the table may provide

the navigation engine with a three-dimensional coordinates and a directional vector that, when integrated in the navigation route, sends command signals to the robot to take a path that avoids crashing against the table. In some embodiments, the navigation destination data **126** is input through a user device **134**, such as a mobile devices, personal computers, tablets, game consoles, media centers, and head-mounted displays, which is received by the navigation engine to be considered in the computation of the navigation route **122**.

In some embodiments, the virtual objects **110** comprise the virtual replicas of real world objects **116**, or purely virtual objects, or combinations thereof. In the current disclosure, the term “virtual replica” refers to accurate and persistent virtual representations of real-world elements **116**. In an embodiment, the virtual replicas of the current disclosure refer to a virtual version, or virtual twin, of a real-world element, or real twin, which may either be mapped or modeled through computer assisted drawing (CAD) or computer-assisted engineering (CAE) methods, input by computer models of the real world objects **116** (e.g., building information models - BIMs) or other suitable methods, and which may mirror not just the appearance but also the behavior of the real twin. The real-world objects **116** may additionally include sensors that can provide the virtual replicas with multi-source input data for enriching and synchronizing the virtual replicas with their respective real counterpart. Thus, virtual replicas may obtain data from one or more sources (e.g., from one or more real-world objects, environmental sensors, computing devices, etc.). As used herein, the term "multi-source data" refers to data that may be obtained from multiple sources.

As explained above, virtual replicas may be updated based on multi-source data, such as by updating known parameters or features, by enriching the virtual replicas with additional parameters or features, or the like. In the current disclosure, the term “enriching” is used to describe the act of providing further properties to a virtual replica based on multi-source data. Enriching a virtual replica may be considered a special form of updating the virtual replica with one or more new forms of data that may not have been previously present in the virtual replica. For example, enriching the virtual replicas may refer to providing real-world data captured from sensing mechanisms on a plurality of devices, wherein the further real-world data comprises video data, temperature data, real-time energy consumption data, real-time water consumption data, speed or acceleration data, or the like.

In some embodiments, the navigation route **122** is further calculated and dynamically updated by the navigation engine **120** in view of the navigation data **132** of the navigational virtual objects **130**.

In some embodiments, the at least one autonomous mobile robot **124** further comprises at least one sensor **130**. The navigation engine **120** further utilizes the data captured by the at least one sensor **130** to update the navigation route **122** in real-time. The at least one sensor **130** may be optical and/or acoustic sensors such as triangulation sensors, cameras, laser scanners, ultrasonic scanners, tactile or touch-sensitive sensors for detecting obstacles, and the like configured to locate the autonomous mobile robot **400** within a reference plane. In other embodiments, sensors may also be included to provide data representations of other characteristics of the autonomous mobile robot **400** or surrounding areas, such as thermometers, pressure sensors, humidity sensors, and the like, as well as inertia sensors (e.g., IMUs, accelerometers, and gyroscopes) for determining the position and changes in the movement of the robot or wheel contact switches that detect a contact between a wheel and the floor.

In some embodiments, the at least one navigational virtual object is transmitted on demand to the at least one autonomous mobile robot via the network as the autonomous mobile robot approaches the real world object.

In some embodiments, the virtual objects comprise the virtual replicas of real world elements, or purely virtual objects, or combinations thereof, wherein at least some of the purely virtual objects are virtual corridors defining the navigation route of the at least one autonomous mobile robot by virtually coupling at least two real world objects via a connection between the virtual corridor and the corresponding virtual replicas of the at least two real world objects.

FIG. 2 depicts a schematic representation of an indoor environment **200** using a location-based autonomous navigation system of the current disclosure, according to an embodiment.

The indoor environment **200** is stored in a virtual world system **202** as a virtual indoor environment **204**, where all or most real world objects **206** in the indoor environment **200** comprise a corresponding virtual replica **208** stored in a virtual world system **210** from at least one server computer connected a robot **212** via a network **224**. A robot **212** receives a navigation route computed by a navigation engine (e.g., navigation engine **120** of **FIG. 1**), thereby navigating the indoor environment **200**.

For example, a memory of the robot **212** may receive, through a suitable network, the computed navigation route, which may be executed by at least one processor of the robot **212** to navigate the indoor environment **200** by activating a plurality of motion mechanisms (e.g., actuators and effectors) enabling the robot's movements. Actuators are the mechanisms that enable the effectors to execute an action, and may include electric motors, hydraulic cylinders, pneumatic cylinders, or combinations thereof. Effectors refer to any device that affects the environment of the robot **212**, such as the indoor environment **200**, and may include the robot's legs, wheels, arms, fingers, etc.

Some of the real world objects **204** are navigational real world objects **214** comprising a corresponding navigational virtual objects **214** representing navigable structures of the indoor environment **200**. The navigational virtual objects **214** comprise navigation data and instructions defining one or more possible navigation paths for the robot **212** within the indoor environment **200**. For example, the navigational virtual objects **214** of the indoor environment **200** comprise doors **216**, floors **218**, and stairs **220**. The navigation route may, in some embodiments, be further calculated and dynamically updated by the navigation engine in view of the navigation data of the navigational virtual objects **214**. In some embodiments, the navigational virtual objects are transmitted on demand to the robot **212** via the network as the robot **212** approaches the navigational real world objects **214**. In some embodiments, the robot **212** further comprises at least one sensor **222**. The navigation engine further utilizes the data captured by the at least one sensor **222** to update the navigation route of the robot **212** in real-time.

In the example illustration of **FIG. 2**, the robot **212** climbs the stairs **220** by receiving and executing data and instructions processed by at least one server computer hosting the virtual world system and navigation engine comprising a navigation route. The navigation route may be computed by the navigation engine by using at least a navigation destination data input by, for example, a human or artificial intelligence user into the navigation engine, and one or more of the virtual three-dimensional geolocation coordinates of the stairs **220**, the navigational data from the stairs **220**, and the sensor data captured by the sensor **222** of the robot **212**.

FIG. 3 depicts a schematic representation of an outdoor environment **300** comprising virtual corridors **302** connecting two buildings **304**, used by a drone **306** to move between the two buildings, according to an embodiment. The outdoor environment **300** may be stored in a virtual world system **308** stored in at least one cloud server computer

and connected to a navigation engine computing the navigation route of the drone **306** through a network **310**. The virtual corridors **302** may define a fixed or semi-fixed navigation route of the drone **306** by virtually setting the path of the drone **306** in the outdoor environment **300**.

In one embodiment, the virtual corridor **302** are configured directly in the virtual world system as public virtual corridors **302** that may be used by any autonomous mobile robot, such as any other drone. In this embodiment, the navigation engine may only need to use the input navigation destination data to calculate the navigation route to include the virtual corridor **302**, which may be transmitted to the drone **306** in real time. In other embodiments, the virtual corridor **302** is calculated ad hoc by the navigation engine based on the navigation destination data, and other data such as the three-dimensional geolocation coordinates of the buildings **304**, the navigational data from the buildings **304**, and sensor data captured by a sensor of the drone **306.**

FIG. 4 depicts a schematic representation of an autonomous mobile robot **400** using location-based autonomous navigation, according to an embodiment.

The autonomous mobile robot **400** may comprise various operational components, such as a drive unit **402**, a sensor unit **404**, a communication unit **406**, and a power source **408**, all connected to a control unit **410** comprising at least one processor **412** and memory **414**. Through the communication unit **406**, the autonomous mobile robot **400** connects to a network **416** enabling connection to at least one server computer **418** and to the navigation engine **420** and virtual world system **422** therein stored. The network **416** further enables connection of the autonomous mobile robot **400** with at least one user device **424** configured for inputting commands (e.g., navigation destination data**)** that may be received and processed by the navigation engine **420** for integrating into the navigation route.

The drive unit **402** may comprise a plurality of elements enabling the autonomous mobile robot **400** to move and perform one or more actions by converting signals from the control unit into a movement of the autonomous mobile robot **400**. For example, the drive unit **402** can comprise motors, transmissions, wheels, wings, actuators, and effectors, or any other part and corresponding circuitry enabling the movement of the autonomous mobile robot **400**.

The sensor unit **404** may comprise a plurality of sensors configured to determine and track the position and orientation of the autonomous mobile robot **400**, to provide data points about the objects and the space around the autonomous mobile robot **400** that may

be synchronized and shared with the virtual world system **420** in the server **416**, and to provide data representations of one or more physical properties of the real objects in the real world to the server **416**. In some embodiments, the sensor unit **404** may be implemented in a plurality of areas of the autonomous mobile robot **400** or in areas surrounding the autonomous mobile robot **400**. For example, the sensor unit **404** may be positioned on a plurality of joints and connectors of autonomous mobile robot **400**. Sensors of the sensor unit **404** may comprise, for example, optical and/or acoustic sensors such as triangulation sensors, cameras, laser scanners, ultrasonic scanners, tactile or touch-sensitive sensors for detecting obstacles, and the like. In other embodiments, sensors may also be included to provide data representations of other characteristics of the autonomous mobile robot **400** or surrounding areas, such as thermometers, pressure sensors, humidity sensors, and the like, as well as inertia sensors (e.g., IMUs, accelerometers, and gyroscopes) for determining the position and changes in the movement of the robot or wheel contact switches that detect a contact between a wheel and the floor.

The communication unit **406** may be implemented as computing software and hardware to communicatively connect to the network **416**, receive computer readable program instructions from the at least one server computer **418**, and forward the computer readable program instructions for storage in the memory **414** for execution by the processor **412**. The communication unit may comprise one or more transceiver (not shown) that may be implemented as computing software and hardware configured to enable real objects 102 to receive wireless radio waves from antennas and to send the data back to the antennas. In some embodiments, millimeter-wave (mW) transceivers may be employed, which may be configured to receive mmW wave signals from antennas and to send the data back to antennas when interacting with immersive content. The transceiver may be a two-way communication transceiver.

The communication unit **406** may further enable connection of the autonomous mobile robot with the at least one user device **424** for receiving input data such as navigation destination data and/or task commands, and/or for displaying autonomous mobile robot status, such as location in the virtual world system, battery levels, functioning parameters, and the like. Said user devices **424** may be implemented as external computing pointing devices for selecting objects and options (e.g., a touch screen, mouse, 3D control, joystick, levers, steering wheels, gamepad, and the like) and/or text entry device for inputting manipulation commands (e.g., a keyboard, buttons, dictation tools, and the like)

configured to interact with elements in the real world through the autonomous mobile robot **400**.

The power source **408** is implemented as computing hardware configured to provide power to the autonomous mobile robot **400**. In one embodiment, the power source **408** may be a battery. The power source **408** may be built into the autonomous mobile robot **400** or removable from the autonomous mobile robot **400**, and may be rechargeable or non-rechargeable. In one embodiment, the devices may be repowered by replacing one power source **408** with another power source **408**. In another embodiment, the power source **408** may be recharged by a cable attached to a charging source, such as a universal serial bus ("USB"), FireWire, Ethernet, Thunderbolt, or headphone cable, attached to a personal computer. In yet another embodiment, the power source **408** may be recharged by inductive charging, wherein an electromagnetic field is used to transfer energy from an inductive charger to the power source **408** when the two are brought in close proximity, but need not be plugged into one another via a cable. In another embodiment, a docking or base station may be used to facilitate charging.

The control unit **410** may be configured to generate commands for the autonomous mobile robot from instructions stored in memory received from the at least one server computer **418**. The processor **412** of the control unit **410** can be configured to process manipulation instructions directly via the user devices **424** or coming from the at least one server computer **418** from the navigation engine **420**. The processor **412** sends the processed instructions to the drive unit **402** for moving the corresponding parts that result in moving or performing tasks by the autonomous mobile robot. The processor **412** may also be capable of implementing analog or digital signal processing algorithms such as raw data reduction or filtering. In some embodiments, the processor **412** may share some computational tasks with the at least one server computer **418**.

The memory **414** may be implemented as computing software and hardware adapted to store application programs and receive data from, e.g., the navigation engine **420**. The memory **414** may be of any suitable type capable of storing information accessible by the processor **412**, including a computer-readable medium, or other medium that stores data that may be read with the aid of an electronic device, such as a hard-drive, memory card, flash drive, ROM, RAM, DVD or other optical disks, as well as other write-capable and read-only memories. The memory 306 may include temporary storage in addition to persistent storage.

FIG. 5 depicts a schematic representation of a method **500** enabling location-based autonomous navigation, according to an embodiment.

The method begins in step **502** by defining, in a virtual world system provided in memory of at least one server computer, virtual three-dimensional geolocation coordinates of at least one virtual object matching the three-dimensional geolocation coordinates of at least one corresponding real world object. The method continues in step **504** by inputting navigation destination data of an autonomous mobile robot through a navigation engine stored in memory of the at least one server computing.

Subsequently, in step **506**, the method continues by computing, by the navigation engine, the navigation route of at least one autonomous mobile robot based on the navigation destination data and considering the three-dimensional geolocation coordinates of the at least one virtual object, enabling the at least one autonomous mobile robot to autonomously navigate the real world through a virtual replica of the at least one autonomous mobile robot comprised in the virtual world system connected to one or more corresponding motion mechanisms and circuitry.

In some embodiments, the method **500** further comprises providing, to some of the virtual objects, navigation data and instructions defining one or more possible navigation paths for the at least one autonomous mobile robot, creating navigational virtual objects representing navigable structures of the real world. In further embodiments, the method **500** comprises by the navigation engine, calculating and dynamically updating the navigation route, in view of the navigation data of the navigational virtual objects. The navigation data comprises a plurality of navigation paths including three-dimensional coordinates and a directional vector that may be used by the navigation engine to calculate the navigation route. The plurality of navigation paths may take into consideration other navigational virtual objects close to the autonomous mobile robot for determining the optimum path to be used in the computation of the navigation route.

In some embodiments, the method **500** further comprises transmitting the at least one navigational virtual object on demand to the at least one autonomous mobile robot via the network as the autonomous mobile robot approaches the real world object.

In some embodiments, the method **500** further comprises updating the navigation route in real-time using data captured by at least one sensor mounted on the autonomous mobile robot in conjunction with the data of the navigational virtual objects.

In some embodiments the virtual objects comprise the virtual replicas of real world elements, or purely virtual objects, or combinations thereof, wherein at least some of the purely virtual objects are virtual corridors defining the navigation path of the at least one autonomous mobile robot. In further embodiments, the method **500** further comprises virtually coupling at least two real world objects via a connection between the virtual corridor and the corresponding virtual replicas of the at least two real world objects.

While certain embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that the invention is not limited to the specific constructions and arrangements shown and described, since various other modifications may occur to those of ordinary skill in the art. The description is thus to be regarded as illustrative instead of limiting.

CLAIMS

1. A system comprising:

at least one server computer of a server computer system comprising at least one processor and memory storing:

a virtual world system comprising at least one virtual object being spatially defined by virtual three-dimensional geolocation coordinates matching the three-dimensional geolocation coordinates of a corresponding real world object;

and a navigation engine configured to compute the navigation route of at least one autonomous mobile robot based on the navigation destination data and considering the three-dimensional geolocation coordinates of the at least one virtual object, enabling the at least one autonomous mobile robot to autonomously navigate the real world through a virtual replica comprised in the virtual world system connected to one or more corresponding motion mechanisms and circuitry.

2. The system of claim 1, wherein some of the virtual objects in the virtual world system are navigational virtual objects representing navigable structures of the real world, the navigational virtual objects comprising navigation data and instructions defining one or more possible navigation paths for the at least one autonomous mobile robot.

3. The system of claims 2, wherein the navigation route is further calculated and dynamically updated by the navigation engine in view of the navigation data of the navigational virtual objects.

4. The system of claim 2, wherein the at least one navigational virtual object is transmitted on demand to the at least one autonomous mobile robot via the network as the autonomous mobile robot approaches the real world object.

5. The system of claim 3, wherein the at least one autonomous mobile robot further comprises at least one sensor, and wherein the navigation engine further utilizes the data captured by the at least one sensor to update the navigation route in real-time.

6. The system of claim 1, wherein the virtual objects comprise the virtual replicas of real world elements, or purely virtual objects, or combinations thereof, wherein at least some of the purely virtual objects are virtual corridors defining the navigation route of the

at least one autonomous mobile robot by virtually coupling at least two real world objects via a connection between the virtual corridor and the corresponding virtual replicas of the at least two real world objects.

7. A method comprising:

defining, in a virtual world system provided in memory of at least one server computer, virtual three-dimensional geolocation coordinates of a at least one virtual object matching the three-dimensional geolocation coordinates of at least one corresponding real world object;

inputting navigation destination data of an autonomous mobile robot through a navigation engine stored in memory of the at least one server computing; and

computing, by the navigation engine, the navigation route of at least one autonomous mobile robot based on the navigation destination data and considering the three-dimensional geolocation coordinates of the at least one virtual object, enabling the at least one autonomous mobile robot to autonomously navigate the real world through a virtual replica of the at least one autonomous mobile robot comprised in the virtual world system connected to one or more corresponding motion mechanisms and circuitry.

8. The method of claim 7, further comprising:

providing, to some of the virtual objects, navigation data and instructions defining one or more possible navigation paths for the at least one autonomous mobile robot, creating navigational virtual objects representing navigable structures of the real world.

9. The method of claim 8, further comprising, by the navigation engine, calculating and dynamically updating the navigation route, in view of the navigation data of the navigational virtual objects.

10. The method of claim 8, further comprising transmitting the at least one navigational virtual object on demand to the at least one autonomous mobile robot via the network as the autonomous mobile robot approaches the real world object.

11. The method of claim 9, further comprising updating the navigation route in real-time using data captured by at least one sensor mounted on the autonomous mobile robot in conjunction with the data of the navigational virtual objects.

12. The method of claim 7, wherein the virtual objects comprise the virtual replicas of real world elements, or purely virtual objects, or combinations thereof, wherein at least some of the purely virtual objects are virtual corridors defining the navigation path of the at least one autonomous mobile robot.

13. The method of claim 12, further comprising virtually coupling at least two real world objects via a connection between the virtual corridor and the corresponding virtual replicas of the at least two real world objects.

14. An autonomous mobile robot comprising:

a drive unit converting signals from a control unit into a movement of the autonomous mobile robot;

a communication unit connecting the autonomous mobile vehicle to a network enabling connection to at least one server computer storing a navigation engine and virtual world system in memory; and

a control unit comprising at least one processor and memory;

wherein the at least one processor receives a navigation route computed by the navigation engine of the at least one server computer considering three-dimensional geolocation coordinates of virtual objects in the virtual world system matching three-dimensional geolocation coordinates of a corresponding real world objects and navigation destination data, prompting the autonomous mobile robot to autonomously navigate the real world through a virtual replica of the at least one autonomous mobile robot comprised in the virtual world system.

15. The autonomous mobile robot of claim 14, wherein some of the virtual objects in the virtual world system are navigational virtual objects representing navigable structures of the real world, the navigational virtual objects comprising navigation data and instructions defining one or more possible navigation paths for the at least one autonomous mobile robot.

16. The autonomous mobile robot of claim 15, wherein the navigation route is further calculated and dynamically updated by the navigation engine in view of the navigation data of the navigational virtual objects.

17. The autonomous mobile robot of claims 15, wherein the at least one navigational virtual object is transmitted on demand to the at least one autonomous mobile robot via the network as the autonomous mobile robot approaches the real world object.

18. The autonomous mobile robot of claim 16, wherein the at least one autonomous mobile robot further comprises at least one sensor, and wherein the navigation engine further utilizes the data captured by the at least one sensor to update the navigation route in real-time.

19. The autonomous mobile robot of claim 14, wherein the virtual objects comprise the virtual replicas of real world elements, or purely virtual objects, or combinations thereof, wherein at least some of the purely virtual objects are virtual corridors defining the navigation route of the at least one autonomous mobile robot by virtually coupling at least two real world objects via a connection between the virtual corridor and the corresponding virtual replicas of the at least two real world objects.

20. Computer readable media having stored thereon instructions configured to cause at least one media server computer comprising a processor and memory to perform steps comprising:

defining, in a virtual world system provided in memory of at least one server computer, virtual three-dimensional geolocation coordinates of a at least one virtual object matching the three-dimensional geolocation coordinates of at least one corresponding real world object;

inputting navigation destination data of an autonomous mobile robot through a navigation engine stored in memory of the at least one server computing; and

computing, by the navigation engine, the navigation route of at least one autonomous mobile robot based on the navigation destination data and considering the three-dimensional geolocation coordinates of the at least one virtual object, enabling the at least one autonomous mobile robot to autonomously navigate the real world through a virtual replica of the at least one autonomous mobile robot comprised in the virtual world system connected to one or more corresponding motion mechanisms and circuitry.