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SYSTEMS AND METHODS FOR CONTROLLING AUTONOMOUS VEHICLE OPERATION BASED ON MONITORING OF A LOADING DOCK

Abstract

The present invention relates, in general, to systems and methods for controlling autonomous forklifts, and specifically, controlling autonomous forklifts based on monitoring of a loading dock. The present invention utilizes monitoring of a loading dock for human personnel and obstacles in order to safely maneuver an autonomous forklift during loading and unloading operations into and out of a trailer.

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Background/Summary

BACKGROUND

Field of the Invention

[0001] The present invention relates, in general, to computer implemented systems and methods for monitoring a loading dock and controlling autonomous vehicle operation to prevent potential safety hazards.

Description of Related Art

[0002] Loading dock facilities, such as in warehouses, typically include multiple loading dock stations that facilitate the movement of goods between the warehouse and a vehicle, such as a semi-truck trailer, parked at the loading dock. Goods being delivered by, or loaded onto, trailers typically are stored on pallets, which are flat transport structures configured to hold goods for easier transportation by vehicles and other equipment, such as forklifts, operating in the warehouse.

[0003] Traditionally, human personnel have operated forklifts. However, with advances in autonomous vehicle technology, autonomous forklifts are increasingly being used in warehouse environments to lift and transport pallets to and from trailers parked at loading docks. While such technological advancement allows for increased operational efficiency within warehouses, the use of autonomous vehicles raises issues around warehouse safety, particularly for human personnel working on loading docks and/or inside trailers. Safety issues are especially pronounced when autonomous vehicles enter a trailer during loading operations, as the interior of trailers have limited opportunities for egress, and the autonomous vehicle sensors and perception systems may be obscured by a load being carried.

[0004] Thus, there is a need for systems and methods that provides safety for human personnel working in environments where autonomous vehicles are operating in, namely, to prevent egress into a trailer within which an autonomous vehicle is performing loading and/or unloading operations.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] These and other embodiments of the present invention will be discussed with reference to the following exemplary and non-limiting illustrations, in which like elements are numbered similarly, and where:

[0006] FIG. **1** is a block diagram of a monitoring system for a loading dock;

[0007] FIG. **2** is top-down diagram of the monitoring system for the loading dock when an autonomous vehicle has not yet traversed through a sensing field;

[0008] FIG. **3** is a top-down diagram of the monitoring system for the loading dock when the autonomous vehicle is traversing through the sensing field;

[0009] FIG. **4** is a top-down diagram of the monitoring system for the loading dock when the autonomous vehicle has fully traversed through the sensing field; and

[0010] FIG. **5** is a flowchart illustrating the steps of operation of the monitoring system.

DEFINITIONS

[0011] The following definitions are meant to aid in the description and understanding of the defined terms in the context of the present invention. The definitions are not meant to limit these terms to less than is described throughout this specification. Such definitions are meant to encompass grammatical equivalents.

[0012] As used herein, the term “autonomous vehicle” can refer to, for example, autonomous mobile robots, automatic guided vehicles, vision guided vehicles, semi-autonomous vehicles, and remote-piloted autonomous vehicles, as examples, which serve as equipment, pallet, object, and cargo moving and transport vehicles, including, but not limited to, forklifts, pallet loaders, side loaders, lift trucks, fork hoists, stacker-trucks, trailer loaders, industrial trucks, pallet jacks, pallet stackers, tow tractors, tugs, and the like.

[0013] As used herein, the terms “sensor” and “detector” can refer to, for example, sensing technologies that utilize LiDAR, radar, infrared sensors, sonar, ultrasonic sensors, optical sensors, such as photoelectric sensors, fiber optic sensors, photoconductive devices, reflective sensors, phototransistors, ambient light sensors, infrared sensors, photodiodes, and optical switches, point sensors, proximity sensors, through beam sensors, light curtains, image and video capturing devices, machine vision systems, any combination thereof, and the like.

[0014] As used herein, the term “network” can refer to, for example, the Internet, a wide area network (WAN), metropolitan area network (MAN), campus area network (CAN), local area network (LAN), but the network could at least theoretically be of an applicable size or characterized in some other fashion (i.e., personal area network (PAN), home area network (HAN), and the like), a wireless network, a wireless mesh network, a cellular network, a landline network, and/or a short-range connection network (i.e., such as Bluetooth, Zigbee, infrared, and the like). The term “network” can further refer to enterprise private networks, edge networks, and/or virtual private networks.

[0015] As used herein, the term “processor” can refer to, for example, any programmable system including systems using micro-controllers, reduced instruction set circuits (RISC), application specific integrated circuits (ASICs), logic circuits, and any other circuit or processor capable of executing the functions described herein. The above examples are exemplary only, and are thus not intended to limit in any way the definition and/or meaning of the term “processor.”

[0016] As used herein, the terms “software” and “firmware” are interchangeable, and can refer to, for example, any computer program stored in memory for execution by a processor, including RAM memory, ROM memory, EPROM memory, EEPROM memory, and non-volatile RAM (NVRAM) memory. The above memory types are example only, and are thus not limiting as to the types of memory usable for storage of a computer program.

[0017] As used herein, the term “database” can refer to, for example, a persistent data store with indexing capabilities to expedite query processing. The database can implement various database management systems types such as relational, object-oriented, hierarchical, document-oriented, flat file, object-relational, and any other structured collection of records. The database can be stored locally, remotely, on a cloud environment, and/or on a distributed ledger.

[0018] As used herein, the term “computing device” can refer to, for example, mobile phones, portable media players, desktop computers, laptop computers, netbooks, smartphones, tablet computers, wearable devices, “smart” watches, “smart” bracelets, “smart” necklaces, enhanced vision devices and systems, augmented vision headsets/glasses, internet-connected streaming media devices, any combination thereof, and the like.

[0019] As used herein, the term “inertial measurement unit” can refer to, for example, accelerometers, gyroscopes, magnetometers, pressure sensors, any combination thereof, and the like.

[0020] As used herein, the term “artificial intelligence” can refer to, for example, machine learning, deep-learning, supervised learning, unsupervised learning, semi-supervised learning, generative artificial intelligence, reinforced learning, fuzzy logic, neural networks, historical data and pattern analysis, any combination thereof, and the like.

[0021] As used herein, the term “engine” can refer to, for example, hardware components, software components, such as source code, packages, libraries, algorithms, and the like, as well as combinations therein.

[0022] As used herein, the term “positioning beacon” can refer to, for example, ultra-wideband (UWB) technology, Bluetooth Low Energy (BLE) technology, proximity detectors, acoustic technology, infrared systems, Wi-Fi positioning systems, any combination thereof, and the like.

DETAILED DESCRIPTION

[0023] It should be understood that aspects of the present invention are described herein with reference to the figures, which show illustrative embodiments. The illustrative embodiments herein are not necessarily intended to show all embodiments in accordance with the invention, but rather are used to describe a few illustrative embodiments. Thus, aspects of the invention are not intended to be construed narrowly in view of the illustrative embodiments. In addition, although the present invention is described with respect to its application for an autonomous forklift operating in a loading dock environment, it is understood that the system could be implemented in any autonomous or semi-autonomous vehicle system operating in any environment where safety measures are required to protect humans, vehicles, objects, access points, and egress/ingress locations.

[0024] FIG. **1** is a block diagram of a monitoring system **100** for a loading dock. In an embodiment, the monitoring system **100** includes a controller **102** communicatively coupled via at least one network to a detector **104**, database **106**, sensors **110** on-board an autonomous vehicle **108**, a warning system **112**, an arming switch **114**, and an artificial intelligence engine **116**. The network may be any type of network suitable to allow interaction between the components of the monitoring system **100**. For example, the network may be a wired network, a wireless network, or any combination thereof. In a preferred embodiment, the network is a wireless network.

[0025] In an embodiment, the controller **100** consists of computing hardware, such as a processor, and software which is executed by the processor. In an embodiment, the controller **100** can include a server coupled to the network. In another embodiment, the controller **100** is cloud-based, and located on remote server, such as on a server provided by Google® Cloud Platform or the like. In yet another embodiment, the controller **100** can be distributed across multiple servers.

[0026] In an embodiment, the controller **102** receives input, such as data, from the detector **104**, the database **106**, the autonomous vehicle **108**, the sensors **110**, the arming switch **114**, and the artificial intelligence engine **116**, and provides output, such as commands, to the detector **104**, the database **106**, the autonomous vehicle **108**, and the warning system **112**.

[0027] In an embodiment, the detector **104** is placed adjacent to a dock plate so that it can detect the presence of the autonomous vehicle **108**, humans, animals, and other objects, both inanimate and living, and both stationary and mobile. The detector **104** can consist of a single hardware component, or multiple hardware components, such as opposing optical devices. In a preferred embodiment, the detector **104** is an industrial light curtain, which can consist of a photoelectric transmitter that projects an array of synchronized, parallel infrared light beams to a receiver unit, thereby creating a sensing field. When an opaque object, such as the autonomous vehicle **108** or human, for example, interrupts one or more beams in the sensing field, circuitry in the detector **104** transmits a signal to the controller **108**.

[0028] The use of an industrial light curtain for the detector **104** is exemplary, and is not intended to be a limiting. In other embodiments, the detector **104** can include LiDAR or other sensing or detecting devices as described herein.

[0029] In an embodiment, the database **106** is configured to store various data, receive queries from the controller **102**, and return data to the controller **102** in response to the queries. The database **106** can store data collected by the detector **104** related to arming, disarming, interruptions to the signal field (i.e., when an autonomous vehicle or human traverses the signal field), faults, warning system activations, and the like.

[0030] Furthermore, he database **106** can store data collected by the sensors **110** on the autonomous vehicle **108**, such as data related to motion, navigation, speed, and trajectory of the autonomous vehicle **108**, as well as detected obstacles, collision avoidance maneuvers undertaken, and work performed such as loading and unloading operations, the number of pallets transported, individual pallet weights, and the like.

[0031] In an embodiment, the data in the database **106** is stored with an identifier related to at least one of the loading dock, the autonomous vehicle **108**, the trailer, and/or any combination thereof. In addition, the data in the database **106** can be stored with timestamps.

[0032] In an embodiment, the autonomous vehicle **108** is an automated forklift that performs various pallet loading and unloading operations. The autonomous vehicle **108** is described in more detail in commonly owned application Ser. No. **18/480**,**214** entitled "Method and system for operating automated forklift", filed on Oct. 3, 2023, and commonly owned application Ser. No. 18/410,774 entitled "Method and system for deep learning based perception", filed on Jan. 11, 2024, both of which are incorporated by reference herein. The autonomous vehicle **108** includes a vehicle controller, battery, and communication module, allowing the autonomous vehicle to send data to, and receive commands and data from, the controller **102**.

[0033] The autonomous vehicle **108** further includes various sensors **110**, such as, but not limited to, cameras, LiDAR, inertial measurement units, odometers, a global positioning system (GPS), and the like. The sensors **110** area used to collect, for example, information related to the autonomous vehicle's surroundings, potential obstacles, depth perception, speed, velocity, orientation, angular rates, gravitational forces, wheel rotation, location, and navigation, and the like.

[0034] This data may be stored locally within a database on the autonomous vehicle **108**, and/or can be transmitted to the controller **102**, which can process the data and further transmit the data to the database **106** for storage and subsequent retrieval.

[0035] In an embodiment, the warning system **112** is configured to alert humans, such as personnel, workers, operators, and the like, in the vicinity of the loading dock and/or inside the trailer of a potential safety hazard. For example, if the autonomous vehicle **108** enters the sensing field, and another autonomous vehicle or human is concurrently within the trailer, the controller **102** transmits an activation command to the warning system **112**, causing the warning system **112** to emit an alert.

[0036] In an embodiment, the warning system **112** can consist of a warning device having a visual display, illumination means, speaker, and/or a combination thereof. The warning system **112** can emit a strobe or flash, emit a siren or audible warning, and/or display a text or visual warning. In an embodiment, the warning system **112** can consist of multiple warning devices located throughout the loading dock and/or the surrounding environment where all of the devices can be activated simultaneously, or alternatively, the controller **102** can selectively activate one or more warning devices based on, for example, the severity of the potential safety hazard, the location of the potential safety hazard, and the like.

[0037] In another embodiment, the warning system **112** can be communicatively coupled to computing devices used by human personnel in the vicinity of the loading dock and/or inside the trailer. Upon receiving an activation command, the warning system **112** can transmit an alert to these computing devices. For example, the alert can be in the form of a text message, multimedia message, e-mail, social media message, telephone call, and the like.

[0038] In yet another embodiment, the warning system **112** can transmit an alert to a software application located on the computing devices, such as a smartphone application, where the software application activates a strobe of the computing device camera/lights, emits an audible warning or siren through the computing device speaker, displays a notification, text, or visual warning on the computing device's display, and/or causes the computing device to vibrate and provide haptic feedback.

[0039] In an embodiment, the arming switch **114** transmits a signal to the controller **102** to activate the detector **104**. In another embodiment, the arming switch can be communicatively coupled to the detector **104**, and can transmit an arming command directly to the detector **104**. The arming switch **114** can be actuated manually through various mechanisms, including, for example, a physical switch or button, actuating a virtual switch through a software application on a computing device, and the like. In an embodiment, human personnel can actuate the arming switch **114** to arm the detector **104** upon manually verifying that no other autonomous vehicles or humans are present within the trailer.

[0040] In another embodiment, the detector **104** can be armed by the controller **102** upon receiving data from other sensors such as motion sensors, cameras, and the like, located within the trailer, or located on the loading dock and positioned to capture data of the entry and the interior of the trailer. For example, upon sensing no motion or movement within the trailer for a predetermined period of time, the controller **102** can transmit an arming command to the detector **104**.

[0041] In yet another embodiment, the detector **104** is armed using a multi-stage approach, where the controller **102** automatically pre-arms the detector **104** as described herein, however, human personnel is required to complete the arming process by actuating the arming switch **114** after manually verifying that no other autonomous vehicles or humans are present within the trailer.

[0042] In an embodiment, the artificial intelligence engine **116** is communicatively coupled to the controller **102** and/or the database **106**. The artificial intelligence engine **116** can analyze data collected over time by the detector **104** and sensors **110**. This analysis by the artificial intelligence engine **116** allows the controller **102** to process the future data more efficiently, quickly generate commands, and improve the efficacy and accuracy of the monitoring system **100**.

[0043] For example, the controller **106** can use analysis from the artificial intelligence engine **116** to determine when to automatically transmit an arming command to the detector **104**.

[0044] FIG. **2** is top-down diagram of the monitoring system **100** for the loading dock **200** when an autonomous vehicle **108** has not yet traversed through a sensing field **206**. In an embodiment, the detector **104** is an industrial light curtain having a transmitter **202** and receiver **204**, as described herein. The light beams emitted between the transmitter **202** and receiver **204** create the sensing field **206**. Prior to the autonomous vehicle **108** traversing through the sensing field **206** and into a safe zone **208** which leads towards the trailer **210**, the detector **104** is armed as described herein. The safe zone **208** is a region which the controller **102** has deemed to be clear of humans and other autonomous vehicles.

[0045] FIG. **3** is a top-down diagram of the monitoring system **100** for the loading dock **200** when the autonomous vehicle **108** is traversing through the sensing field **206**. Once the autonomous vehicle **108** starts traversing through the sensing field **206**, the detector **104** is disarmed by the controller **102**, and data from the sensors **110** on the autonomous vehicle **108** are used by the controller **102** to detect if any obstacles, such as humans or other autonomous vehicles are present in the safe zone **208** and/or within the trailer **210**. During traversal, if the sensors **110** detect a fault (i.e., detect a human or another autonomous vehicle in the safe zone **208**), the autonomous vehicle **108** will cease operation and movement.

[0046] FIG. **4** is a top-down diagram of the monitoring system **100** for the loading dock **200** when the autonomous vehicle **108** has fully traversed through the sensing field **206**. Once the autonomous vehicle **108** has completely passed through and traversed the sensing field **206**, the detector **104** is armed by the controller **102**, and the controller **102** uses data from the detector **104** to determine if any obstacles, such as humans or other autonomous vehicles are present in the safe zone **208** and/or within the trailer **210**. In an embodiment, the sensors **110** on the autonomous vehicle **108** are deactivated and do not collect data. In another embodiment, the sensors **110** continue to collect data, however, this data is not utilized by the controller **102** to determine if a potential safety hazard exists.

[0047] In yet another embodiment, once the autonomous vehicle **108** has fully traversed through the sensing field **206**, data from both the detector **104** and the sensors **110** are utilized by the controller **102** to determine if a potential safety hazard exists.

[0048] FIG. **5** is a flowchart illustrating the steps of operation of the monitoring system **100**. At step **502**, the detector **104** is armed and engaged by human personnel actuating the arming switch **104**, and/or by the controller **102** transmitting an arming command to the detector **104**, as described herein.

[0049] At step **504**, the controller **102** determines if the autonomous vehicle **108** is traversing the sensing field **206**. In an embodiment, the controller **102** continuously receives signals from the detector **104** once the detector **104** has been armed. In another embodiment, the controller **102** receives a signal from the detector **104** at predetermined intervals, such as, for example, every 1 second, 5 seconds, 10 seconds, and so on.

[0050] In an embodiment, the predetermined interval can be set by the controller **102** based on historical fault data analyzed by the artificial intelligence engine **116**. Such historical fault data can be related to prior operation and/or events associated with the autonomous vehicle **108**, the loading dock **200**, the trailer **208**, the arming switch **114**, and/or the warning system **112**. For example, if a particular loading dock has historically been prone to a high number of faults (i.e., potential safety hazards), then the controller **102** can increase the frequency at which it receives signals from the detector **104**.

[0051] In yet another embodiment, the predetermined interval can be set by human personnel.

[0052] In an embodiment, the detector **104** pushes signals to the controller **102** as soon as the data is collected by the detector **104** in real-time. In another embodiment, the controller **102** pulls or polls data from the detector **104**.

[0053] If the controller **102** determines that the autonomous vehicle **108** is not traversing through the sensing field **206**, then the process returns to step **502** where the controller **102** continues to receive data from the detector **104**.

[0054] If, however, the controller **102** determines that the autonomous vehicle **108** is traversing through the sensing field **206**, then the process continues to step **506**, where the controller **102** determines if the autonomous vehicle **108** is at the correct loading dock.

[0055] In an embodiment, to determine if the autonomous vehicle **108** is at the correct loading dock, the controller **102** first issues a command to mute the detector **104**, and subsequently issues a command to un-mute the detector **104**. While in a muted state, the controller **102** does not process data from the detector **104** for the purposes of determining if there is a potential safety hazard. However, while in the muted state, the sensing field **206** remains active.

[0056] If the autonomous vehicle **108** traverses the sensing field **206** within a window of time after the controller issues the command to mute the detector **104**, and completes traversing the sensing field **206** field within another window of time after the controller **102** issues the command to un-mute the detector **104**, then the autonomous vehicle **108** is deemed to be at the correct loading dock.

[0057] In addition, the monitoring system **100** can further utilize positioning beacons, such as, for example, UWB positioning beacons, in conjunction with the timed window functions described herein, to determine if the autonomous vehicle **108** is at the correct loading dock.

[0058] In another embodiment, the database **106** includes a mapping of the autonomous vehicle **108**, loading docks which the autonomous vehicle **108** is scheduled to operate at, trailers which the autonomous vehicle **108** is scheduled to operate within, and corresponding scheduled time slots therein. Table 1 below depicts an exemplary database record, where each autonomous vehicle has a unique identifier (i.e., AV1, AV2, etc.), each detector has a unique identifier (i.e., D1, D2, etc.), each loading dock has a unique identifier (i.e., DOCK1, DOCK2, etc.), each trailer has a unique identifier (i.e., T1, T2, etc.), and for each mapping, there is an operation code (i.e., LOAD, UNLOAD, SORT, etc.). In another embodiment, each autonomous vehicle is mapped in the database **106** to only a particular loading dock or trailer for a particular scheduled operation time slot.

TABLE-US-00001 TABLE 1 Scheduled Autonomous Detector Loading Trailer Operation Vehicle ID ID Dock ID ID Time Slot Operation AV1 D1 DOCK1 T1 0900-1000 LOAD AV1 D2 DOCK2 T2 1400-1430 UNLOAD AV2 D1 DOCK1 T3 1100-1300 UNLOAD AV2 D3 DOCK3 T4 2200-0300 LOAD

[0059] The controller **102** can query the database **106** to determine if an autonomous vehicle is scheduled to be at a particular loading dock at a current time. If the controller **102** determines that the autonomous vehicle **108** is not at the correct loading dock, then the controller **102** instructs the autonomous vehicle **108** to navigate to the correct loading dock at step **508**.

[0060] In another embodiment, the autonomous vehicle **106** can query the database **108** and/or the controller **102**, to determine if the autonomous vehicle **108** is scheduled to be at a particular loading dock.

[0061] If, however, the controller **102** determines that the autonomous vehicle is at the correct loading dock, the process continues to step **510** where the controller **102** transmits a disarming command to the detector **104**, and transmits a command to the autonomous vehicle **108** to activate the sensors **110**. The controller **102** subsequently receives data from the sensors **110**, and uses this data to determine if humans or other autonomous vehicles are present in the safe zone **208** and/or within the trailer **210**.

[0062] In another embodiment, the autonomous vehicle **108** can locally process the data from the sensors **110** and determine if humans or other autonomous vehicles are present in the safe zone **208** and/or within the trailer **210**. This determination can be transmitted to the controller **102** by the autonomous vehicle **108**.

[0063] If the detector **104** is disarmed when the autonomous vehicle **108** arrives at the loading dock **200**, the autonomous vehicle **108** will not proceed to attempt to enter the loading dock **200**. That is, the autonomous vehicle **108** will only proceed with step **510** and transmit a disarming command to the detector **104** if the detector is in an armed state.

[0064] In yet another embodiment, the controller **102**, detector **104** and/or the autonomous vehicle **108** can be communicatively coupled to an edge server located in closer proximity to the detector **104** than the controller **102**. The edge server **102** can receive data from the sensors **110** and/or the detector **104** and can process this data to determine if humans or other autonomous vehicles are present in the safe zone **208** and/or within the trailer **210**. This determination can be transmitted to the controller **102** by the edge server, or alternatively, the edge server can issue appropriate commands to the autonomous vehicle **108**, the detector **104**, the warning system **112**, and/or the arming switch **114**.

[0065] At step **512**, the controller **102** determines if the autonomous vehicle **108** has fully traversed the sensing field **206**. If the autonomous vehicle **108** has not fully traversed the sensing field **206**, then the process reverts to step **510** where the sensors **110** of the autonomous vehicle **108** remain activated, the detector **104** remains disarmed, and the controller **102** continues to utilize the data from the sensors **110**.

[0066] If, however, the autonomous vehicle **108** has fully traversed the sensing field **206**, then the process continues to step **514** where the controller **102** arms the detector **104**, and commands the sensors **110** deactivate. Alternatively, the controller **102** ceases to receive and/or process data from the sensors **110**, but the sensors **110** may continue to collect data.

[0067] At step **516**, the controller **102** determines if humans or other autonomous vehicles are traversing the sensing field **206**. If the sensing field **206** is being traversed, indicating a fault due to a human or other autonomous vehicle attempting to enter the safe zone **208** and/or the trailer **210** while the autonomous vehicle **108** is operating within the trailer **210**, the controller **102** commands the autonomous vehicle **108** to cease operation and movement at step **518**. In an embodiment, the controller **102** can alternatively, or additionally, command the warning system **112** to issue an alert at step **518**, as described herein.

[0068] In an embodiment, if another autonomous vehicle is traversing the sensing field **206**, the controller **102** can command the other autonomous vehicle to navigate away from the loading dock, and can also command the autonomous vehicle **108** to navigate away from the safe zone **208** in order to avoid a potential collision with the other autonomous vehicle.

[0069] In another embodiment, the controller **102** can command both the other autonomous vehicle and the autonomous vehicle **108** to cease operation and movement so that human personnel can come assess the scene.

[0070] In yet another embodiment, if a human is traversing the sensing field **206**, the controller **102** can command the autonomous vehicle **108** to navigate away from the safe zone **208** in order to avoid a potential collision with the human, or command the autonomous vehicle **108** to cease operation and movement so that it does not come into contact with the human.

[0071] Once the operation(s) with the trailer **210** have been completed by the autonomous vehicle **108**, the detector **104** can be disarmed by the controller **102**.

[0072] In another embodiment, the detector **104** is manually disarmed by human personnel after the autonomous vehicle **108** has completed its designated operation(s).

[0073] As described herein, in the event of a fault, an audit log containing data related to the fault is stored in the database **106** by the controller **102**. Such data can include the identifiers for all of the autonomous vehicles involved, the loading dock identifier, the trailer identifier, a timestamp of when the sensing field was traversed, etc., as well as manually entered data such as any damage, injury, or loss which may have occurred, and any manual remedial measures taken by human personnel. Furthermore, the audit log is historical fault data which can be accessed by the artificial intelligence engine **116** as described herein.

[0074] In another embodiment, the autonomous vehicle **108** includes a vehicle controller that performs all or some of the operations of the controller **102** described herein, such the autonomous vehicle **108** is controlled locally by the vehicle controller versus by a remote system. In this embodiment, the controller **102** and the vehicle controller may be responsible for distinct, independent functions, or alternatively, the two controllers can work in conjunction with one another where responsibilities for certain functions are shared and/or distributed between the two controllers.

[0075] For example, the vehicle controller may be responsible for verifying an armed and/or disarmed state of the detector **104**, arming and/or disarming the detector **104** during transit of the autonomous vehicle **108**, continuously verifying or monitoring the armed and/or disarmed state of the detector **104** while the autonomous vehicle **108** is within the safe zone **208** and/or the trailer **210**, ensuring that the detector **104** remains in an armed state while the autonomous vehicle **108** is within the safe zone **208** and/or the trailer **210**, and ceasing operation of the autonomous vehicle **108** in the event of a fault of the detector **104**.

[0076] Furthermore, the controller **102** may be responsible for receiving a manual arming command when the trailer **200** initially arrives at the loading dock **200**, disarming the detector **104** in the event of a fault of the detector **104**, and verifying the status of other hardware, components, and/or systems related to the loading dock **200**, such as, for example, dock levelers and locking mechanisms.

[0077] In yet another embodiment, the controller **102** is located within the autonomous vehicle **108**, and acts as both a vehicle controller as well as a controller for the monitoring system **100**.

[0078] While the principles of the disclosure have been illustrated in relation to the exemplary embodiments shown herein, the principles of the disclosure are not limited thereto and include any modification, variation, or permutation thereof.

Claims

1. A system for monitoring a loading dock, comprising: an autonomous vehicle communicatively coupled to a controller; a detector communicatively coupled to the controller, the detector located proximate to the loading dock, and the detector having an armed state and a disarmed state; a sensing field generated by the detector in the armed state; and a database communicatively coupled to the controller, wherein the controller is configured to: determine if the autonomous vehicle is permitted to operate at the loading dock by querying the database upon sensing arrival of the autonomous vehicle at the loading dock, command the detector to switch to the disarmed state from the armed state if the autonomous vehicle is permitted to operate at the loading dock, command the autonomous vehicle to traverse the sensing field such that the autonomous vehicle enters the loading dock, and command the detector to switch to the armed state from the disarmed state upon determining that the autonomous vehicle has fully traversed the sensing field.

2. The system of claim 1, wherein the detector is a light curtain.

3. The system of claim 1, wherein the controller is further configured to command the autonomous vehicle to cease operation upon sensing a fault of the detector when the detector is in the armed state.

4. The system of claim 1, wherein the autonomous vehicle is an automated forklift.

5. The system of claim 1, wherein the controller is located within the autonomous vehicle.

6. The system of claim 1, wherein the controller is located remote from the autonomous vehicle.

7. The system of claim 1, further comprising a warning system communicatively coupled to the controller.

8. The system of claim 1, wherein the controller is further configured to transmit data to the database related to at least one of (1) when the controller commands the detector to switch from the armed state to the disarmed state, (2) when the controller senses a fault of the at least one detector, and (3) when the controller commands the autonomous vehicle to cease operation.

9. The system of claim 8, wherein the data further comprises at least one of (1) an autonomous vehicle identifier, (2) a loading dock identifier, and (3) a trailer identifier.

10. A system for monitoring a loading dock, comprising: an autonomous vehicle communicatively coupled to a controller; a light curtain communicatively coupled to the controller, the light curtain located proximate to the loading dock, and the light curtain having an armed state and a disarmed state; a sensing field generated by the light curtain in the armed state; and a database communicatively coupled to the controller, wherein the controller is configured to: determine if the autonomous vehicle is permitted to operate at the loading dock by querying the database upon sensing arrival of the autonomous vehicle at the loading dock, command the light curtain to switch to the disarmed state from the armed state if the autonomous vehicle is permitted to operate at the loading dock, command the autonomous vehicle to traverse the sensing field such that the autonomous vehicle enters the loading dock, and command the light curtain to switch to the armed state from the disarmed state upon determining that the autonomous vehicle has fully traversed the sensing field.

11. The system of claim 10, wherein the light curtain comprises a transmitter and a receiver located opposite the transmitter.

12. The system of claim 10, wherein the controller is further configured to command the autonomous vehicle to cease operation upon sensing a fault of the light curtain when the light curtain is in the armed state.

13. The system of claim 10, wherein the autonomous vehicle is an automated forklift.

14. The system of claim 10, wherein the controller is located within the autonomous vehicle.

15. The system of claim 10, wherein the controller is located remote from the autonomous vehicle.

16. The system of claim 10, further comprising a warning system communicatively coupled to the controller.

17. A system for monitoring a loading dock, comprising: an autonomous vehicle communicatively coupled to a controller; a light curtain communicatively coupled to the controller, the light curtain located proximate to the loading dock, and the light curtain having an armed state and a disarmed state; at sensor communicatively coupled to the controller; a sensing field generated by the light curtain in the armed state; and a database communicatively coupled to the controller, wherein the controller is configured to: determine if the autonomous vehicle is permitted to operate at the loading dock by querying the database upon sensing arrival of the autonomous vehicle at the loading dock, command the light curtain to switch to the disarmed state from the armed state if the

autonomous vehicle is permitted to operate at the loading dock, command the autonomous vehicle to traverse the sensing field such that the autonomous vehicle enters the loading dock, and command the autonomous vehicle to cease movement if an obstacle is detected by the sensor.
18. The system of claim 17, wherein the light curtain comprises a transmitter and a receiver located opposite the transmitter.
19. The system of claim 17, wherein the sensor is located on the autonomous vehicle.
20. The system of claim 17, wherein the sensos is located remove from the autonomous vehicle.