United States Patent	12384061
Kind Code	B2
Date of Patent	August 12, 2025
Inventor(s)	Swann; Anthony L. et al.

Safeguard enclosure and method of operating an autonomous part processing system

Abstract

A safeguard enclosure of an autonomous part processing system for enclosing an autonomous guided vehicle (AGV) is provided. The safeguard enclosure includes a frame having panels defining an enclosed space. The frame has an opening allowing the AGV to enter and exit the enclosed space. The frame surrounds a parking spot for the AGV in the enclosed space. The safeguard enclosure includes a safety system for controlling operation of the AGV. The safety system includes an AGV location sensor configured to detect presence of the AGV at the parking spot. The safety system configured to control operation of the AGV based on an AGV location signal from the AGV location sensor. The safety system includes a presence sensor configured to detect presence of an object other than the AGV in the enclosed space. The safety system configured to control operation of the AGV based on an object presence signal from the presence sensor.

Inventors: **Swann; Anthony L. (Lancaster, PA), Solanki; Swapnilsinh (Harrisburg, PA), Burk; Tim (Middletown, PA), Roper; Craig S. (Mount Joy, PA)**

Applicant: **TE Connectivity Solutions GmbH** (Schaffhausen, CH)

Family ID: **1000008748935**

Assignee: **TE Connectivity Solutions GmbH (N/A, CH)**

Appl. No.: **18/159225**

Filed: **January 25, 2023**

Prior Publication Data

Document Identifier	Publication Date
US 20240246249 A1	Jul. 25, 2024

Publication Classification

Int. Cl.: **B25J19/06** (20060101); **B25J9/16** (20060101)

U.S. Cl.:

CPC **B25J19/06** (20130101); **B25J9/162** (20130101); **B25J9/1676** (20130101); **B25J9/1697** (20130101);

Field of Classification Search

CPC: B25J (19/06); B25J (9/162); B25J (9/1676); B25J (9/1697); B25J (21/00)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2012/0163953	12/2011	Murano	414/788.1	B65G 61/00
2021/0116923	12/2020	Swann	N/A	B25J 13/086
2023/0303354	12/2022	Fei	N/A	B65H 19/123
2023/0416035	12/2022	Swann	N/A	B65H 18/103

Primary Examiner: Jen; Ian

Assistant Examiner: LaRose; Renee

Background/Summary

BACKGROUND OF THE INVENTION

(1) The subject matter herein relates generally to autonomous guided vehicles.

(2) AGVs (Automatic Guided Vehicles) are becoming increasingly popular in production facilities to transport parts and materials autonomously from one location to the another one. Production facilities that utilize AGVs typically include workstations where an operator processes parts and loads the parts onto the AGVs. Such systems typically involve considerable human processing and time to load the parts. Some know AGVs have been proposed that automatically load the parts at workstations, such as using a robotic arm to pick up the parts and load the parts into the AGV. However, during use, the robotic arm moves in the space around the AGV. Such movements may lead to damage of the robotic arm if the robotic arm bumps into an object in the vicinity of the AGV during the loading process. Additionally, the robotic arm may injure human operators that are working in the vicinity of the AGV.

(3) A need remains for a system that allows safe operation of an autonomous mobile vehicle in a controlled work environment.

BRIEF DESCRIPTION OF THE INVENTION

(4) In one embodiment, a safeguard enclosure of an autonomous part processing system for enclosing an autonomous guided vehicle (AGV) is provided. The safeguard enclosure includes a frame having panels defining an enclosed space. The frame has an opening allowing the AGV to enter and exit the enclosed space. The frame surrounds a parking spot for the AGV in the enclosed

space. The safeguard enclosure includes a safety system for controlling operation of the AGV. The safety system includes an AGV location sensor configured to detect presence of the AGV at the parking spot. The safety system configured to control operation of the AGV based on an AGV location signal from the AGV location sensor. The safety system includes a presence sensor configured to detect presence of an object other than the AGV in the enclosed space. The safety system configured to control operation of the AGV based on an object presence signal from the presence sensor.

(5) In another embodiment, an autonomous part processing system is provided and includes a part processing station for processing parts. The autonomous part processing system includes an autonomous guided vehicle (AGV) movable relative to the part processing station. The AGV has a base and a platform assembly supported by the base. The base has a motor that drives wheels to move the AGV in a logistics facility. The platform assembly includes a collaborative manipulator has an arm and an end effector at an end of the arm. The end effector configured to manipulate the parts. The autonomous part processing system includes a safeguard enclosure positioned adjacent the part processing station. The safeguard enclosure enclosing the AGV when the AGV is manipulating the parts at the part processing station. The safeguard enclosure includes a frame has panels defining an enclosed space. The frame has an opening allowing the AGV to enter and exit the enclosed space. The frame surrounds a parking spot for the AGV in the enclosed space, wherein the AGV is configured to interface with the parts at the part processing station when the AGV is at the parking spot. The safeguard enclosure includes a safety system for controlling operation of the AGV. The safety system includes an AGV location sensor configured to detect presence of the AGV at the parking spot. The safety system configured to control operation of the AGV based on an AGV location signal from the AGV location sensor. The safety system includes a presence sensor configured to detect presence of an object other than the AGV in the enclosed space. The safety system configured to control operation of the AGV based on an object presence signal from the presence sensor.

(6) In a further embodiment, a method of processing parts using an autonomous guided vehicle (AGV) is provided. The method guides the AGV into a safeguard enclosure. The safeguard enclosure includes a frame that has panels defining an enclosed space surrounds a parking spot for the AGV in the enclosed space. The safeguard enclosure includes a safety system for controlling operation of the AGV. The safety system includes an AGV location sensor configured to detect presence of the AGV at the parking spot. The safety system includes a presence sensor configured to detect presence of an object other than the AGV in the enclosed space. The method controls operation of the AGV based on an AGV location signal from the AGV location sensor and controls operation of the AGV based on an object presence signal from the presence sensor.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a schematic illustration of an autonomous part processing system in accordance with an exemplary embodiment.

(2) FIG. **2** is a front perspective view of the safeguard enclosure in accordance with an exemplary embodiment showing the AGV in the safeguard enclosure.

(3) FIG. **3** is a rear view of the safeguard enclosure in accordance with an exemplary embodiment showing the AGV in the safeguard enclosure.

(4) FIG. **4** is a side view of the safeguard enclosure in accordance with an exemplary embodiment showing the AGV in the safeguard enclosure.

(5) FIG. **5** is a flowchart showing a method of processing parts using an AGV in accordance with an exemplary embodiment.

(6) FIG. **6** is a flowchart showing a method of processing parts using an AGV in accordance with an exemplary embodiment.

DETAILED DESCRIPTION OF THE INVENTION

(7) FIG. **1** is a schematic illustration of an autonomous part processing system **100** in accordance with an exemplary embodiment. The autonomous part processing system **100** is used to control movements of one or more automatic guided vehicles (AGVs) **102** within a logistics facility **104**, such as a warehouse, a distribution center, and manufacturing facility, a retail facility, and the like. The AGV **102** may be a mobile robot or autonomous mobile vehicle. In various embodiments, multiple AGVs **102** are used within the logistics facility **104** and controlled relative to each other by the autonomous part processing system **100**. The AGVs **102** are automatically controlled and used for part processing, such as part pick up, part assembly, part loading, labeling, part drop-off, and the like within the logistics facility **104**.

(8) In an exemplary embodiment, various processes may occur within a safeguard enclosure **200** at a processing station **108**. The safeguard enclosure **200** is used to protect the AGV **102** from damage and/or to prevent injury to persons working within the logistics facility. In an exemplary embodiment, the safeguard enclosure **200** includes a safety system that controls operation of the AGV **102** to restrict/allow operation under certain conditions to prevent damage and injury.

(9) In an exemplary embodiment, the AGVs **102** may be used to pick up parts **106** (for example, boxes, bins, individual parts of a product, individual products, and the like) from one or more processing stations **108**. The AGVs may be used to manipulate, form, assemble, package, or perform other processes to the parts at the processing stations **108**. The AGVs **102** may be used to deliver the parts **106** to one or more drop off stations. In various embodiments, the processing stations **108** may be manned working stations where an operator or user is stationed at the working station to perform loading, unloading, assembly, sorting or other tasks. In other various embodiments, tasks at the processing stations **108** may be performed autonomously (without human action) by one or more robots and/or by the AGVs **102**.

(10) In an exemplary embodiment, a defined parking spot **110** for the AGV **102** is provided at or adjacent to the processing station **108**. The safeguard enclosure **200** may enclose the parking spot to shield the AGV **102** when parked at the parking spot **110**. The AGV **102** navigates to the parking spot **110** and stops at the parking spot **110** for processing the parts **106**. In an exemplary embodiment, the processing station **108** includes one or more processing machines **112** that processes the parts **106**. For example, the processing machine **112** may be a sorting machine for sorting parts, a forming machine for forming parts, a molding machine for molding parts, an assembly machine for assembling parts into an assembly, a packing machine for packing the parts into a box or bin, a labeling machine for labeling the parts, and the like. In various embodiments, the processing station **108** may include multiple processing machines **112** adjacent the parking spot **110**. As such, the parts **106** from the multiple processing machines **112** may be manipulated and handled by the AGV **102** at a single stop and/or the parts **106** may undergo multiple processing steps (for example, parts may be molded, other parts may be formed, the parts may be assembled, and many parts may be packaged into a box prior to loading the box onto the AGV **102**).

(11) In an exemplary embodiment, the processing station **108** includes a call module **114**. The call module **114** is accessible to the operator to allow the operator to communicate with the autonomous part processing system **100**. The call module **114** includes a user interface **116**. The user interface **116** includes one or more activation buttons **118** configured to be activated by the operator. The operator may activate the activation buttons **118** to initiate certain operations. For example, the operator may activate the activation buttons **118** to make a call request for a part pick up by the AGV **102** at the processing station **108**. The operator may activate the activation buttons **118** upon completion of the part pick up, such as when all of the parts are loaded onto the AGV **102** to signal pick up completion and cause the AGV **102** to move out of the processing station **108**. The activation buttons **118** may include an emergency stop button to stop operation of the AGV **102**.

The activation buttons **118** may be push buttons, toggle switches, and the like. In various embodiments, the user interface **116** may be a touch screen. The user interface **116** may be a keypad or keyboard. In various embodiments, the call module **114** may be mobile, such as being worn by or carried by the operator. The call module **114** includes a communication module **115** configured to communicate with other components of the autonomous part processing system **100**. The communication module **115** may communicate wirelessly, such as via Wi-Fi.

(12) In an exemplary embodiment, the logistics facility **104** includes a docking station **120** for the AGV **102**. The docking station **120** may be used to store and or charge the AGV **102**. The docking station **120** may be provided at the processing station **108**. For example, the docking station **120** may be provided at the parking spot **110**. In an exemplary embodiment, the docking station **120** may be provided within the safeguard enclosure **200**. In other embodiments, the docking station **120** may be separate or remote from the processing station **108**. In such embodiments, a separate safeguard enclosure **200** may be provided at the docking station **120**.

(13) In an exemplary embodiment, the autonomous part processing system **100** includes a system control module **130** located within the logistics facility **104**. The system control module **130** may include a circuit board or other control circuit to control operation of the autonomous part processing system **100**. The system control module **130** may receive inputs and generate outputs to control operation of the autonomous part processing system **100**.

(14) In an exemplary embodiment, the system control module **130** includes a system communication module **132** communicatively coupled with the communication modules **115** of the call modules **114** and communicatively coupled to the AGVs **102**. The system communication module **132** may communicate wirelessly with the communication modules **115** and the AGVs **102**. The system communication module **132** may include an antenna for wireless communication. In other various embodiments, the system communication module **132** may communicate over a wired connection with the call modules **114**, such as via a communication bus.

(15) The system control module **130** is communicatively coupled to the processing stations **108** to receive requests, tasks, status signals, and the like. For example, the system control module **130** may communicate with the communication modules **115** of the call modules **114** to receive signals and requests from the call modules **114**. The system control module **130** is communicatively coupled to the AGVs **102** to control the AGVs **102** within the logistics facility **104**, such as movement of the AGVs **102** to/from the stations **108**, **110**. The system control module **130** controls movement of the AGVs **102** between the multiple stations **108**. The system control module **130** controls operations of components of the AGV **102**, such as to control collaborative manipulators of the AGVs **102**. The AGVs **102** transport the parts **106** autonomously from one location to another, such as between the stations **108** based on control signals received from the system control module **130**. In an exemplary embodiment, the system control module **130** is configured to receive manual calls or signals to perform a task at the processing stations **108**. For example, an operator or user may manually activate the activations buttons **118** to call the AGVs **102** to the corresponding processing station **108**, such as to pick up the products **106**. The products **106** may be manually loaded or automatically loaded onto the AGV **102** for removal form the processing station **108**. In an exemplary embodiment, the system control module **130** is configured to receive automated calls or signals to perform a task at the processing stations **108**. The system control module **130** controls the AGVs **102** based on the manual signals and the automated signals.

(16) In an exemplary embodiment, the system control module **130** includes one or more processors **134** for controlling the autonomous part processing system **100**. The processors **134** receive inputs, perform calculations, make operation decisions, send outputs, and the like to control operations of the components of the autonomous part processing system **100**. For example, the processors **134** may receive signals from the processing stations **108**, from the docking stations **120**, from the safeguard enclosures **200** from the AGVs **102**, and the like. The processors **134** process the signals to control the AGVs **102**. For example, the processors **134** navigate the AGVs **102** within the

logistics facility **104** between the processing stations **108**. The processors **134** may control movements or operations of components of the AGV's **102**, such as the collaborative manipulators.

(17) FIG. **2** is a front perspective view of the safeguard enclosure **200** in accordance with an exemplary embodiment showing the AGV **102** in the safeguard enclosure **200**. FIG. **3** is a rear view of the safeguard enclosure **200** in accordance with an exemplary embodiment showing the AGV **102** in the safeguard enclosure **200**. FIG. **4** is a side view of the safeguard enclosure **200** in accordance with an exemplary embodiment showing the AGV **102** in the safeguard enclosure **200**. The safeguard enclosure **200** is used to protect the AGV **102** from damage and/or to prevent injury to persons working within the logistics facility. In an exemplary embodiment, the safeguard enclosure **200** includes a safety system **202** that controls operation of the AGV **102** to restrict/allow operation under certain conditions to prevent damage and injury. The safety system **202** may be communicatively coupled to the system control module **130** (shown in FIG. **1**). Optionally, various components of the safety system **202** (for example, controllers, processors, and the like) may be part of the system control module **130**.

(18) The AGV **102** includes a base **150** and a platform assembly **160** coupled to the base **150**. The base **150** houses a motor **152** and wheels **154** driven by the motor **152** for moving the AGV **102**. The AGV **102** includes a battery **156** coupled to the motor **152** to power the motor **152**. In an exemplary embodiment, the AGV **102** includes an AGV controller **158** for controlling movement of the AGV **102**. The AGV controller **158** is operably coupled to the motor **152**. The AGV controller **158** controls operation of the motor **152** to move the AGV **102**. The AGV controller **158** is communicatively coupled to the system control module **130** and/or the safety system **202** to receive control signals for operating the AGV **102**. For example, the AGV controller **158** may receive route information to guide the AGV **102** along a particular path, such as between the processing stations **108** (shown in FIG. **1**). The AGV controller **158** may receive movement information to guide the AGV within the safeguard enclosure **200**, such as to the parking spot **110**. The AGV controller **158** may receive information instructing the AGV **102** to stop, to move forward, to move rearward, and/or to turn right or left for controlling movement of the AGV **102**.

(19) The platform assembly **160** includes a platform enclosure **162** and a collaborative manipulator **170** coupled to the top of the platform enclosure **162**. The platform enclosure **162** includes walls **164** enclosing a cavity **166**. The cavity **166** may house components of the platform assembly **160**. The cavity **166** may form a space to receive the parts **106**, such as for transport by the AGV **102**. In an exemplary embodiment, the platform assembly **160** includes a support plate **168** at a top of the platform enclosure **162**. The support plate **168** supports the collaborative manipulator **170**. The bottom of the platform enclosure **162** is mounted to the base **150** of the AGV **102**. The platform assembly **160** is moved with the AGV **102**. In an exemplary embodiment, the platform assembly **160** includes an emergency stop button (not shown) on one of the walls of the platform enclosure **162** that may be used to stop operation of the AGV **102** and/or the collaborative manipulator **170**.

(20) In an exemplary embodiment, the collaborative manipulator **170** includes a mounting base **172** that is mounted to the support plate **168**, such as using fasteners. The mounting base **172** fixes the collaborative manipulator **170** relative to the platform assembly **160**. In an exemplary embodiment, the collaborative manipulator **170** includes an arm **174** and an end effector **176** at an end of the arm **174** used for manipulating the parts **106**, such as picking up the parts **106** and moving the parts **106**. The end effector **176** may include a gripper, such as pinching fingers or vacuum grippers to hold the parts **106**. The arm **174** may be a four-axis manipulating arm or a six-axis manipulating arm in various embodiments. Other types of robot arms may be used in alternative embodiments. In other various embodiments, other types of part manipulators may be utilized rather than the end effector **176** and/or the arm **174**. For example, the collaborative manipulator **170** may include a conveyor or other type of manipulator.

(21) In an exemplary embodiment, the platform assembly **160** includes a collaborative manipulator controller **178** for the collaborative manipulator **170**. The collaborative manipulator controller **178**

controls operation of the collaborative manipulator **170**. For example, the collaborative manipulator controller **178** controls operation of the arm **174** and controls operation of the end effector **176**. The collaborative manipulator controller **178** may be contained within the platform enclosure **162**. The collaborative manipulator controller **178** is communicatively coupled to the system control module **130** and/or the safety system **202** and/or the AGV controller **158** to send control signals therebetween.

(22) In an exemplary embodiment, the collaborative manipulator controller **178** is configured to move the arm **174** and the end effector **176** to a home position. In the home position, the arm **174** and the end effector **176** may be contained within the footprint or envelope of the base **150**. For example, the arm **174** and the end effector **176** may be consolidated or folded into a compact arrangement. The collaborative manipulator **170** is moved to the home position to make the AGV **102** as small as possible to move the AGV **102**. By collapsing the collaborative manipulator **170** inward into the condensed arrangement the risk of damage to the collaborative manipulator **170** or damaging other machines or components in the logistics facility or injuring a person during moving is reduced.

(23) The safeguard enclosure **200** includes a frame **210** having panels **220** defining an enclosed space **212**. The frame **210** surrounds the parking spot **110** for the AGV **102** in the enclosed space **212**. In an exemplary embodiment, the docking station **120** is coupled to the frame **210**, such as at the parking spot **110**. The AGV **102** is configured to be docked at the docking station **120** when the AGV **102** is parked at the parking spot **110** to recharge the AGV **102**. The enclosed space **212** is large enough to allow the AGV **102** to operate without interference with the frame **210**. For example, the collaborative manipulator **170** may move in three-dimensional space without crashing into the frame **210**. The frame **210** keeps other objects and persons outside of the enclosed space **212** to prevent damage to the collaborative manipulator **170** and/or injury to the person. The safety system **202** provides safety measures to shut down operation of the AGV **102** if other objects or persons are detected within the enclosed space **212**.

(24) In an exemplary embodiment, the frame **210** includes a plurality of frame members **214** that support the panels **220**. The frame members **214** may include vertical members and horizontal members. For example, the frame members **214** may include a bottom plate, a top plate, studs, headers, Sills, cripple studs, blocks, cross-braces, and the like. The panels **220** may be coupled to the exterior surfaces of the frame members **214** and/or the interior surfaces of the frame members **214**.

(25) In various embodiments, the safeguard enclosure **200** may be rectangular having a top **230**, a front **232**, a rear **234**, a first side **236**, and a second side **238**. The bottom of the safeguard enclosure **200** may rest on the floor. The safeguard enclosure **200** may have other shapes having greater or fewer walls in alternative embodiments. The panels **220** include one or more front panels **222**, one or more rear panels **224**, one or more first side panels **226**, and one or more second side panels **228**. The panels **220** may include top panels **221**. The panels **220** prevent ingress and egress through the walls of the safeguard enclosure **200**. In an exemplary embodiment, the safeguard enclosure **200** includes an opening **216** at the front **232**. The opening **216** allows the AGV **102** to enter and exit the enclosed space **212**. Optionally, a door (not shown) may be provided to close the opening **216**. In an exemplary embodiment, the safeguard enclosure **200** includes a port **218** at the rear **234**. The port **218** may be provided at other locations in alternative embodiments, such as at the first side **236** and/or at the second side **238**. The port **218** may be located adjacent the processing station **108**. The port **218** provides access through the corresponding wall of the frame **210**, such as to allow the AGV **102** to interface with parts at the processing station **108** outside of the enclosed space **212** through the port **218**. The parking spot **110** may be located adjacent the port **218**.

(26) In an exemplary embodiment, the safeguard enclosure **200** includes a guide track **240** to guide the AGV **102** within the enclosed space **212**. In various embodiments, the guide track **240** includes rails **242** extending between the front **232** and the rear **234**. The rails **242** extend from the opening

216 to the parking spot **110**. The rails **242** define a runway for the AGV **102** to move between the opening **216** and the parking spot **110**. In an exemplary embodiment, the guide track **240** includes guide panels **244** forming a funnel **246** two laterally position the AGV **102** within the frame **210**. The guide panels **244** may be coupled to the rails **242**, such as proximate to the rear **234**. The guide panels **244** may be located at the parking spot **110** to guide the AGV **102** into the parking spot **110**. The guide panels **244** laterally position the AGV **102** between the rails **242**, such as centered between the rails **242**. As the AGV **102** moves into the safeguard enclosure **200**, the AGV **102** may engage one or more of the guide panels **244** to properly position the AGV **102** relative to the frame **210**. The guide panels **244** may engage the base **150** and/or the platform enclosure **162** of the AGV **102** to position the AGV **102** side-to-side within the guide track **240**. Other types of guide features may be used in alternative embodiments to position the AGV **102** within the enclosed space **212**.

(27) In an exemplary embodiment, the safeguard enclosure **200** includes a securing device **250** to secure the AGV **102** relative to the frame **210**. For example, the securing device **250** may interface with the AGV **102** when the AGV **102** is in the parking spot **110**. The securing device **250** may hold the AGV **102** in the parking spot **110** when the collaborative manipulator **170** is operated to interface with the parts **106**. In an exemplary embodiment, the securing device **250** includes one or more locking pins **252** that are movable between a locked position and an unlocked position. Actuators **254** are operably coupled to the locking pins **252** to move the locking pins **252** between the unlocked position and the locked position.

(28) In an exemplary embodiment, the safeguard enclosure **200** includes one or more AGV location sensors **270** configured to sense a location of the AGV **102** within the enclosed space **212**. For example, the AGV location sensor **270** may detect presence of the AGV **102** at the parking spot **110**. In various embodiments, the AGV location sensor **270** is a proximity sensor. The AGV location sensor **270** may be a non-contact safety sensor, such as a magnetic safety switch, a transponder safety switch, an inductive safety switch, and the like. The AGV location sensor **270** may be provided at the rear **234** of the frame **210**, such as proximate to the port **218**. The AGV location sensor **270** detects when the AGV **102** is located at the port **218**. The AGV location sensor **270** is configured to transmit AGV location signals, such as to the safety system **202**. For example, the AGV location sensor **270** may transmit a first signal, such as a PRESENT signal when the AGV **102** is at the parking spot **110**. The AGV location sensor **270** may transmit a second signal, such as an ABSENT signal when the AGV **102** is not detected at the parking spot **110**. In other various embodiments, no signal is sent when the AGV **102** is not detected at the parking spot **110**. Other AGV location signals may be transmitted in alternative embodiments.

(29) During operation, when the presence of the AGV **102** is detected, the securing device **250** may be operated to interface with the AGV **102** and secure the AGV **102** and the parking spot. For example, the actuators **254** may be operated when an AGV location signal is transmitted by the AGV location sensor **270**. When the presence of the AGV **102** is detected, the safety system **202** may allow the AGV **102** to operate normally, such as to allow the collaborative manipulator **170** to be utilized. However, when the presence of the AGV **102** is not detected, the safety system **202** may restrict operation of the AGV **102**, such as to restrict operation of the collaborative manipulator **170**. In various embodiments, the safety system **202** may restrict operation of the AGV **102** until the securing device **250** properly secures the AGV **102** relative to the frame **210**.

(30) In an exemplary embodiment, the safeguard enclosure **200** includes one or more presence sensors **280** configured to detect presence of an object in the enclosed space **212**. The presence sensor **280** may be used to detect presence of objects other than the AGV **102**. The presence sensor **280** may be used to detect presence of a person in the enclosed space **212**. The presence sensor **280** is configured to transmit object presence signals, such as when the object is detected and/or when no object is detected. The safety system **202** is configured to control operation of the AGV **102** based on object presence signals from the presence sensor **280**. For example, when the presence of an object is detected, the safety system **202** may restrict operation of the AGV **102**. In an

exemplary embodiment, the safety system **202** stops movement of the collaborative manipulator **170** when the presence of an object is detected. When no object is detected, the safety system **202** allows normal operation of the AGV **102**. For example, the collaborative manipulator **170** may move within the enclosed space **212** to manipulate the parts **106**.

(31) In an exemplary embodiment, the presence sensors **280** include an enclosure scanner **282** configured to scan the enclosed space **212** for objects. For example, the enclosure scanner **282** may detect movement of an object within the enclosed space **212**. The enclosure scanner **282** may be a motion sensor. Other types of scanners may be used in alternative embodiments. The enclosure scanner **282** may scan certain regions of the enclosed space **212**, such as above or below a particular height, the area of forward of the AGV **102**, or the areas to the left or right sides of the AGV **102**. The enclosure scanner **282** may intentionally avoid scanning certain regions of the enclosed space **212**, such as the region where the collaborative manipulator **170** is able to move to avoid sensing movement of the collaborative manipulator **170**. In an exemplary embodiment, the safety system **202** shuts down operation of the AGV **102** when the object is detected in the enclosed space **212**.

(32) In an exemplary embodiment, the presence sensors **280** include an opening scanner **284** configured to detect objects passing through the opening **216**. The opening scanner **284** may be a photoelectric sensor emitting one or more light beams from a light-emitting element. The photoelectric sensor may be a reflective type photoelectric sensor that detects the light beam when reflected from the object passing through the opening **216**. The photoelectric sensor may be a through beam type sensor used to measure a change in light quality caused by an object crossing the optical axis. In other various embodiments, the opening scanner **284** may be a light curtain sensor used to detect the object passing through the opening **216**. Other types of scanners or sensors may be used to detect objects within the opening **216**. In an exemplary embodiment, the safety system **202** shuts down operation of the AGV **102** when the object is detected in the opening **216**.

(33) In an exemplary embodiment, the safeguard enclosure **200** includes an AGV detection sensor **260** at the opening **216** or within the enclosed space **212** to detect presence of the AGV **102**. The AGV detection sensor **260** may disable the presence sensors **280**, such as the enclosure scanner **282** and/or the opening scanner **284**, when the AGV **102** is moving into and out of the enclosed space **212**. As such, the safety system **202** does not improperly shut down the AGV **102** while the AGV **102** is moving through the opening **216** or the enclosed space **212** between the opening **216** and the parking spot **110**. The AGV detection sensor **260** may disable the presence sensors **280** for a predetermined period of time to allow maneuvering of the AGV **102** into or out of the enclosed space **212**.

(34) In an exemplary embodiment, the safeguard enclosure **200** includes a vision system **290** to control operation of the AGV **102**. The vision system **290** includes one or more imaging devices **292** configured to image the AGV **102**, such as at the parking spot **110**. In the illustrated embodiment, the imaging device **292** is provided at the top **230** of the frame **210**. Other locations are possible in alternative embodiments. The vision system **290** may be configured to control operation of the AGV **102** based on the images from the imaging device **292**. For example, the AGV **102** may be positioned (operation of the wheels) relative to the frame **210** using the images from the imaging device **292**. In an exemplary embodiment, the collaborative manipulator **170** is controlled using the images from the imaging device **292**. For example, the arm **174** and/or the end effector **176** may be operated based on the images. The images may detect a position of the end effector **176** and a position of the part **106** to move the arm **174** and/or the end effector **176** to manipulate the part **106**.

(35) FIG. **5** is a flowchart showing a method of processing parts using an AGV in accordance with an exemplary embodiment. The flowchart shows a method of operating the AGV in a normal mode of operation **500**, in a safe mode of operation **502**, and an emergency stop mode of operation **504**.

The method may be performed by a controller, such as the system control module. The safety system of the safeguard enclosure may provide inputs to the system control module to control operation of the AGV.

(36) Operation of the AGV begins at step **506**. The operation may begin by powering on the AGV. The operation may begin by resetting the system to begin operation of the AGV. For example, a reset button or power on button may be pressed by an operator to begin the operation of the AGV.

(37) At **510**, the system determines if the AGV is moving. The AGV controller may communicate with the system control module to determine if the AGV is moving. For example, the system may determine if the wheels of the AGV are rotating. Alternatively, the system may use a GPS system to determine if the AGV is moving. In other various embodiments, the system may use motion sensors to determine if the AGV is moving. If the AGV is moving, at **512**, the system determines if the robotic arm of the collaborative manipulator is at the home position. The collaborative manipulator controller may send a signal to the system control module indicating the status or position of the collaborative manipulator. If the robotic arm is at the home position, the AGV is safe to move and thus the process continues in the AGV may continue normal operation. If the robotic arm is not at the home position, the system control module enters the emergency stop mode of operation **504** and shuts down the AGV. Because it may be unsafe for the AGV to move when the robotic arm is not in the home position, the system control module shuts down the AGV and does not allow the AGV to move until the system can be reset. For example, the robotic arm needs to be reset to the home position in the reset button on the AGV can then be pressed to restart the system at step **506**.

(38) Returning to step **510**, if the system determines that the AGV is not moving, the system then determines **514** if the AGV is at the docked position at the parking spot. If the AGV is not at the docked position, the system control module enters the safe mode of operation **502**. In the safe mode of operation, the AGV has restricted operation. For example, in the safe mode of operation, the AGV is able to move (for example, wheels can move); however, the robotic arm of the collaborative manipulator is restricted from movement. As such, the system control module is able to move the AGV to the docked position but the robotic arm of the collaborative manipulator is unable to perform tasks or move until the AGV is in the docked position. If, at step **514**, the system determines that the AGV is in the docked position, the system then determines **516** if the AGV is secured within the safeguard enclosure at the parking spot. For example, the system determines if the securing device of the safeguard enclosure interfaces the AGV. The system may determine that the locking pins securely couple the AGV to the frame of the safeguard enclosure to restrict movement of the AGV from the parking spot. If the AGV is not secured, the system control module enters the safe mode of operation **502** and allows the AGV to have restricted operation. However, if the AGV is secured, the system control module enters the normal mode of operation **500** and allows the AGV to perform the designated tasks. For example, the system may power on the robotic arm and allow the collaborative manipulator to operate normally to perform the tasks.

(39) The method of operation described herein allows safe operating of the AGV to reduce risk of damage to the collaborative manipulator, to reduce risk of damage to other machines or components, and to reduce risk of injury to human operators. The method of operation described herein limits or restricts movement of the robotic arm of the collaborative manipulator to a situation in which the AGV is safely and securely positioned within the safeguard enclosure.

(40) In an exemplary embodiment, the system includes multiple safeguards to shut down the AGV in unsafe situations. For example, at **520**, when an emergency stop button is pressed, the system control module enters the emergency stop mode of operation **504**. The emergency stop button may be provided on the AGV, within the safeguard enclosure, at one of the processing machines, or at the system control module. In other various embodiments, at **522**, if an unsafe condition is encountered within the safeguard enclosure, the system determines **524** if the power is on at the collaborative manipulator. If the power is on, the system control module enters the emergency stop

mode of operation **504**. However, if the power is off, the system may allow restricted operation of the AGV, such as to allow the AGV to move but to restrict movement of the collaborative manipulator. Unsafe conditions within the safeguard enclosure may be encountered when an object or person enter the enclosed space of the safeguard enclosure. For example, presence sensors are provided within the safeguard enclosure to monitor for objects or persons entering the enclosed space. If such objects or persons are identified within the enclosed space, it may be desirable to restrict or cease operation of the AGV to prevent damage or injury and thus the system may enter the emergency stop mode of operation **504**.

(41) FIG. **6** is a flowchart showing a method of processing parts using an AGV in accordance with an exemplary embodiment. The flowchart shows a method of operating the AGV in a normal mode of operation **600** and in an emergency stop mode of operation **604**. The method may be performed by a controller, such as the system control module. The safety system of the safeguard enclosure may provide inputs to the system control module to control operation of the AGV.

(42) Operation of the AGV begins at step **606**. The operation may begin by powering on the AGV. The operation may begin by resetting the system to begin operation of the AGV. For example, a reset button or power on button may be pressed by an operator to begin the operation of the AGV. Various processes may be performed in series or in parallel by the system control module as the AGV is operating.

(43) At **610**, the system determines if the AGV is at a first entry position to the opening of the safeguard enclosure. The first entry position may be located outside of the safeguard enclosure, such as adjacent the opening to the safeguard enclosure. The AGV may be at the first entry position to enter the safeguard enclosure through the opening. If the AGV is at the first entry position, the system determines **612** if the AGV is entering the safeguard enclosure. For example, the system may determine if the AGV is moving toward the opening to enter the safeguard enclosure. If the AGV is entering the safeguard enclosure, at step **614**, the system disables the light curtain. The light curtain is provided at the opening. The light curtain is disabled to allow the AGV to pass through the opening without triggering the emergency stop mode of operation. Returning to the decision at **612**, if the system determines that the AGV is not entering the safeguard enclosure (for example, the AGV is stationary or moving away from the opening), at step **616**, the system enables the light curtain. The light curtain is enabled as a safety feature for the safeguard enclosure, such as to detect objects or persons entering the safeguard enclosure through the opening.

(44) At **620**, the system determines if the AGV is at a second entry position to the opening of the safeguard enclosure. The second entry position may be located inside of the safeguard enclosure, such as adjacent the opening to the safeguard enclosure. The AGV may be at the second entry position to exit the safeguard enclosure through the opening. If the AGV is at the second entry position, the system determines **622** if the AGV is exiting the safeguard enclosure. For example, the system may determine if the AGV is moving toward the opening to exit the safeguard enclosure. If the AGV is exiting the safeguard enclosure, at step **614**, the system disables the light curtain. The light curtain is disabled to allow the AGV to pass through the opening without triggering the emergency stop mode of operation. Returning to the decision at **622**, if the system determines that the AGV is not exiting the safeguard enclosure (for example, the AGV is stationary or moving away from the opening), at step **616**, the system enables the light curtain. The light curtain is enabled as a safety feature for the safeguard enclosure, such as to detect objects or persons entering the safeguard enclosure through the opening.

(45) At **630**, the system determines if the AGV is at the dock position at the parking spot. If the AGV is not at the dock position, the system continues to monitor the location of the AGV. If the AGV is in the dock position, the system activates **632** the securing device of the safeguard enclosure to interface with the AGV. For example, the system actuates the locking pins to engage the age of the and secure the AGV relative to the frame of the safeguard enclosure. Once the securing device is secured, the system control module enters the normal mode of operation **600** and

allows the AGV to perform the designated tasks. For example, the system may power on the robotic arm of the collaborative manipulator and allow the collaborative manipulator to operate normally to perform the tasks.
(46) The method of operation described herein allows safe operating of the AGV to reduce risk of damage to the collaborative manipulator, to reduce risk of damage to other machines or components, and to reduce risk of injury to human operators. The method of operation described herein limits or restricts movement of the robotic arm of the collaborative manipulator to a situation in which the AGV is safely and securely positioned within the safeguard enclosure and other objects or persons are outside of the enclosed space of the safeguard enclosure.
(47) In an exemplary embodiment, the system includes multiple safeguards to shut down the AGV in unsafe situations. For example, at **640**, when an emergency stop button is pressed, the system control module enters the emergency stop mode of operation **604**. The emergency stop button may be provided on the AGV, within the safeguard enclosure, at one of the processing machines, or at the system control module. In other various embodiments, the system monitors the safeguard enclosure for unsafe conditions, such as objects or persons entering or within the enclosed space. At **650**, the system determines if an object or person is present at the opening. For example, the light curtain monitors for objects or persons passing through the opening. When an object or person is detected, the system control module enters the emergency stop mode of operation **604**. If such objects or persons are identified, it may be desirable to restrict or cease operation of the AGV to prevent damage or injury and thus the system may enter the emergency stop mode of operation **604**. At **660**, the system determines if an object or person is present within the enclosed space of the safeguard enclosure. For example, scanners or other monitoring devices are used to scan for objects or persons within the enclosed space. In various embodiments, motion detectors may be used to identify objects or persons within the enclosed space. If such objects or persons are identified, the system control module enters the emergency stop mode of operation **604**.
(48) It is to be understood that the above description is intended to be illustrative, and not restrictive. For example, the above-described embodiments (and/or aspects thereof) may be used in combination with each other. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from its scope. Dimensions, types of materials, orientations of the various components, and the number and positions of the various components described herein are intended to define parameters of certain embodiments, and are by no means limiting and are merely exemplary embodiments. Many other embodiments and modifications within the spirit and scope of the claims will be apparent to those of skill in the art upon reviewing the above description. The scope of the invention should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms “including” and “in which” are used as the plain-English equivalents of the respective terms “comprising” and “wherein.” Moreover, in the following claims, the terms “first,” “second,” and “third,” etc. are used merely as labels, and are not intended to impose numerical requirements on their objects. Further, the limitations of the following claims are not written in means-plus-function format and are not intended to be interpreted based on 35 U.S.C. § 112(f), unless and until such claim limitations expressly use the phrase “means for” followed by a statement of function void of further structure.

Claims

1. A safeguard enclosure of an autonomous part processing system for enclosing an autonomous guided vehicle (AGV), the safeguard enclosure comprising: a frame having panels defining an enclosed space, the frame having an opening allowing the AGV to enter and exit the enclosed space, the frame surrounding a parking spot for the AGV in the enclosed space; and a safety system for controlling operation of the AGV, the safety system including an AGV location sensor

configured to detect presence of the AGV at the parking spot, the safety system configured to control operation of the AGV based on an AGV location signal from the AGV location sensor, the safety system including a presence sensor configured to detect presence of an object other than the AGV in the enclosed space, the safety system configured to control operation of the AGV based on an object presence signal from the presence sensor, wherein the safety system allows normal operation of the AGV when presence of the AGV at the parking spot is detected by the AGV location sensor.

2. The safeguard enclosure of claim 1, wherein the panels include a front panel, a rear panel, a first side panel between the front and rear panels, and a second side panel between the front and rear panels, the front panel, the rear panel, the first side panel, and the second side panel surrounding the enclosed space on four sides.

3. The safeguard enclosure of claim 1, wherein the safety system stops operation of the AGV when the object is detected.

4. The safeguard enclosure of claim 3, wherein the safety system allows normal operation of the AGV when no object is detected.

5. The safeguard enclosure of claim 1, wherein the safety system restricts operation of the AGV when no presence of the AGV is detected by the AGV location sensor.

6. The safeguard enclosure of claim 1, wherein the presence sensor includes an enclosure scanner configured to detect the object within the enclosed space.

7. The safeguard enclosure of claim 1, wherein the presence sensor includes an opening scanner configured to detect the object passing through the opening.

8. The safeguard enclosure of claim 1, wherein the presence sensor is deactivated when the AGV moves between the opening and the parking spot.

9. The safeguard enclosure of claim 1, wherein the AGV location sensor includes a proximity sensor.

10. The safeguard enclosure of claim 1, further comprising a locking pin coupled to the frame, the locking pin being actuated to engage the AGV and secure a position of the AGV at the parking spot, the safety system being operably coupled to the locking pin and causing the locking pin to move to a locked position based on the AGV location signal from the AGV location sensor.

11. The safeguard enclosure of claim 1, wherein the frame further comprises a guide track extending between the opening in the parking spot to guide the AGV between the opening and the parking spot.

12. The safeguard enclosure of claim 1, further comprising a vision system having an imaging device configured to image the AGV at the parking spot, the vision system configured to control operation of the AGV based on images by the imaging device.

13. The safeguard enclosure of claim 1, wherein the safety system further comprises an emergency stop button, the safety system configured to control operation of the AGV based on an emergency stop signal from the emergency stop button.

14. The safeguard enclosure of claim 1, wherein the frame includes a port through one of the panels, the parking spot located adjacent the port to allow the AGV to interface with parts at a part processing station outside of the enclosed space through the port.

15. The safeguard enclosure of claim 1, wherein the safety system includes a communication module having an antenna configured to wirelessly communicate with the AGV to control operation of the AGV.

16. An autonomous part processing system comprising: a part processing station for processing parts; an autonomous guided vehicle (AGV) movable relative to the part processing station, the AGV having a base and a platform assembly supported by the base, the base having a motor driving wheels to move the AGV in a logistics facility, the platform assembly including a collaborative manipulator having an arm and an end effector at an end of the arm, the end effector configured to manipulate the parts; and a safeguard enclosure positioned adjacent the part

processing station, the safeguard enclosure enclosing the AGV when the AGV is manipulating the parts at the part processing station, the safeguard enclosure including a frame having panels defining an enclosed space, the frame having an opening allowing the AGV to enter and exit the enclosed space, the frame surrounding a parking spot for the AGV in the enclosed space, wherein the AGV is configured to interface with the parts at the part processing station when the AGV is at the parking spot, the safeguard enclosure including a safety system for controlling operation of the AGV, the safety system including an AGV location sensor configured to detect presence of the AGV at the parking spot, the safety system configured to control operation of the AGV based on an AGV location signal from the AGV location sensor, the safety system including a presence sensor configured to detect presence of an object other than the AGV in the enclosed space, the safety system configured to control operation of the AGV based on an object presence signal from the presence sensor, wherein the safety system prevents operation of the collaborative manipulator based on an AGV location signal from the AGV location sensor and based on an object presence signal from the presence sensor.

17. A method of processing parts using an autonomous guided vehicle (AGV), the method comprising: guiding the AGV into a safeguard enclosure, the safeguard enclosure including a frame having panels defining an enclosed space surrounding a parking spot for the AGV in the enclosed space, the safeguard enclosure including a safety system for controlling operation of the AGV, the safety system including an AGV location sensor configured to detect presence of the AGV at the parking spot, the safety system including a presence sensor configured to detect presence of an object other than the AGV in the enclosed space; controlling operation of the AGV based on an AGV location signal from the AGV location sensor by restricting operation of the AGV when no presence of the AGV is detected by the AGV location sensor and allowing normal operation of the AGV when presence of the AGV at the parking spot is detected by the AGV location sensor; and controlling operation of the AGV based on an object presence signal from the presence sensor by restricting operation of the AGV when the object is detected and allowing normal operation of the AGV when no object is detected.

18. The safeguard enclosure of claim 1, wherein the safety system prevents operation of the collaborative manipulator based on an AGV location signal from the AGV location sensor and based on an object presence signal from the presence sensor.

19. The autonomous part processing system of claim 16, wherein the safety system restricts operation of the AGV when no presence of the AGV is detected by the AGV location sensor.

20. The autonomous part processing system of claim 16, wherein the safety system allows normal operation of the AGV when presence of the AGV at the parking spot is detected by the AGV location sensor.