A system includes a glove, sensors, actuator assemblies, and controller. The sensors include load sensors which measure an actual grasping force and attitude sensors which determine a glove attitude. The actuator assembly provides a grasp assist force to the glove. Respective locations of work cells in the work environment and permitted work tasks for each work cell are programmed into the controller. The controller detects the glove location and attitude. A work task is selected by the controller for the location. The controller calculates a required grasp assist force using measured actual grasping forces from the load sensors. The required grasp assist force is applied via the glove using the actuator assembly to thereby assist the operator in performing the identified work task.

18 Claims, 2 Drawing Sheets
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GRASP ASSIST DEVICE WITH AUTOMATIC MODE CONTROL LOGIC

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

This invention was made with government support under NASA Space Act Agreement number SAA-AI-07-003. The invention described herein may be manufactured and used by or for the U.S. Government for U.S. Government (i.e., non-commercial) purposes without the payment of royalties thereon or therefor.

TECHNICAL FIELD

The present disclosure relates to a grasp assist device with automatic mode control logic.

BACKGROUND

Ergonomics is an evolving scientific discipline that ultimately seeks to understand and improve human interactions with the various pieces of equipment used within a work environment, such as keyboards, workstations, torque wrenches, control input devices, and the like. Modern ergonomic design practices seek to optimize all aspects of an operator’s physical work environment. Even so, repetitive motion may adversely affect product quality and process efficiency over time.

For some types of repetitive tasks requiring application of a grasping force by an operator to a tool or other object, the operator’s grip strength may gradually decline over the course of a work day. Grip strength can also vary widely between different operators performing the same work tasks, e.g., due to differences in strength, physical stature, or muscle fatigue. The variable nature of a given operator’s grip strength may result in relatively inefficient execution of certain grasp-related work tasks in a work environment.

SUMMARY

A system and an associated control method are disclosed herein for a grasp assist device, such as a glove-based grasp assist device of the type generally known in the art. The range of possible work tasks for a given work environment may vary from relatively coarse actions such as heavy lifting and positioning of a relatively large object, for instance a vehicle wheel, to finer actions such as positioning and installing fasteners. As such, existing control schemes for conventional grasp assist devices, which typically require manual determination and selection of an appropriate control mode by an operator using a user interface, may be less than optimal when used in certain types of work environments. The present design is therefore intended to address some of these performance concerns by offloading the grasp assist mode selection decision process and implementation from the operator to an onboard controller.

The grasp assist device disclosed herein adds a sensor array and associated control logic to help improve the performance of prior art grasp assist devices. The sensor array enables the controller to automatically locate the grasp assist device within a work environment and determine a location of an operator wearing the grasp assist device. The sensors in the array also detect an attitude of the grasp assist device, for example pitch, roll, yaw, acceleration, magnetic field, and/or general orientation of various portions of the device. Collectively, the location and attitude data allow the controller, with minimal required input from the operator, to automatically select an appropriate grasp control mode that is suitable for the work task at hand. Optional features may be programmed into the controller such as a calibration mode and an on/off gesture detection mode as set forth herein to further optimize performance of the grasp assist device.

The operator may wear a glove portion of the present grasp assist device on a hand. In such an embodiment, multiple flexible tendons are selectively tensioned with a calculated tensile force by a corresponding actuator assembly, for example a motorized ball screw. The actuator assembly applies tension to one or more of the tendons to help close the operator’s hand into a predetermined grasp pose. Load sensors positioned on the finger and thumb portions or other surfaces of the glove collectively provide force feedback signals to the controller. The controller then calculates and commands a required tensile force from the various tendons at levels that depend on the particular work task being performed by the operator. All of this occurs in conjunction with the location- and attitude-based automatic control mode selection described herein.

In general, as an operator moves through a facility wearing the grasp assist device, the controller automatically identifies the operator’s location/heading and a target work cell, either via measurement/detection or calculation, and thereafter automatically restricts operation of the grasp assist device to a subset of permitted work tasks, for instance by automatically selecting from a global list of predetermined work tasks programmed into the controller’s memory. GPS or RFID sensors are possible example location sensors usable as part of the sensor array, when location is detected, to provide the required location/heading data to the controller. Within the work cell itself, the attitude sensors collectively determine the attitude of the glove or other portion of the grasp assist device, e.g., using joint angle sensors and/or accelerometers positioned on various surfaces of the grasp assist device. Thereafter, the controller closely restricts permitted functions of the grasp assist device to a particular work task or tasks selected by the controller from the restricted list of predetermined work tasks.

The location and/or the attitude of the grasp assist device can also be used to turn the grasp assist functionality on or off as needed, such as when the operator steps out of the work cell into an adjacent walkway, a break area, or another designated area in which operation of the grasp assist device is not desirable, and/or when the operator moves the grasp assist device with a predetermined gesture signaling a desire to temporarily discontinue or disable grasp assist functionality regardless of location.

In some embodiments, a mobile or static data display device in communication with the controller can receive and display information in a manner that is dependent upon where the operator is in the facility. For example, the display device may present a build schedule or other build information, work steps, production cues, and the like.

In particular, a system as set forth herein includes a glove, an array of sensors, an actuator assembly, and a controller. The sensors are positioned with respect to the glove, and include load sensors which measure an actual grasping force applied to an object by the operator while wearing the glove, and attitude sensors which collectively determine an attitude of the glove, and which may be used to determine the location alone and/or with optional location sensors. The actuator assembly or assemblies are operable for providing a grasp assist force to the glove.
The controller is programmed with a set of coordinates for work cells in the work environment, and also with a set of permitted work tasks for each of the work cells. The controller is further programmed to detect a location of the operator within the work environment and an attitude of the glove within the detected location. Additionally, the controller selects a work task from a list of permitted work tasks for the detected location using the determined location and attitude, and receives a measured actual grasping force via the load sensors. The controller then calculates a grasp assist force suitable for assisting in performing of the identified work task using the measured grasping force and automatically selects and applies the required grasp assist force to the glove via the actuator assembly. In this manner, the operator is assisted in performing the identified work task.

An associated method is also disclosed. In a possible embodiment, the method includes the steps of determining the location of the operator and then determining the attitude of the glove within the determined location using the attitude signals. The method also includes identifying a work task from a list of permitted work tasks for the determined location using the determined location and attitude, measuring an actual grasping force applied by the operator to an object via the load sensors, and calculating the required grasp assist force for the identified work task using the measured actual grasping force. Thereafter, the method includes commanding application of the required grasp assist force to the glove via the actuator assembly using the controller to thereby assist the operator in performing the identified work task.

The above-described and other features and advantages of the present disclosure are readily apparent from the following detailed description of the best modes for carrying out the disclosure when taken in connection with the accompanying drawings.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a schematic illustration of an example grasp assist device and an associated controller configured to automatically control mode selection of the grasp assist device as set forth herein.

FIG. 2 is a schematic illustration of an operator wearing the grasp assist device of FIG. 1 while moving within an example work environment having multiple designated work task areas.

FIG. 3 is a schematic logic flow diagram describing the programmed mode selection operation of the controller of FIG. 1.

FIG. 4 is a flow chart describing an example method for controlling the grasp assist device shown in FIG. 1.

**DETAILED DESCRIPTION**

With reference to the drawings, wherein like reference numbers refer to the same or similar components throughout the several views, an example grasp assist device 10 is shown in FIG. 1 having a controller 50. The grasp assist device 10 may include a glove 12 and a sleeve 18. When the grasp assist device 10 is worn on a hand and forearm of an operator, the device automatically assists the operator in grasping an object and/or performing any number of manual work tasks. The range of possible work tasks in a given work environment may vary from relatively coarse actions such as heavy lifting or general positioning of relatively large objects such as vehicle wheels to fine motor skills such as locating and installing fasteners or supporting body panels during an installation process.

Existing control schemes used for conventional grasp assist devices may be less than optimal in facilities having a large variety of work tasks divided into different work cells, as such designs tend to require a mode decision and affirmative selection by an operator. For example, an operator may be required to alert a controller as to the particular task to be performed, or select a desired grasp assist level, or the grasp assist device may be programmed to provide only a limited range of predetermined grasp assist levels. The present design is intended to address this control problem by offloading the control decision to the controller in cooperation with a sensor array as described herein, and to thereby optimize operator efficiency when performing device-assisted work tasks.

Apart from the automatic control functionality described below with reference to FIGS. 2-4, which utilizes control signals from a location sensor 78 and a plurality of attitude sensors 88 shown at example locations in FIG. 1, or derives location from the attitude sensors 88 while forgoing use of the location sensor 78 in another embodiment, the controller 50 also calculates and applies an assisting tensile force (arrow F_a) to one or more flexible tendons 20, as is well known in the art. A tendon drive system (TDS) 16 contained fully or partially within the sleeve 18 and linked to the glove 12 via the tendon(s) 20 may be used for such a purpose, with the assisting tensile force (arrow F_a) applied to some or all of the flexible tendons 20 in response to force feedback signals (arrow 24) received by the controller 50 from one or more load sensors 28 positioned with respect to the glove 12.

Such load sensors 28 are indicated in FIG. 1 as stars for illustrative clarity. The locations and/or numbers of the load sensors 28 may vary from those shown in FIG. 1 and therefore are not limited to fingertip placement as shown.

The glove 12 may include one or more digit portions, i.e., a thumb portion 14 and/or one or more finger portions 15. The glove 12 may be configured as a conventional full four-finger/one thumb glove as shown, or with fewer fingers 15/no thumb 14 in other embodiments. Connected to material 17 of the glove 12, for example sewn in place, may be a plurality of phalange rings 26 or another suitable load bearing structure. Each of the phalange rings 26 may at least partially circumscribe a digit of the operator’s hand, i.e., by at least partially circumscribing a respective one of the thumb portion 14 or finger portions 15 of the glove 12. Alternatively, the phalange rings 26 may be positioned within the thumb portion 12/finger portions 15. Thus, any tensile force (arrow F_a) imparted by some or all of the tendons 20 can indirectly act on an operator’s actual fingers/thumb through the phalange rings 26.

The load sensors 28 shown in FIG. 1 may be positioned with respect to the glove 12 such as at a medial (arrow Md) portion or distal end (arrow D) of the thumb portion 14 and/or the finger portions 15, or alternatively on a palm of the glove 12. Only one load sensor 28 may be used in an alternative embodiment. The location sensor 78 and the attitude sensor(s) 88 may be disposed on one or more of the thumb portion 14 and/or the finger portions 15, or the palm, with the load sensors 28, the location sensor 78, and the attitude sensor(s) 88 collectively forming a sensor array of the grasp assist device 10.

Within the sensor array, the load sensors 28 are used to signal a desired grasp/grasp release, and to trigger a corresponding controlled application or discontinuation of the tensile force (arrow F_a) as noted above. The location sensor 78 is used to detect a present location and also calculate a
direction or heading of the grasp assist device 10 in a work cell as needed, as set forth below with reference to FIG. 2, and to further restrict the range of allowable control modes for a given work cell. The attitude sensor(s) 88 in turn are used by the controller 50 to select from the restricted list of allowed work tasks for the operator’s present work cell, and to possibly execute other control modes including a calibration mode and an on/off mode as described below with reference to FIG. 3.

Examples of the attitude sensors 88 include any wireless location positioning sensors, transceivers, receivers, or devices operable to determine an orientation or pose of the grasp assist device 10 within an inertial frame of reference, and/or for determining the location of the glove 12 when a dedicated location sensor 78 is not used, for instance joint angle sensors, gyroscopes, digital compasses, accelerometers, altimeters, magnetometers, and the like. Such devices may include multi-axis motion tracking chip-based devices of the types known in the art for use in smartphones and wearable sensors. For instance, magnetometers may be used to determine orientation of the glove 12 with respect to earth’s magnetic field, as is known in the art, and when used in conjunction with accelerometers can help eliminate drift from any derived location when locations sensors 78 are not used. More or fewer attitude sensors 88 may be used in a given design relative to the number shown in FIG. 1. Likewise, the locations of the attitude sensors 88 may vary. In an example configuration, a respective joint angle sensor may be positioned at the wrist and finger/thumb portions of the glove 12, and one or more accelerometers may be positioned on the glove 12.

With respect to the optional location sensor(s) 78, a radio frequency identification (RFID) sensor system may be used in one possible approach. As is well known in the art, typical RFID sensors suitable for indoor use include wireless RFID tags and antennas. When used with the grasp assist device 10 of FIG. 1, the attitude sensors 88 may be embodied as such RFID tags, with the required location information transmitted to or from the RFID tags by way of fixed antennas, e.g., one per work cell, to thereby alert the controller 50 to the present position of the device 10. When configured as an alternative global positioning system (GPS) device, the location sensor 78 may be embodied as a GPS receiver communicating with a navigation satellite (not shown) so as to determine the geospatial coordinates of an operator wearing the grasp assist device 10. The use of GPS receivers in an indoor facility, however, may be less than optimal due to the presence of a roof and walls, which can interfere with GPS signals. As noted above, the function of the location sensor 78 may be provided by some or all of the attitude sensors 88, e.g., by deriving the location of the glove 12 from the attitude sensors 88 as based on changes in the values of the attitude signals (arrow AJ and an attitude sensor(s) 88).

In general, a grasp force exerted on an object in the operator’s grasp activates the load sensor(s) 28. The phalanx rings 26 in turn are connected to the tendons 20 that run through the phalanx rings 26, with at least some of the phalanx rings 26 acting as guides for the tendons 20. Two types of phalanx rings 26 may be provided herein: the phalanx rings positioned at the distal end (arrow D) of each finger portion 15 and thumb portion 14, and respective medial (arrow Md) and proximal (arrow Pr) phalanx rings 26. In some embodiments, the tendons 20 may terminate at the distal (arrow D) phalanx rings 26, while the medial (arrow Md) and proximal (arrow Pr) phalanx rings 26 are primarily used to guide or direct the tendons 20 and to support the operator’s finger. However, other configurations may be envisioned within the intended inventive scope.

The load sensors 28 may be optionally configured as a braided polymer, e.g., fluorocarbon, to increase the wear life of each tendon 20. However, other materials and/or designs may also be used without departing from the intended scope of the invention. The tendons 20 may pass through an optional tendon concentrator 21 located on or near the base of the palm or wrist area of the operator. The tendons 20 run through the conduit 30 for at least part of the lengths of the tendons 20, and freely between the tendon concentrator 21 and the phalanx rings 26. This arrangement may help isolate the grasping assist motion to the area on the operator’s hand from the fingertips to the base of the operator’s palm, i.e., isolate the effect of any augmenting tensile force to the area between the tendon concentrator 21 and the phalanx rings 26. From the finger side of the tendon concentrator 21 to the distal phalanx rings 26, the tendons 20 may be contained in channels embedded or contained within the material of the glove 12.

As shown in phantom, multiple actuator assemblies 32, for instance motorized ball screw devices, may be configured in an array within the TDS 16. Each actuator assembly 32 acts on a portion of a corresponding flexible tendon 20. While not shown for illustrative simplicity, a tendon 20 may loop through a nut within a given one of the actuator assemblies 32 so that the tendon 20 can slide freely, with ends of the tendons 20 attached, for example, to different finger portions 15. In such a design, as one finger portion 15 grasps or comes in contact with an object, the tendon 20 will slide through the nut so that the other finger portion 15 can continue to grasp or close. Thereafter, the actuator assembly 32 can apply a grasping force to both finger portions 15. Other tendon-driven designs may be envisioned, as well as drive systems that do not use tendons, without departing from the intended scope. When only one TDS 16 is used, the tendon concentrator 21 may be used to connect the flexible tendons 20 leading from a thumb portion 14 and each finger portion 15 to a single actuator tendon, i.e., the flexible tendon shown via solid lines in FIG. 1. In this case, the tendon concentrator 21 provides an area for the multiple flexible tendons 20 to be connected to a single tendon.

Still referring to FIG. 1, the actuator assembly 32 may include a servo motor 34 and a drive assembly 36, e.g., a ball screw-type linear actuator device according to one possible embodiment. Operation of the TDS 16 is provided via the
controller 50, which draws any required power from an energy supply (E) 40. The energy supply 40 may be configured as a miniature battery pack, e.g., a lithium ion cell or other relatively lightweight or low-mass energy storage device. An optional sleeve display 42 may be connected to the sleeve 18 and placed in communication with the controller 50 to display a controller-selected selected control mode. The sleeve display 42 may be a small operator-accessible control panel, touchpad, or touch screen allowing an operator to view a particular mode of operation or other message.

The controller 50 may include one or more integrated circuits, which may be augmented by various electronic devices such as voltage regulators, capacitors, drivers, timing crystals, communication ports, etc. The controller 50 may be a microcontroller having a processor and memory, e.g., optical or magnetic read only memory (ROM), as well as sufficient amounts of random access memory (RAM) and/or electrically-programmable read only memory (EPROM), input/output (I/O) circuitry, signal conditioning and buffer electronics, and the like. Output signals (arrow 13) may be transmitted to an optional static or mobile display screen 45 (see FIG. 2) to communicate detailed task-related information to the operator in the performance of a given work task.

Referring to FIG. 2, an example work environment 60 is shown schematically as having three different work cells WC_A, WC_B, and WC_C defined by boundaries 19, 190, 290, and 500. As is typical of manufacturing facility layouts, the work cells WC_A, WC_B, and WC_C may be located adjacent to a walkway 21, i.e., a demarcated corridor a walkway along an operator 11 can freely move. The work cell WC_A may be separated from the work cell WC_B by an inner boundary 390. Similarly, work cell WC_B may be separated from work cell WC_C by an inner boundary 490.

The boundaries 19, 190, 290, 390, 490, and 590 may be real or imaginary. For example, while walls or other solid physical barriers may be used to separate the work cells WC_A, WC_B, and WC_C from each other and from the walkway 21, the boundaries 19, 190, 290, 390, 490, and 590 may simply denote defined imaginary perimeters of the work cells WC_A, WC_B, and WC_C. In either case, the coordinates of each of the boundaries 19, 190, 290, 390, 490, and 590 may be programmed into memory M of the controller 50 of FIG. 1 and thus are known by the controller 50.

As the operator 11 wearing the grasp assist device 10 moves within the work environment 60 of FIG. 2, the controller 50 is continuously updated as to the location and heading of the operator 11 primarily via operation of the location sensor 78 of FIG. 1. Therefore, while the operator 11 is traveling along the walkway 21 or is otherwise not present in any of the work cells WC_A, WC_B, or WC_C, the controller 50 may maintain the grasp assist device 10 in an off or standby state. In such an embodiment, the grasp assist device 10 automatically powers down when the operator 11 departs a work cell WC_A, WC_B, or WC_C, and does not enter another adjacent work cell. While in a work cell WC_A, WC_B, or WC_C, the operator 11 may optionally request deactivation of the grasp assist device 10 via a predetermined gesture as noted below with reference to FIG. 3.

To enable the functionality noted above, the controller 50 may be programmed with the geographic coordinates of the various work cells in the work environment. Thus, the controller 50 may compare received location signals from the location sensor 78 of FIG. 1 to predetermined coordinates demarcating the boundary lines 190, 290 noted above. In this manner, the controller 50 is able to determine the physical location and heading of the operator 11 relative to the work environment 60. Control of the device 10 proceeds in a different manner once the operator 11 arrives at a given work cell.

With respect to the optional display screens 45, such devices may be static display screens such as video monitors in wireless communication with the controller 50 of FIG. 1. The size of the sleeve 18 is limited, a comparatively large screen 45 may be arranged in each work cell WC_A, WC_B, or WC_C, or may be worn by the operator 11, e.g., as a smart phone or glasses, such that the operator 11 is alerted via test, sound, video, and the like to information pertaining to the task at hand. For example, as the controller 50 selects a predetermined task for a given work cell WC_A, WC_B, or WC_C, the display screen 45 for the particular work cell can present information such as a build schedule, sequence, or instructions in response to receipt of the output signal (arrow 13) from the controller 50.

Referring to FIG. 3, a logic flow diagram 80 depicts the location and attitude sensing functionality of the controller 50 of FIG. 1. A representative table 83 of possible work cells WC_A, WC_B, and WC_C is programmed into memory (M) of the controller 50 shown in FIG. 1, with the three work cells WC_A, WC_B, and WC_C shown for consistency with the non-limiting embodiment of FIG. 2. For a given grasp assist device 10, the table 83 may include all possible work cells in a given work environment 60 or just a subset of such work cells, such that the grasp assist device 10 will only work in certain areas. Location signals (arrow L13) from the optional location sensor 78 as shown in FIG. 1 may be transmitted to the controller 50 in some embodiments, and as the operator 11 enters a given work cell, e.g., work cell WC_A, a corresponding work cell table 183 is accessed by the controller 50, with the work cell table 183 including a calibrated list of work tasks 93 authorized for that specific work cell. When the location sensor 78 is not used, location may be derived via the attitude sensors 88 as noted above.

The calibrated list of work tasks 93 includes example work tasks WT_1, WT_2, WT_3, and WT_4 as shown. For instance, for a given work cell WC_A, the operator 11 of FIG. 2 may be permitted to grasp and lift a vehicle wheel as work task WT_1, place the wheel onto a hub of a vehicle as the work task WT_2, secure the positioned wheel via placement of nuts as work task WT_3, and fasten the nuts via a torque wrench as the work task WT_4. Each work task may correspond to a different set of grasp assist parameters, e.g., different tensile forces (F_a) acting on different finger portions 15 and/or the thumb 14, which in turn may vary with each operator 11 wearing the grasp assist device 10. For instance, for example work task WT_4, a maximum amount of assisting force may be provided at all finger portions 15 and the thumb portion 14, while only the thumb portion 14 and one finger portion 15 may be activated for work tasks WT_3 and WT_4.

In order to quickly differentiate between all of the possible work tasks in the example work cell WC_A, the controller 50 receives and processes signals (arrow A13) from the attitude sensor(s) 88 of FIG. 1. Example signals include acceleration of a palm of the grasp assist device 10, and/or pitch, yaw, and roll of different portions of the glove 12. In other words, the controller 50 detects a gesture of the operator 11 of FIG. 2 and auto-selects a control mode for an associated work task 193 based on the detected gesture, doing so from the calibrated list of work tasks 93. This capability also allows the controller 50 to be programmed with a predetermined.
on/off gesture, such as a predetermined wave, rather than
having the operator physically activate a switch or an
on/off button.

Optionally, the controller may be programmed with a
calibration mode. Such a mode may be desirable as each
grasp assist device may be worn at different times by
different operators, and as each operator may exhibit
unique grasp characteristics relative to other operators. Thus,
a one-size-fits-all design may be less than optimal. In
such a calibration mode, the operator of FIG. 2 may be
prompted to move through a series or range of predeter-
mined gestures and/or conduct predetermined work tasks
while the controller learns the operator’s tendencies. In
this manner, glove variance can be minimized between
different operators.

Referring to FIG. 4, an example embodiment of the
method for controlling the grasp assist device of FIG. 1
begins with step S102 wherein the operator puts on the
grip assist device and then begins moving through the
work space as shown in FIG. 2. The method then proceeds
to step S104.

At step S104, the controller next determines the
location of the glove within the work environment. For
instance, the controller may receive and process location
signals (arrow L ID) from the location sensor or
may derive the location via the attitude sensors as noted
above and known in the art. This step enables the controller
to determine the location of the operator wearing the
glove within the work environment. The method then
proceeds to step S106 as the location continues to be
read and tracked by the controller.

Step S106 entails determining, again via the controller,
whether the operator has entered a predetermined work
cell, e.g., WC, WC, or WC. For instance, the controller
may compare the present coordinates of the operator to
determined coordinates demarcating the perimeters of
the various work cells WC, WC, and WC to determine if
the operator has entered one of the work cells WC, WC,
or WC. The method then proceeds to step S108 if the
operator has entered one of the work cells WC, WC,
or WC. Otherwise, step S106 is repeated and the grasp assist
device remains off or in a default standby mode.

Step S108 entails identifying a work task from a list of
permitted work tasks for the determined location of step
S106 using the determined location and attitude. As part of
step S108, the controller extracts the calibrated list of
work tasks, which is shown in FIG. 3 as the example
work tasks WT, WT, and WT. Completion of step S108 may
include preventing the grasp assist device from
assisting in work tasks other than those of the calibrated
list of tasks. As such, the grasp assist device is enabled
solely for a localized set of work tasks corresponding to
the work to be performed in the present work cell. The controller also reads the attitude signals (arrow A) from the
titude sensors as noted above and known in the art.

As part of step S108 the controller determines whether
the received attitude signals (arrow A) correspond to one
of the predetermined work tasks, permitted for the present
work cell, e.g., work tasks WT, WT, and WT for
example work cell WC. If so, the controller extracts
instructions from its memory for assisting the detected
task and proceeds to step S112. Otherwise, step S110 is
repeated. Optionally, an alert or error message may be
displayed via the display screen if the operator’s gestures do not match any of the authorized work tasks for
the present work cell.

At step S112, the controller receives measured actual
grasping forces from the load sensors of FIG. 1 as the
force feedback signals (arrow 24) and calculates a required
grasp assist force needed for assisting the operator in
performing the identified work task. The controller
then commands application of the required grasp assist force
to the glove for the present authorized work task, such as
by commanding application of a tensile force to the thumb
portion and a finger portion of FIG. 1 via tendons when manually tightening a lug nut, or assisting all finger
portions and the thumb portion when lifting a heavy
object. As this process continues the method proceeds to
step S114.

Step S114 includes detecting a default gesture of the
operator signaling a desire to temporarily disable the
grasp assist device of FIG. 1. By way of example, the
controller may be programmed with a default gesture
such as a wave of the glove back and forth in a set motion.
The method proceeds to step S116 when such a gesture is
detected. Steps S112 and S114 otherwise continue in a
loop until the operator moves to another work task or
departs the work cell, at which point the method commences anew at step S102.

By using the above-described approach, those of ordinary
skill in the art will appreciate that conventional operator-
tensive grasp assistance controls may be optimized via
the use of dynamic mode selection based on sensor data. Position information can be used to determine the location
and heading of an operator, while inertial and joint angle/
position sensors can provide attitude data, i.e., pitch, roll,
yaw, etc. Together, the sensor data is processed with minimal
operator interference to thereby increase operator efficiency.

Additionally, the number of possible control modes is
increased relative to manually-selected/(UI-based devices,
which are limited in large part due to the limited space on the
sleeve of FIG. 1 and the need for an operator to scroll
through lists while wearing the grasp assist device along
with the requirement that the operator will always make
the appropriate mode selection from such displayed modes.
While the best modes for carrying out the disclosure have
been described in detail, those familiar with the art to which
this disclosure relates will recognize various alternative
designs and embodiments for practicing the disclosure
within the scope of the appended claims.

The invention claimed is:

1. A system comprising:
a glove;
ap plurality of sensors positioned with respect to the glove,
including load sensors configured to measure an actual
grasping force applied to an object by an operator
wearing the glove, and attitude sensors configured to
determine an attitude of the glove;
an actuator assembly operable for providing a grasp assist
force via the glove; and

2. A controller programmed with a respective location of
each of a plurality of work cells in a work environment,
and also with a set of permitted work tasks for each
of the work cells, wherein the controller is further
programmed to:
determine a location of the glove within the work
environment;
determine the attitude of the glove within the detected
location by processing the attitude signals from the
attitude sensors;
select a work task from a list of permitted work tasks
for the detected location using the determined location
and attitude;
calculate a required grasp assist force using the actual grasping force from the load sensors; and

command an application of the required grasp assist force to the object, via the glove using the actuator assembly, to thereby assist the operator in performing the identified work task.

2. The system of claim 1, further comprising flexible tendons connected to the glove, wherein the actuator assembly is configured to apply the required grasp assist force by applying a tensile force to the flexible tendons.

3. The system of claim 1, wherein the plurality of sensors includes a location sensor configured to determine the location of the glove within the work environment.

4. The system of claim 3, wherein the location sensor is a global positioning system (GPS) sensor.

5. The system of claim 3, wherein the location sensor is a radio frequency identification (RFID) sensor.

6. The system of claim 1, wherein the attitude sensors include at least one accelerometer.

7. The system of claim 1, wherein the attitude sensors include at least one joint angle sensor.

8. The system of claim 1, further comprising a display screen in communication with the controller, wherein the controller is programmed to communicate information regarding the identified work task via the display screen.

9. The system of claim 1, wherein the controller is programmed to detect a predetermined gesture of the glove and to temporarily discontinue the commanded application of the required grasp assist force in response to the detected predetermined gesture.

10. A method for controlling a system having a glove, load sensors configured to measure an actual grasping force applied to an object by an operator wearing the glove, attitude sensors configured to determine an attitude of the glove, and an actuator assembly operable for applying a required grasp assist force to the glove, the method comprising:

determining a location of the glove within the work environment via a controller;

determining the attitude of the glove within the determined location, via the controller, by processing attitude signals from the attitude sensors;

identifying a work task from a list of permitted work tasks for the determined location using the determined location and attitude;

measuring, via the load sensors, an actual grasping force applied by the operator to an object;

calculating the required grasp assist force for the identified work task via the controller using the measured actual grasping force;

and commanding an application of the required grasp assist force to the object, via the glove using the actuator assembly, to thereby assist the operator in performing the identified work task.

11. The method of claim 10, wherein the system includes flexible tendons connected to the glove, the method further comprising: applying the required grasp assist force by applying a tensile force to the flexible tendons.

12. The method of claim 10, wherein the system includes a location sensor operable for determining the location of the glove, and wherein determining the location of the glove includes processing a location signal from the location sensor using the controller.

13. The method of claim 12, wherein the location sensor is a global positioning system (GPS) sensor.

14. The method of claim 12, wherein the location sensor is a radio frequency identification (RFID) sensor.

15. The method of claim 10, wherein determining an attitude of the glove includes using an accelerometer as at least one of the attitude sensors.

16. The method of claim 10, wherein determining an attitude of the glove includes using a joint angle sensor as at least one of the attitude sensors.

17. The method of claim 10, further transmitting an output signal from the controller to a display screen within the determined location to thereby present information regarding the identified work task.

18. The method of claim 10, further comprising:

detecting a predetermined gesture of the glove; and temporarily discontinuing the application of the required grasp assist force in response to the detected predetermined gesture.

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