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(54) **ASSIST SYSTEM CONFIGURED FOR MOVING A MASS**

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B66C 13/18 (2006.01)

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(58) **Field of Classification Search** 212/197, 212/279, 320; 700/213
See application file for complete search history.

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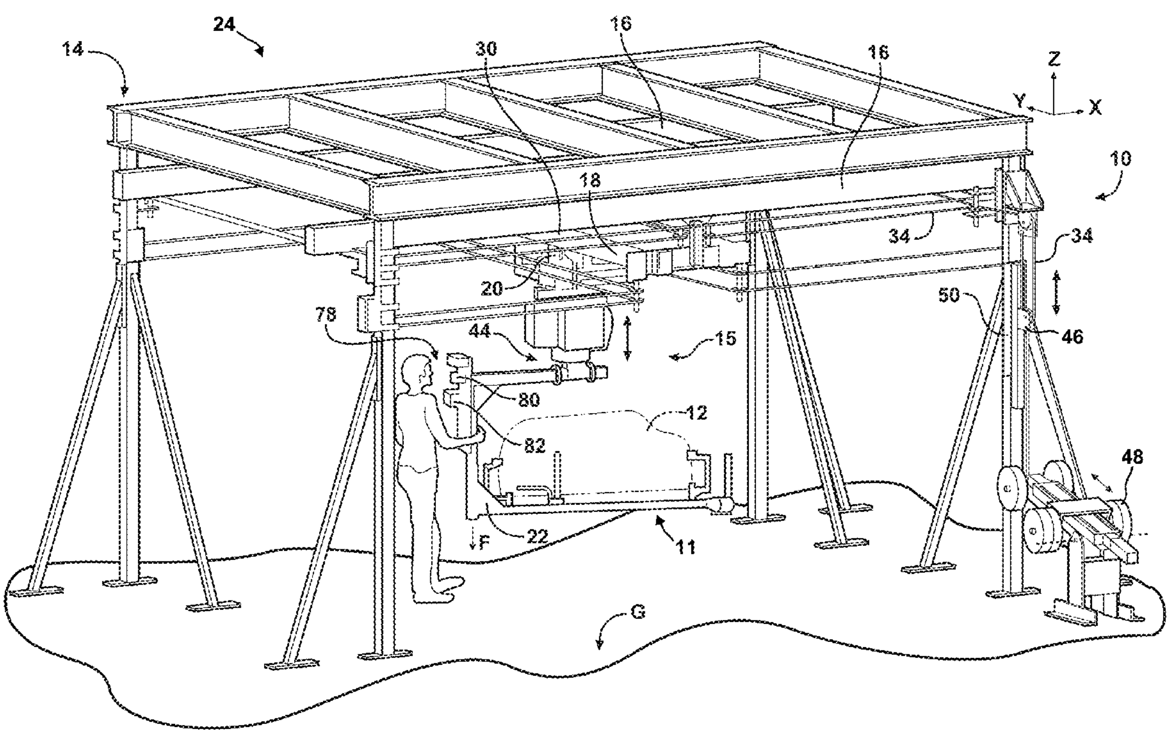
(57) **ABSTRACT**

An assist system is configured for moving a mass vertically, along a Z axis. The assist system includes a vertical actuation system, a cable, a plurality of pulleys, an actuator, and a mass. The pulleys are operatively attached to the support structure and an assist device that is movable attached to the support structure. The cable is routed around each of the pulleys and attached to the support structure. One of the pulleys supports the mass. The mass moves vertically in response to the actuator.

20 Claims, 6 Drawing Sheets



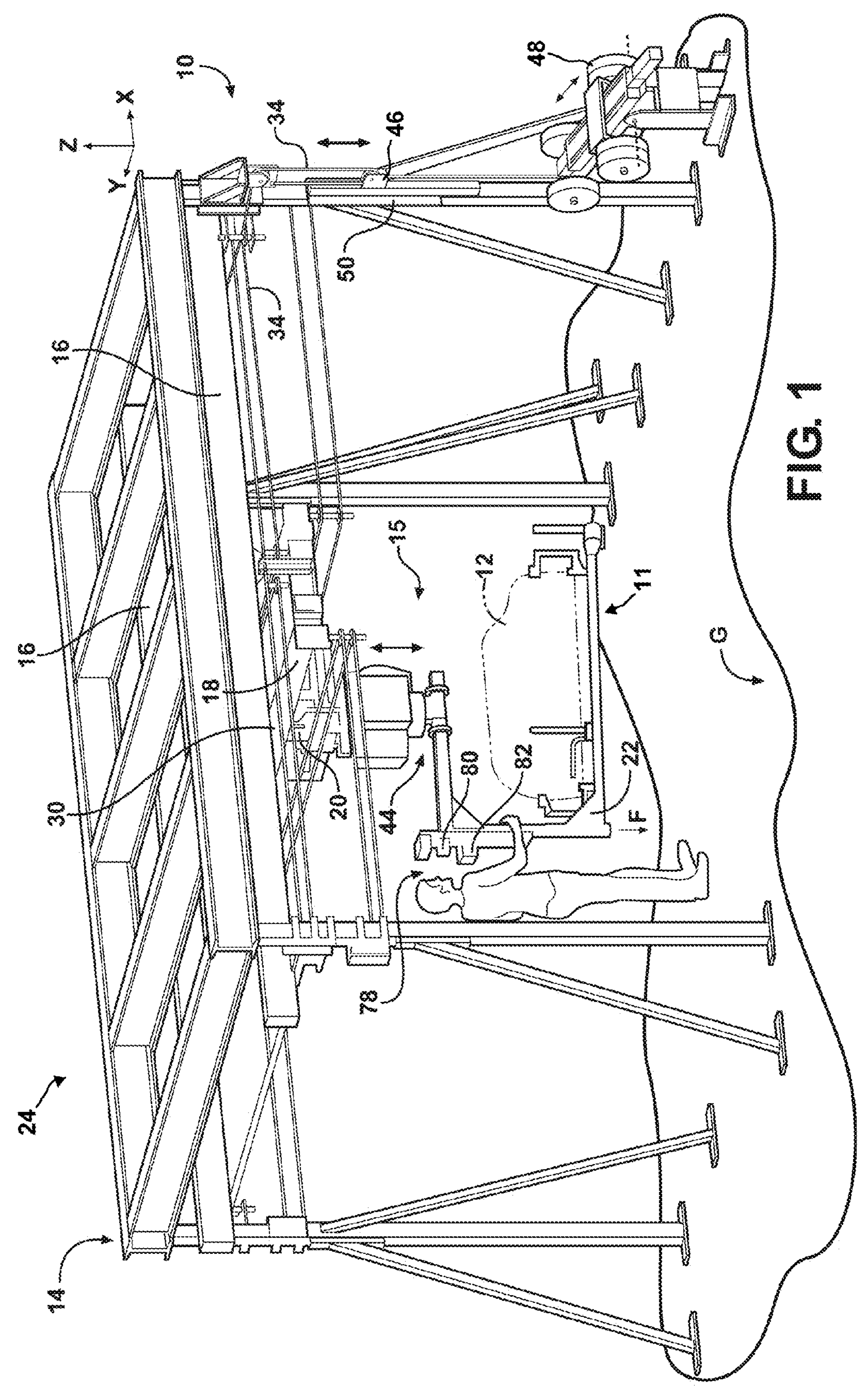


FIG. 1

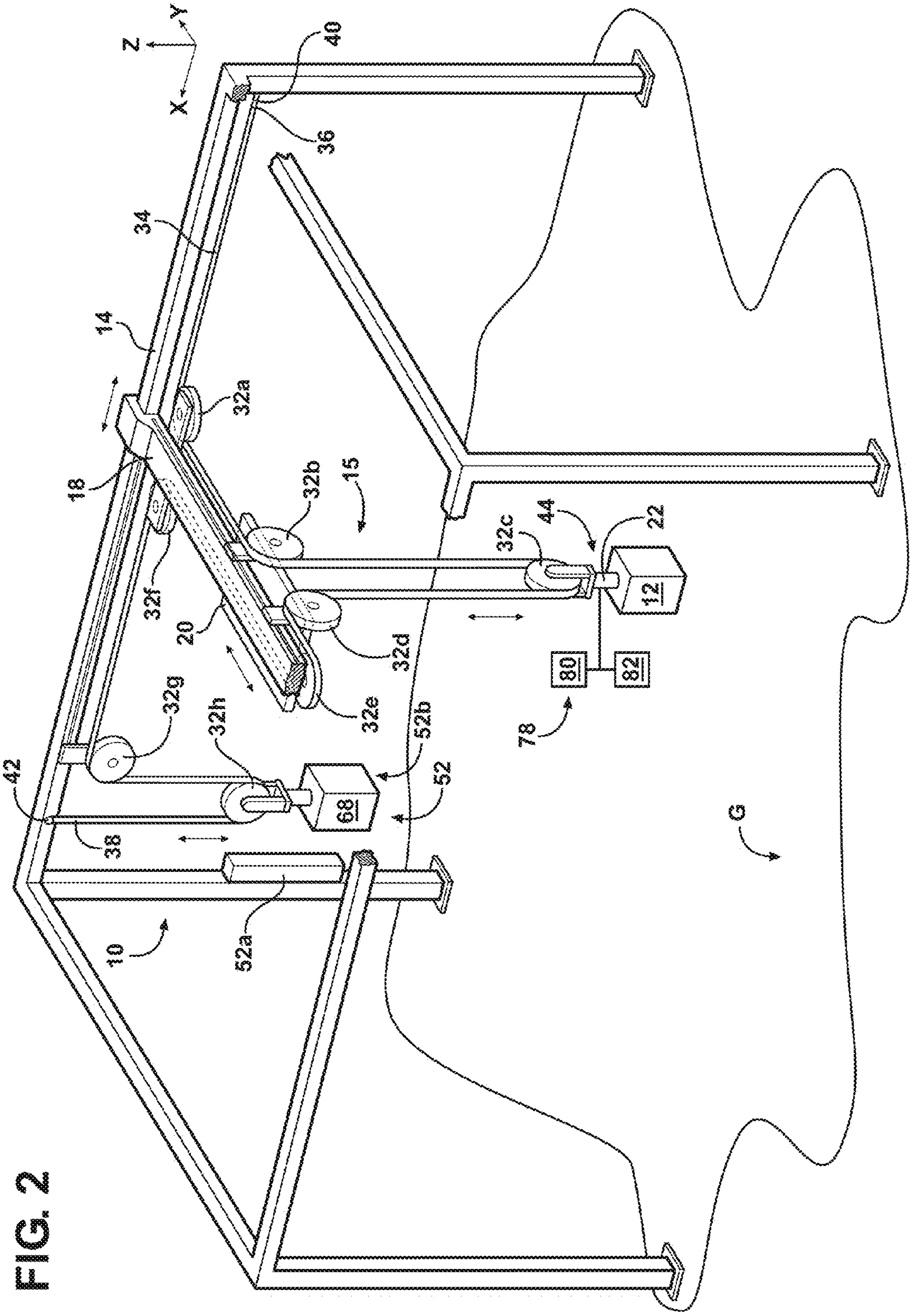


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FIG. 2

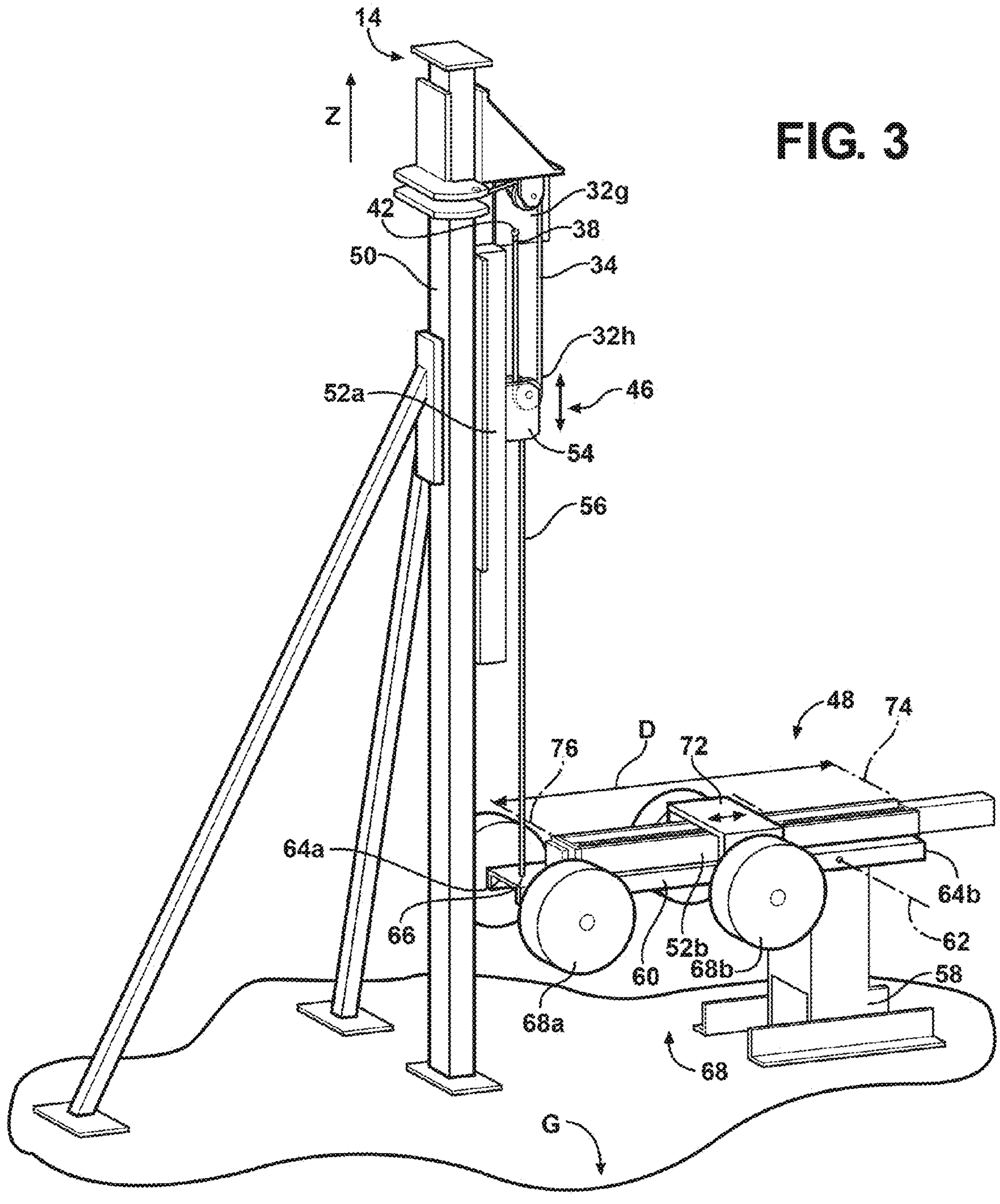
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FIG. 3

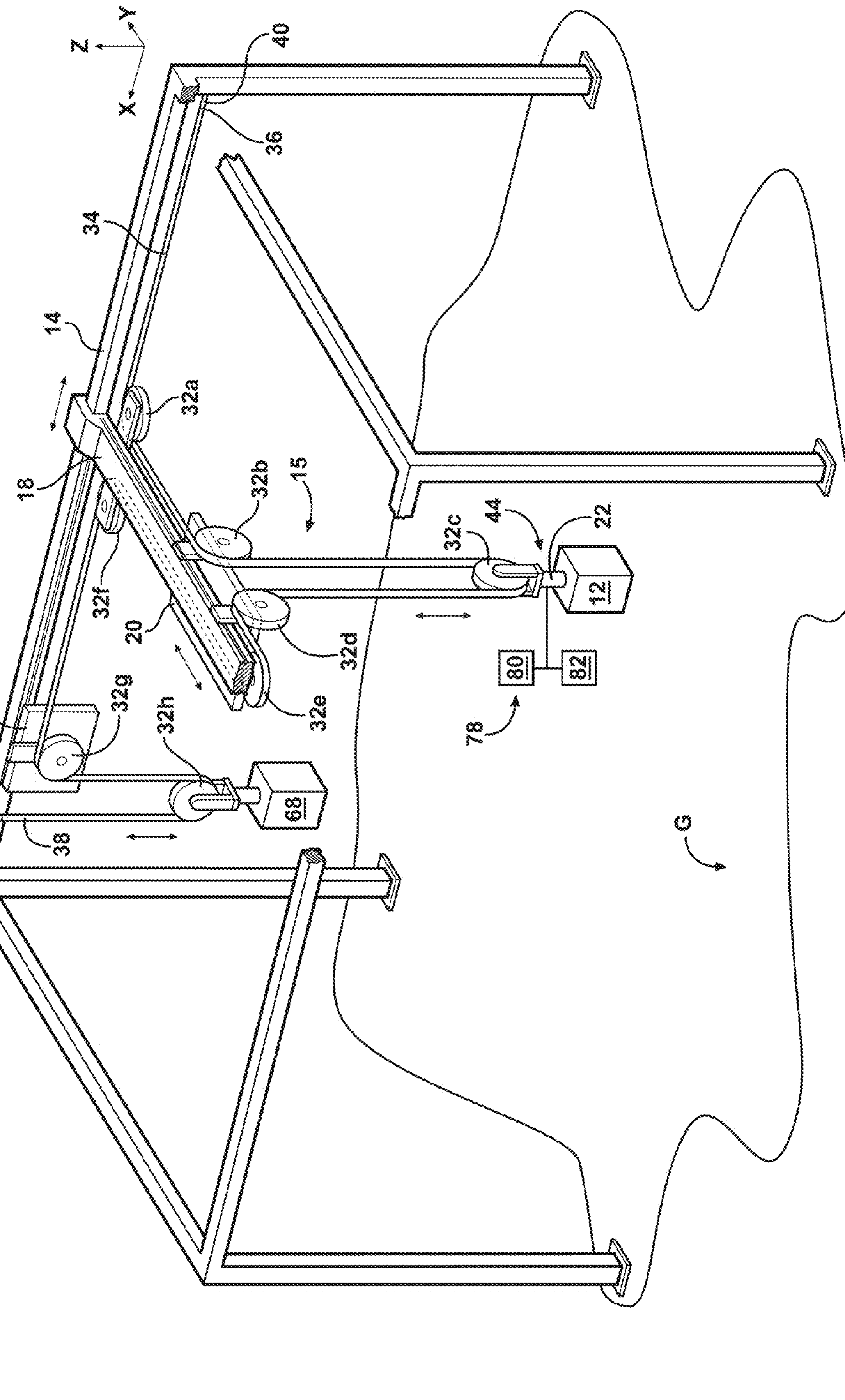
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FIG. 4

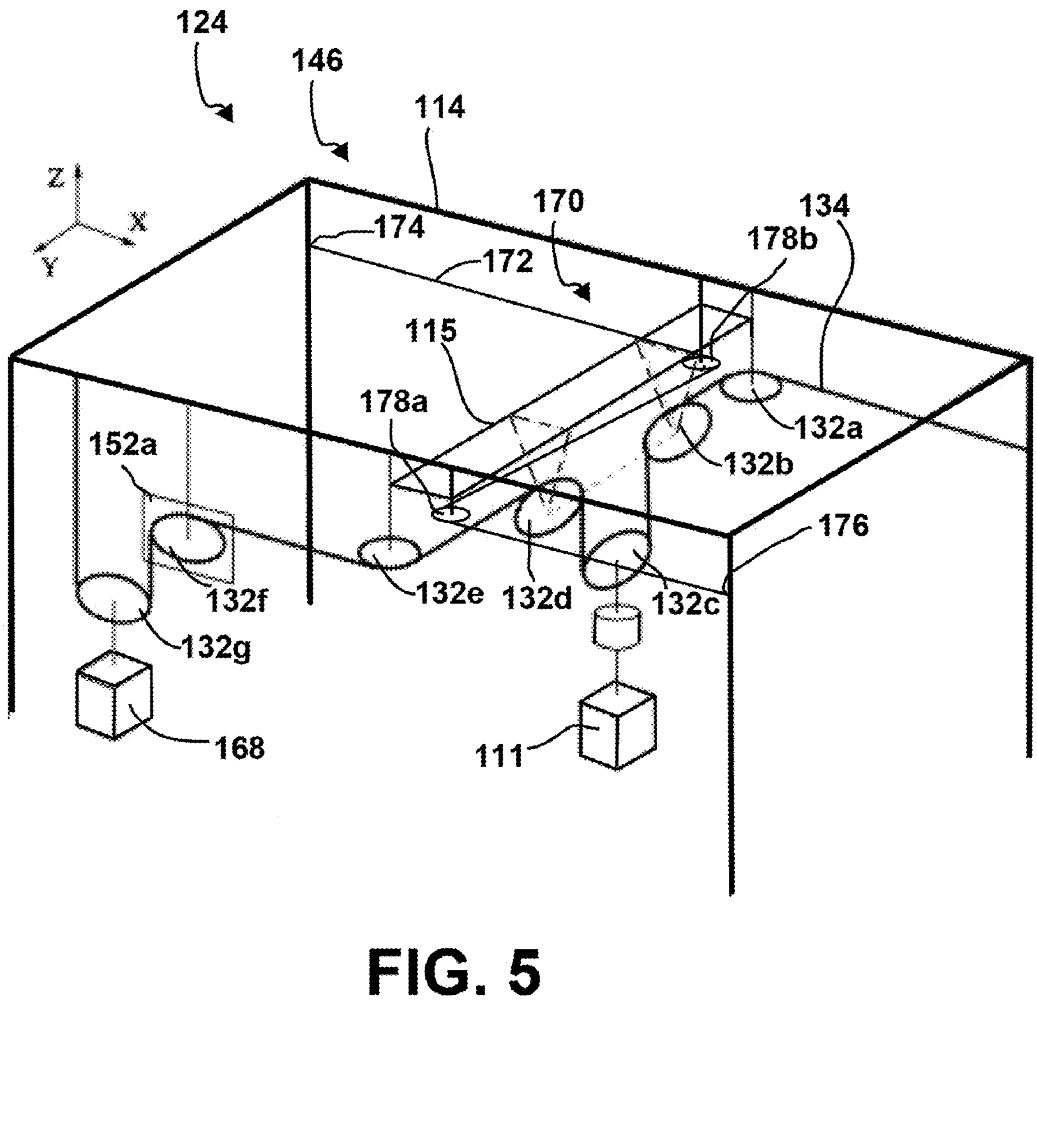
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FIG. 5

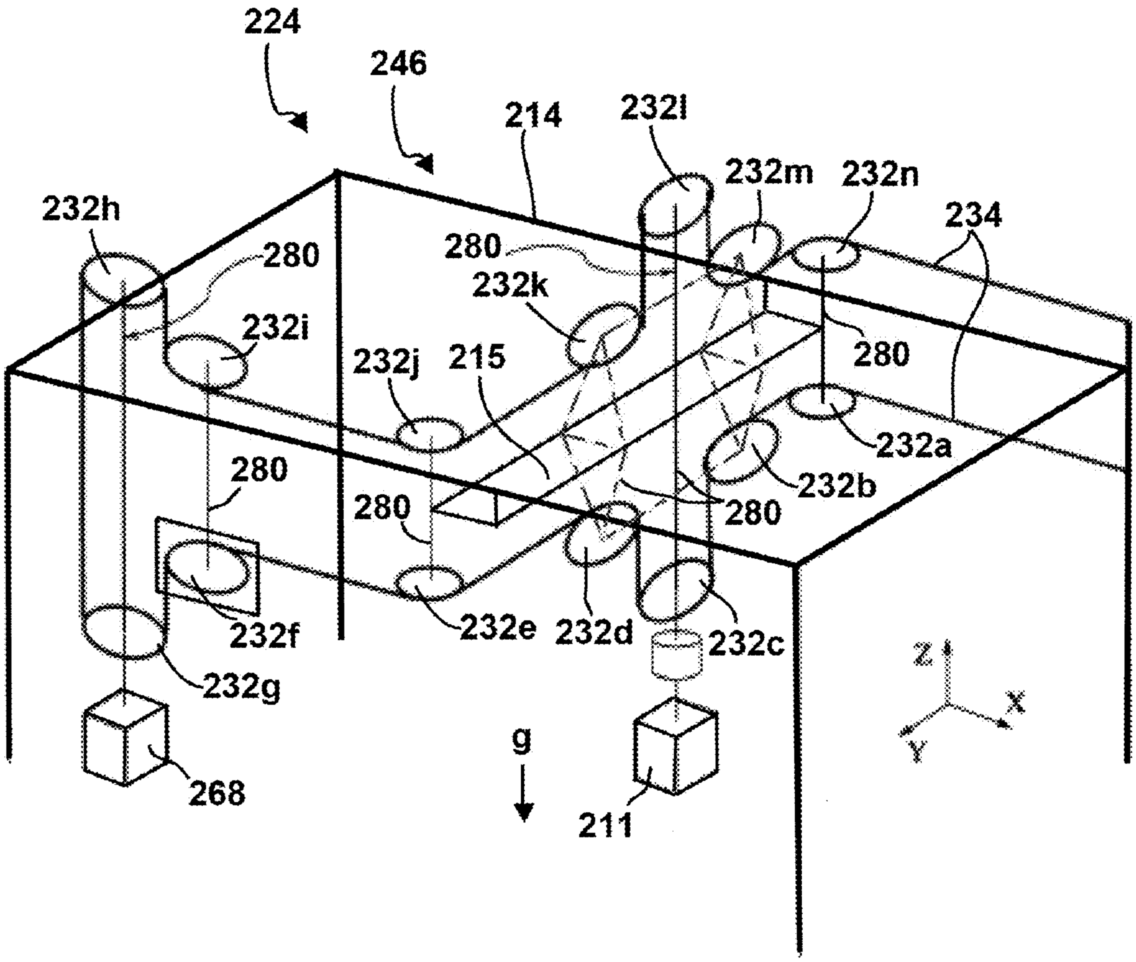
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FIG. 6

ASSIST SYSTEM CONFIGURED FOR MOVING A MASS

TECHNICAL FIELD

The present invention relates to an assist system that is configured for moving a mass in a vertical direction.

BACKGROUND OF THE INVENTION

Overhead bridge cranes are widely used to lift and relocate large payloads. Generally, the displacement in a pick and place operation involves three translational degrees of freedom and a rotational degree of freedom along a vertical axis. This set of motions, referred to as a Selective Compliance Assembly Robot Arm ("SCARA") motions or "Schönflies" motions, is widely used in industry. A bridge crane allows motions along two horizontal axes. With appropriate joints, it is possible to add a vertical axis of translation and a vertical axis of rotation. A first motion along a horizontal axis is obtained by moving a bridge on fixed rails while the motion along the second horizontal axis is obtained by moving a trolley along the bridge, perpendicularly to the direction of the fixed rails. The translation along the vertical axis is obtained using a vertical sliding joint or by the use of a belt. The rotation along the vertical axis is obtained using a rotational pivot with a vertical axis.

There are partially motorized versions of overhead bridge cranes that are displaced manually along horizontal axes and rotated manually along the vertical axis by a human operator, but that include a motorized hoist in order to cope with gravity along the vertical direction. Also, some bridge cranes are displaced manually along all of the axes, but the weight of the payload is compensated for by a balancing device in order to ease the task of the operator. Such bridge cranes are sometimes referred to as assist devices. Balancing is often achieved by pressurized air systems. These systems need compressed air in order to maintain pressure or vacuum—depending on the principle used—which requires significant power. Also, because of the friction in the cylinders, the displacement is not very smooth and can even be bouncy. Balancing can be achieved using counterweights, which add significant inertia to the system. Although helpful and even necessary for the vertical motion, such systems attached to the trolley of a bridge crane add significant inertia regarding horizontal motion. In the case of balancing systems based on counterweights, the mass added can be very large, even larger than the payload itself. If the horizontal traveling speed is significant, the inertia added to the system becomes a major drawback.

There are also fully motorized versions of such bridge cranes that require powerful actuators, especially for the vertical axis of motion which has to support the weight of the payload. These actuators are generally attached to the trolley or bridge and are then in motion. The vertical translation actuator is sometimes attached to the bridge and linked to the trolley by a system similar to what is used in tower cranes.

SUMMARY OF THE INVENTION

A vertical actuation system includes a cable, a plurality of assist device pulleys, a mass pulley, a fixed pulley and an actuation pulley. The cable has a first end and a second end. The first end is configured for operative attachment to a support structure at a first location and the second end is configured for operative attachment to the support structure at a second location, different from the first location. The assist

device pulleys are configured for operative attachment to an assist device that is movably attached to the support structure. The cable is configured to be routed around each of the plurality of assist device pulleys, the mass pulley, the fixed pulley, and the actuation pulley such that each of the pulleys are configured to be operatively disposed between the first and second ends of the cable. The mass pulley is configured to be operatively supported by the cable and a pair of the plurality of assist device pulleys. The fixed pulley is configured for operative attachment to the support structure. The actuation pulley is configured to be operatively supported by the cable and each of the fixed pulley and the second end of the cable. A mass extends from the mass pulley. An actuator is configured to move the cable relative to the fixed pulley such that the actuation pulley moves vertically, relative to the ground, as the mass pulley and the mass move vertically in an opposite direction. The vertical movement of the mass is configured to be independent of the horizontal movement of the assist device.

In another embodiment, an assist system is configured to statically balance a mass in a vertical direction along a Z axis, relative to the ground. The assist system includes a support structure, an assist device, a cable, a plurality assist device pulleys, a mass pulley, a fixed pulley, and an actuation pulley. The assist device is movably attached to the support structure and is configured for horizontal movement along at least one of an X axis and a Y axis, relative to the ground. The cable has a first end and a second end. The first end is operatively attached to the support structure at a first location and the second end is operatively attached to the support structure at a second location, different from the first location. The assist device pulleys are operatively attached to the assist device. The cable is configured to be routed around each of the plurality of assist device pulleys, the mass pulley, the fixed pulley, and the actuation pulley such that each of the pulleys are operatively disposed between the first and second ends of the cable. The mass pulley is operatively supported by the cable and a pair of the plurality of assist device pulleys. The fixed pulley is operatively attached to the support structure. The actuation pulley is operatively supported by the cable and each of the fixed pulley and the second end of the cable. A mass extends from the mass pulley. An actuator is configured to move the cable relative to the fixed pulley such that the actuation pulley moves vertically, relative to the ground, as the mass pulley and the mass move vertically in an opposite direction. The vertical movement of the mass is independent of the horizontal movement of the assist device.

In another embodiment, an assist system includes a cable, a plurality of pulleys, a mass, and a variable balancing system. The cable has a first end and a second end. The first end is configured for operative attachment to a support structure at a first location and the second end is configured for operative attachment to the support structure at a second location, different from the first location. The pulleys are configured for operative attachment to at least one of the support structure and an assist device that is movably attached to the support structure. The cable is configured to be routed around each of the plurality of pulleys. One of the pulleys is configured to be operatively supported by the cable. The mass is configured to extend from the one of the plurality of pulleys. Another one of the pulleys is configured to be operatively supported by the cable. The variable balancing system is configured to be operatively attached to another one of the pulleys. The variable balancing system includes a balance platform, a lever, a balancing actuator, and a counterweight. The lever is pivotally attached to the balance platform about a balance axis. The balancing actuator is disposed along the lever. The counterweight is operatively attached to the balancing actuator such that the counterweight is configured to move a distance along the balancing actuator between a minimum position and a maximum position. The minimum position corresponds to the mass having a minimum weight such that the mass is statically balanced along the Z axis. The maximum position corresponds to the mass having a maximum weight such that the mass is statically balanced along the Z axis.

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

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the figures, which are exemplary embodiments and wherein like elements are numbered alike:

FIG. **1** is a schematic perspective view of an assist system including a vertical actuation system and a variable balancing system operatively connected to a support structure;

FIG. **2** is a schematic perspective view of the vertical actuation system of FIG. **1**, configured for vertically moving a mass along a Z axis;

FIG. **3** is a schematic perspective view of the vertical actuation system and the variable balancing system of FIG. **1**;

FIG. **4** is a schematic perspective view of another embodiment of the vertical actuation system configured for moving a mass along a Z axis;

FIG. **5** is a schematic perspective view of a second embodiment of the vertical actuation system of FIG. **1**, configured for vertically moving a mass along a Z axis; and

FIG. **6** is a schematic perspective view of a third embodiment of the vertical actuation system of FIG. **1**, configured for vertically moving a mass along a Z axis.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings, wherein like reference numbers refer to like components, an assist system is shown at **24** in FIG. **1**. The assist system **24** includes a vertical actuation system **46**, a stationary support structure **14**, an assist device **15**, and a mass **11**. The vertical actuation system **46** is configured for moving the mass **11** in a vertical direction along a Z axis, relative to the ground G, is shown at **10** in FIG. **1**. The vertical actuation system **46** is mounted to the stationary support structure **14** that is configured to at least partially support the vertical actuation system **46**, the assist device **15**, and the mass **11**. The mass **11** may include an end effector **22**, where the end effector **22** is supported by the assist device **15**. The end effector **22** may selectively support a payload **12**. The support structure **14** includes, but is not limited to, a pair of parallel rails **16** or runway tracks. Generally, an assist device **15** is supported by the parallel rails **16** of the support structure **14**. The assist device **15** may include a bridge crane **18** and a trolley **20**. The bridge crane **18** is a structure that includes at least one girder **30** that spans the pair of parallel rails **16**. The bridge crane **18** is adapted to carry the payload **12** horizontally, relative to the ground G, along an X axis. The trolley **20** is movably attached to the girders **30** of the bridge crane **18** such that the trolley **20** is adapted to carry the payload **12** horizontally, relative to the ground G, along a Y axis. The end effector **22** is rotatably attached to the trolley **20** such that the end effector **22** rotates about the Z axis. The Z axis extends in a generally vertical direction, relative to the ground G. Additionally, the end effector **22** movably extends from the trolley **20** such that the end effector **22** is adapted to carry or support the payload **12** in the generally vertical direction along the Z axis.

Referring to FIG. **2**, the vertical actuation system **46** allows motion of the end effector **22**, and any associated payload **12**, along the Z axis. Movement along the Z axis is decoupled from horizontal movement of the assist device **15** along the X and Y axes. This means that the vertical movement of the assist device **15**, via the vertical actuation system **46**, is decoupled from the horizontal movements of the end effector **22** and any associated payload **12**, along the X and Y axes. To decouple the vertical movements from the horizontal movements, the vertical actuation system **46** is disposed in spaced relationship to the assist device **15** and the mass **11**. This means that the vertical actuation system **46** may be attached to the support structure **14** and/or the ground G so that any mass associated with movement of the vertical actuation system **46** does not move horizontally with the assist device **15** and inertia of the system is reduced. The vertical actuation system **46** will be described in more detail below.

Referring again to FIG. **2**, first, second, third, fourth, fifth, sixth, seventh, and eighth pulleys **32*a*-32*h*** are shown. The pulleys **32*a*-32*h*** include a plurality of assist device pulleys **32*a***, **32*b***, **32*d*-32*f***. The assist device pulleys **32*a***, **32*b***, **32*d*-32*f*** include the first pulley **32*a*** that operatively extends from the bridge crane **18**, the second and fourth pulleys **32*b***, **32*d*** that extend from the trolley **20**, and the fifth and sixth pulleys **32*e***, **32*f*** extend from the bridge crane **18**. The end effector **22** includes the third pulley, or mass pulley, **32*c***. The seventh pulley, or fixed pulley, **32*g*** extends from the support structure **14**. The eighth pulley, or actuation pulley, **32*h*** is operatively attached to the vertical actuation system **46**. It should be appreciated that the total number of pulleys **32*a*-32*h*** is not limited to the eight described herein as any other number of pulleys **32*a*-32*h*** may be used as known to those skilled in the art. A cable **34** has a first end **36** and a second end **38**. The first end **36** of the cable **34** is operatively attached, or anchored, to the support structure **14** at a first fixed location **40**. The second end **38** of the cable **34** is operatively attached, or anchored, to the support structure **14** at a second fixed location **42**. The cable **34** is routed to extend from the first fixed location **40** and to then be routed around the first pulley **32*a*** and then the second pulley **32*b***. The end effector **22** includes a vertical rotational joint **44** that operatively interconnects the end effector **22** and the trolley **20**. The vertical rotational joint **44** is configured to allow rotation of the end effector **22**, and any associated payload **12**, about the Z axis while preventing the cable **34** from also rotating. The vertical rotational joint **44** includes the third pulley **32*c*** and the cable **34** is routed from the second pulley **32*b***, around the third pulley **32*c***, and then around the fourth pulley **32*d***. The cable **34** is next routed around the fifth, sixth, and seventh pulleys **32*e***, **32*f***, **32*g***, respectively. The cable **34** is routed around the eighth pulley **32*h*** such that the eighth pulley **32*h*** is at least partially supported by the seventh pulley **32*g*** and the second fixed location **42** of the second end **38** of the cable **34**. It should be appreciated that the routing of the cable **34** between pulleys **32*a*-32*h*** is not limited to the eight described herein as any other suitable configuration of the cable **34** and the pulleys **32*a*-32*h*** may be used as known to those skilled in the art.

Referring to FIG. **3**, the vertical actuation system **46** may be operatively disposed on the support structure **14**. More specifically, the vertical actuation system **46** may be disposed on a vertically extending leg **50** of the support structure **14**. It should be appreciated, however, that the vertical actuation system **46** is not limited to being mounted to the support structure **14**, but may be mounted to any other object that does not move in the horizontal direction with the assist device **15**.

Referring to FIG. **3**, the vertical actuation system **46** includes a vertical actuator **52***a* that is operatively attached to the support structure **14**. A vertical slide **54** is operatively attached to the vertical actuator **52***a*. The vertical slide **54** is configured to move along the vertical actuator **52***a* in response to actuation of the vertical actuator **52***a*. The vertical actuator **52***a* may be configured with a transmission that supplies a large transmission ratio. The large transmission ratio provides translational motion to the end effector **22**, and any association payload **12**, via the cable **34** that is routed around each of the pulleys **32***a*-**32***h*. In one embodiment, the transmission of the vertical actuator **52***a* includes a ball screw. In addition to providing a large transmission ratio, the ball screw is configured to control a speed that the end effector **22**, and any associated payload **12**, moves vertically along the Z axis. However, it should be appreciated that the vertical actuator **52***a* is not limited to using a ball screw, as any other transmission, known to those skilled in the art, may also be used. Additionally, a brake may be operatively connected to the vertical actuator **52***a* to slow down and/or stop the vertical actuator **52***a*. Additionally, the brake may allow the vertical slide **54** to be in a locked position relative to the vertical actuator **52***a* when transporting the end effector **22**, and any associated payload **12**, horizontally along the X and/or Y axes to prevent movement of the end effector **22**, and any associated payload **12**, along the Z axis.

It should be appreciated that the routing of the cable **34** among the pulleys **32***a*-**32***h* is not limited to that as described herein. It is possible to modify a transmission ratio between the vertical motion of the end effector **22**, and any associated payload **12**, and the motion of the vertical actuator **52***a* and the variable balancing system **48** by changing the cable **34** routing and/or the number and location of the pulleys **32***a*-**32***h*, as known to those skilled in the art.

The variable balancing system **48** may be disposed on the ground G. The variable balancing system **48** is configured to provide a counterbalance to the end effector **22**, and any associated payload **12**, such that the end effector **22**, and any associated payload **12**, is statically balanced along the Z axis. Statically balanced means that the end effector **22**, and any associated payload **12**, may selectively move along the Z axis in response to operating the vertical actuation system **46** and/or application of a vertical force F to the end effector **22**, and any associated payload **12**, as will be described in more detail below. However, when the operation of the vertical actuation system **46** is stopped, the end effector **22**, and any associated payload **12**, generally remains in the same vertical position along the Z axis as they are "statically balanced". A balancing cable **56** operatively interconnects the vertical actuation system **46** and the variable balancing system **48**. More specifically, at one end, the balancing cable **56** is operatively connected to the vertical slide **54**. The balancing cable **56** may be a cable **34**, a belt, a chain, or any other object or device configured to interconnect the vertical actuation system **46** and the variable balancing system **48**, as known to those skilled in the art.

As shown in FIG. **3**, the variable balancing system **48** includes a balance platform **58** and a lever **60** that is pivotally attached to the balance platform **58** such that the lever **60** pivots about a balance axis **62**. The lever **60** has opposing ends **64***a*, **64***b* and the balancing cable **56** is operatively attached to the lever **60** at an attachment point **66** near one of the opposing ends **64***a*, **64***b*. At least one counterweight **68** is operatively attached to the lever **60**. In the embodiment shown in FIG. **3**, there is a fixed counterweight **68***a* and a mobile counterweight **68***b*. It should be appreciated, however, that more or less counterweights **68** may be used, as known to those skilled in the art. The fixed counterweight **68***a* may be disposed on the lever **60**, proximate the attachment point **66** of the balancing cable **56**. A balancing actuator **52***b* may be disposed along the lever **60**. A balancing slide **72** may be operatively attached to the balancing actuator **52***b* and the mobile counterweight **68***b* may be operatively attached to the balancing slide **72**. The balancing slide **72**, along with the mobile counterweight **68***b*, is configured to move a distance D along the balancing actuator **52***b* between a minimum position **74** and a maximum position **76** to counter the weight associated with the end effector **22**, and any associated payload **12** and statically balance the end effector **22**, and any associated payload **12**. When the mobile counterweight **68***b* is at the minimum position **74**, the mobile counterweight **68***b* is moved along the lever **60** such that the mobile counter weight is closer to the balance axis **62** than when the mobile counterweight **68***b* is at the maximum position **76**. The position of the mobile counterweight **68***b* at the minimum position **74**, the maximum position **76**, or at any other position between the minimum and maximum positions **74**, **76**, are configured to statically balance the end effector **22**, and any associated payload **12**, along the Z axis. Therefore, when the mobile counterweight **68***b* is at the minimum position **74**, the end effector **22** may not be supporting a payload **12**, or may be supporting a minimum payload **12**, i.e., the payload **12** having a minimum weight for the design of the variable balancing system **48**, while remaining statically balanced along the Z axis. Likewise, when the mobile counterweight **68***b* is at the maximum position **76**, the end effector **22** is supporting a maximum payload **12**, i.e., the payload **12** having a maximum weight for the design of the variable balancing system **48**, while remaining statically balanced along the Z axis. However, the mobile counterweight **68***b* may also be positioned anywhere along the lever **60** between the minimum position **74** and the maximum position **76** that is configured to vertically balance the end effector **22** that is supporting a payload **12** that weighs less than the maximum payload **12**, but more than the minimum payload **12**.

As shown in FIGS. **1** and **2**, the end effector **22** may include controls **78** that are configured for remotely actuating the vertical actuator **52***a* and/or the balancing actuator **52***b*. More specifically, the controls **78** may include a selector **80** and a directional control **82**. The selector **80** may be configured for selecting between having no payload **12** on the end effector **22** and/or between a plurality of other payloads **12** having differing weights. For example, if the operator operates the selector **80** to choose that the end effector **22** is not supporting a payload **12**, the balancing actuator **52***b* moves the mobile counterweight **68***b* along the lever **60** to the minimum position **74** to balance the end effector **22**. Likewise, if the operator operates the selector **80** to choose the maximum payload **12**, the balancing actuator **52***b* moves the mobile counterweight **68***b* along the lever **60** to the maximum position **76** to balance the end effector **22**, and the maximum payload **12**. It should be appreciated that the selector **80** may be configured to move the balancing actuator **52***b* to any number of locations between the minimum position **74** and the maximum position **76** to statically balance any number of other payloads **12**, as known to those skilled in the art.

In an alternative embodiment, the balancing cable **56** is operatively connected to the cable **34**. Alternatively, balancing cable is replaced by the cable **34**, such that the cable **34** is attached to the lever **60** at the attachment point **66**. In this embodiment, the mass **11** is movable along the Z axis in response to the application of a force F applied directly to the mass **11**. Likewise, the mass **11** is configured to remain statically balanced along the Z axis when the force F is removed.

The directional control **82** may be configured for selectively moving the payload **12** upward or downward along the Z axis. More specifically, if the operator decides that the end effector **22**, and any associated payload **12**, needs to move vertically upward, relative to the ground G, the operator operates the associated directional control **82** to actuate the vertical actuator **52***a*. As a result of being actuated, the vertical actuator **52***a* moves the vertical slide **54** vertically downward to move the end effector **22**, and any associated payload **12**, upward along the Z axis. When the vertical slide **54** moves vertically downward, the eighth pulley **32***h* also moves vertically downward. As the eighth pulley **32***h* moves vertically downward, the cable **34** is tightened between the first and second attachment points **66** to raise the end effector **22**, and any associated payload **12**, along the Z axis.

Likewise, as shown in FIGS. **1** and **2**, if the operator decides that the end effector **22**, and any associated payload **12**, needs to move vertically downward along the Z axis, the operator operates the associated directional control **82** to actuate the vertical actuator **52***a*. As a result of being actuated, the vertical actuator **52***a* moves the vertical slide **54** vertically upward. When the vertical slide **54** moves vertically upward, the eighth pulley **32***h* also moves vertically upward such that the cable **34** is slackened between the first and second attachment points **66** to lower the end effector **22**, and any associated payload **12**, along the Z axis. When the operator wants to maintain the vertical position of the end effector **22**, and any associated payload **12**, the operator refrains from operating any of the directional controls **82** and the end effector **22**, and any associated payload **12**, remains in the same vertical position along the Z axis.

Referring to the embodiment shown in FIG. **4**, an actuator **52** extends from the support structure **14** and is operatively connected to the seventh pulley **32***g*. The cable **34** winds around the seventh pulley **32***g*. A counterweight **68** is supported by the eighth pulley **32***h*. The eighth pulley **32***h* is disposed along the cable **34** between the seventh pulley **32***g* and the second attachment point **66** such that the eighth pulley **32***h* and the counterweight **68** hang from the seventh pulley **32***g* and the second attachment point **66** to statically balance the weight of the end effector **22**, and any associated payload **12**. If the operator decides that the end effector **22**, and any associated payload **12**, needs to move vertically upward or downward along the Z axis, the operator operates the associated control and the actuator **52** is actuated in response. As a result of being actuated, the actuator **52** turns the seventh pulley **32***g* to move the cable **34** in a direction associated with moving the payload **12** in the desired vertical direction along the Z axis.

Referring to FIG. **5**, a second embodiment of an assist system **124** is shown. The assist system **124** includes a support structure **114**, an assist device **115**, a vertical actuation system **146**, a counterweight **168**, and a mass **111**. The assist device **115** is operatively attached to the support structure **114** and is configured for moving the mass **111** horizontally along the X and Y axes. The vertical actuation system **146** is operatively attached to a support structure **114** and includes an actuator **152***a* that is configured to provide translational motion to the mass **11**, vertically along the Z axis, via a cable **134** that is routed around each of a plurality of pulleys **132***a*-**132***g*. To compensate for undesired torque that may be applied to the assist device **115** when moving the assist device **115** along the X and Y axes, a second cable routing **170** may be provided. The second cable routing **170** includes a second cable **172** that is secured to the support structure **114** at opposing ends **174**, **176**. A pair of second pulleys **178***a*, **178***b* are supported by the assist device **115** in spaced relationship to one another. The second cable **172** is routed around the second pulleys **178***a*, **178***b*, as shown in FIG. **5**, in a Z-shaped pattern to compensate for any torque that may be applied to the assist device **115**.

Referring to FIG. **6**, a third embodiment of an assist system **224** is shown. The assist system **224** includes a support structure **214**, an assist device **215**, a vertical actuation system **246**, a mass **211**, and a counterweight **268**. The assist device **215** is operatively attached to the support structure **214** and is configured for moving the mass **211** horizontally along the X and Y axes. The vertical actuation system **246** is operatively attached to a support structure **214** and includes an actuator **252***a* that is configured to provide translational motion to the mass **211**, vertically along the Z axis, via a cable **234** that is routed around each of a plurality of pulleys **232***a*-**232***n*. The pulleys **232***a*-**232***n* are configured to provide a "double routing" configuration as shown in FIG. **6**. In the double routing, pulleys **232***a*-**232***g* are disposed in mirrored relationship to pulleys **232***h*-**232***n*, respectively. These pulleys **232***a*-**232***g* and **232***h*-**232***n* may be held in mirrored relationship to one another via rigid bars or links **280**. However, they may also be held in mirrored relationship through any other mechanism known to those skilled in the art. A double routing may be used when a vertical acceleration g is larger than 1. Otherwise, the cable **234** may become slack when a vertical acceleration that is greater than 1 is applied. The double routing synchronizes motion of the mass **211** and the counterweight **268**.

While the best modes for carrying out the invention have been described in detail, those familiar with the art to which this invention relates will recognize various alternative designs and embodiments for practicing the invention within the scope of the appended claims.

The invention claimed is:

1. A vertical actuation system comprising:

a cable having a first end and a second end;

wherein the first end is configured for operative attachment to a support structure at a first location and the second end is configured for operative attachment to the support structure at a second location, different from the first location;

a plurality assist device pulleys, a mass pulley, a fixed pulley, and an actuation pulley;

wherein the plurality of assist device pulleys are configured for operative attachment to an assist device that is movably attached to the support structure in a horizontal direction, relative to the ground;

wherein the cable is configured to be routed around each of the plurality of assist device pulleys, the mass pulley, the fixed pulley, and the actuation pulley such that each of the pulleys are configured to be operatively disposed between the first and second ends of the cable;

wherein the mass pulley is configured to be operatively supported by the cable and a pair of the plurality of assist device pulleys;

wherein the fixed pulley is configured for operative attachment to the support structure;

wherein the actuation pulley is configured to be operatively supported by the cable and each of the fixed pulley and the second end of the cable;

a mass extending from the mass pulley; and

an actuator configured to move the cable relative to the fixed pulley such that the actuation pulley moves vertically, relative to the ground, as the mass pulley and the mass move vertically in an opposite direction;

wherein the vertical movement of the mass is configured to be independent of the horizontal movement of the assist device.

2. A vertical actuation system, as set forth in claim 1, wherein the actuator is operatively connected to the actuation pulley; and

wherein the actuator is a vertical actuator configured for vertically moving the actuation pulley vertically along the Z axis as the mass pulley and the mass move vertically in an opposite direction.

3. A vertical actuation system, as set forth in claim 2, further comprising a vertical slide operatively attached to the vertical actuator;

wherein the vertical slide is configured to move along the vertical actuator in response to actuation of the vertical actuator.

4. A vertical actuation system, as set forth in claim 1, further comprising controls operatively connected to the assist device and configured to actuate the actuator.

5. A vertical actuation system, as set forth in claim 1, further comprising a variable balancing system including:

a balance platform and a lever pivotally attached to the balance platform about a balance axis;

a balancing actuator disposed along the lever;

a counterweight operatively attached to the balancing actuator such that the counterweight is configured to move a distance along the balancing actuator between a minimum position and a maximum position;

wherein the minimum position corresponds to the mass having a minimum weight such that the mass is statically balanced along a Z axis; and

wherein the maximum position corresponds to the mass having a maximum weight such that the mass is statically balanced along the Z axis.

6. A vertical actuation system, as set forth in claim 5, further comprising a vertical actuation system operatively connected to the variable balancing system.

7. A vertical actuation system, as set forth in claim 5, wherein a balancing cable operatively interconnects the lever of the variable balancing system and the cable.

8. A vertical actuation system, as set forth in claim 5, wherein the actuator is operatively connected to the fixed pulley; and

wherein the actuator is a rotary actuator configured for turning the fixed pulley to move the cable relative to the fixed pulley such that each of the actuation pulley and the counterweight move vertically as the mass pulley and the mass move vertically in an opposite direction.

9. A vertical actuationsystem, as set forth in claim 5, wherein the counterweight is a fixed counterweight and a mobile counterweight;

wherein the fixed counterweight is operatively attached to the lever such that the fixed counterweight does not move relative to the lever; and

wherein the mobile counterweight is operatively attached to the balancing actuator such that the mobile counterweight is configured to move the distance along the balancing actuator between the minimum position and the maximum position.

10. A vertical actuation system, as set forth in claim 5, further comprising controls operatively connected to the assist device and configured to actuate the balancing actuator.

11. A vertical actuation system, as set forth in claim 1, wherein the plurality of assist pulleys are five pulleys.

12. An assist system configured to statically balance a mass in a vertical direction along a Z axis, relative to the ground, the system comprising:

a support structure;

an assist device movably attached to the support structure and configured for horizontal movement along at least one of an X axis and a Y axis, relative to the ground;

a variable actuation system including;

a cable having a first end and a second end,

wherein the first end is operatively attached to the support structure at a first location and the second end is operatively attached to the support structure at a second location, different from the first location,

a plurality assist device pulleys, a mass pulley, a fixed pulley, and an actuation pulley,

wherein the plurality of assist device pulleys are operatively attached to the assist device;

wherein the cable is configured to be routed around each of the plurality of assist device pulleys, the mass pulley, the fixed pulley, and the actuation pulley such that each of the pulleys are operatively disposed between the first and second ends of the cable;

wherein the mass pulley is operatively supported by the cable and a pair of the plurality of assist device pulleys;

wherein the fixed pulley is operatively attached to the support structure;

wherein the actuation pulley is operatively supported by the cable and each of the fixed pulley and the second end of the cable;

a mass extending from the mass pulley; and

an actuator configured to move the cable relative to the fixed pulley such that the actuation pulley moves vertically, relative to the ground, as the mass pulley and the mass move vertically in an opposite direction;

wherein the vertical movement of the mass is independent of the horizontal movement of the assist device.

13. An assist system, as set forth in claim 12, further comprising a rotary actuator operatively connected to the fixed pulley;

wherein the rotary actuator is configured for turning the fixed pulley to move the cable relative to the fixed pulley such that each of the actuation pulley moves vertically as the mass pulley and the mass move in a vertically opposite direction.

14. An assist system, as set forth in claim 12, further comprising a vertical actuator configured for vertically moving the actuation pulley vertically as the mass pulley and the mass move in a vertically opposite direction.

15. An assist system, as set forth in claim 14, wherein the vertical actuation system includes a vertical slide operatively attached to the vertical actuator;

wherein the vertical slide is configured to move along the vertical actuator in response to actuation of the vertical actuator.

16. An assist system, as set forth in claim 12, further comprising a variable balancing system including:

a balance platform and a lever pivotally attached to the balance platform about a balance axis;

a balancing actuator disposed along the lever;

a counterweight operatively attached to the balancing actuator such that the counterweight is configured to move a distance along the balancing actuator between a minimum position and a maximum position;

wherein the minimum position corresponds to the mass having a minimum weight such that the mass is statically balanced along the Z axis; and

wherein the maximum position corresponds to the mass having a maximum weight such that the mass is statically balanced along the Z axis.

17. An assist system, as set forth in claim **16**, wherein a balancing cable operatively interconnects the vertical actuation system and the lever of the variable balancing system.

18. An assist system, as set forth in claim **16**, wherein the counterweight is a fixed counterweight and a mobile counterweight;

wherein the fixed counterweight is operatively attached to the lever such that the fixed counterweight does not move relative to the lever; and

wherein the mobile counterweight is operatively attached to the balancing actuator such that the mobile counterweight is configured to move the distance along the balancing actuator between the minimum position and the maximum position.

19. An assist system, as set forth in claim **16**, further comprising controls operatively connected to assist device;

wherein the controls are configured to actuate at least one of the actuator and the balancing actuator.

20. An assist system comprising:

a cable having a first end and a second end;

wherein the first end is configured for operative attachment to a support structure at a first location and the second end is configured for operative attachment to the support structure at a second location, different from the first location;

a plurality of pulleys configured for operative attachment to at least one of the support structure and an assist device that is movably attached to the support structure;

wherein the cable is configured to be routed around each of the plurality of pulleys;

wherein one of the plurality of pulleys is configured to be operatively supported by the cable;

a mass configured to extend from the one of the plurality of pulleys;

wherein another one of the plurality of pulleys is configured to be operatively supported by the cable;

wherein the vertical movement of the mass is independent of the horizontal movement of the assist device;

a variable balancing system configured to be operatively attached to another one of the plurality of pulleys, the variable balancing system including:

a balance platform and a lever pivotally attached to the balance platform about a balance axis;

a balancing actuator disposed along the lever;

a counterweight operatively attached to the balancing actuator such that the counterweight is configured to move a distance along the balancing actuator between a minimum position and a maximum position;

wherein the minimum position corresponds to the mass having a minimum weight such that the mass is statically balanced along the Z axis; and

wherein the maximum position corresponds to the mass having a maximum weight such that the mass is statically balanced along the Z axis.

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