PATIENT TRANSPORT METHOD AND APPARATUS

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A transport method and apparatus is provided capable of reducing the accelerations encountered by an item or patient due to an external energy input to the transport device, by utilizing an active control system adapted to input a second energy to offset the effect of the external energy input.
FIG. 3A

Comparison of system Position responses

- Existing System
- Passive Suspension
- Compensated System

FIG. 3B

Comparison of system Acceleration responses

- Existing System
- Passive Suspension
- Compensated System
FIG. 4

100 - providing a patient transport device having an ACS in accordance with embodiments of the present invention, and that includes a sensor in electrical communication with a controller that is in electrical communication with a force controller, the force controller adapted to at least generate and control linear motion.

110 - sensing a response characteristic of the patient support device as a result of an external energy input.

120 - sending a signal representative of the response characteristic to the controller.

130 - generating and sending to the force controller a control signal that is representative of a required amount of a second energy input.

140 - Inputting a second energy in a direction and amount necessary to reduce the amount of the external energy input transmitted to a patient on the patient transport device.
PATIENT TRANSPORT METHOD AND APPARATUS

FIELD OF THE INVENTION

[0001] Embodiments of the present invention relate to a transport device and methods, and particularly to reducing the effects and damage to items or patients being transported as a result of certain energy inputs to the transport device and resulting acceleration-related inputs to the patient or item.

BACKGROUND OF THE INVENTION

[0002] Patient transport devices, often referred to as gurneys, stretchers, and the like, have long been used to transport people having injuries from one place to another, such as from an accident site to a hospital, or from hospital to hospital, etc. In addition to being themselves mobile, many patient transport devices may be adapted for use with a number of different transport vehicles, including ambulances, airplanes, helicopters, snow machines, and the like. When these vehicles are transporting patients from one location to another, they inevitably encounter disturbances such as bumps, potholes, turbulence, or other inconsistencies in the transport medium, which in turn causes a sudden change in position of the patient transport device. This abrupt change in position is transmitted to the patient, and can cause the patient to be subject to accelerations in various directions.

[0003] The magnitude of these external energy inputs and the resulting accelerations of the patient in different directions can have a severe and oftentimes detrimental impact on the patient being transported, particularly if the patient has head, neck, and/or spinal trauma, for example. Any undue energy input cannot only further aggravate an existing injury, but may ultimately result in death.

[0004] Another particularly susceptible category of patients are neonatal patients. Oftentimes being several weeks if not months premature, the biological systems within the neonatal patient, particularly the vascular system, has not fully developed and is extremely susceptible to damage. Even the smallest amount of vibrations and accelerations transmitted to the neonatal patients through the transport device during transfer can have traumatic impacts. One serious concern, but not the only serious concern, is intraventricular hemorrhage, which is where blood vessels in the brain rupture. Because the blood vessels in the brain of neonatal patients are underdeveloped (i.e., very thin and not prepared for significant stress), the vibrations and the accelerations of the patient as a result of the vibrations may cause the blood flowing through those vessels to be inclined to suddenly stop and/or change directions. Since this is not possible due to the continuous flow of blood through the system, an outward pressure is applied to the underdeveloped vessel causing them to fatigue and/or rupture.

[0005] Current patient transport devices often have a number of inherent passive energy and vibration absorption systems, such as a mattress, rubber in the wheels of the transport device, and when a vehicle is used, for example, the vehicle’s suspension. Some patient transport devices may even have additional passive systems, such as shock absorption devices to further absorb various energy inputs. These devices may not provide an acceptable energy and vibration absorption capability for the susceptible patients described above. While the passive systems may ultimately absorb external energy inputs and vibrations, they are often too slow, may initially amplify the accelerations resulting from certain energy inputs, and cannot adequately attenuate the acceleration encountered by the patient.

[0006] Accordingly, it is desirable to develop a patient transport device that somewhat decouples the patient from the transport device such that the external energy inputs, such as vibrations, impulse inputs, and step inputs encountered by a patient transport device, will be minimized and any accelerations of the patient as a result will be reduced so as to reduce the creation and/or aggravation of existing injuries.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Embodiments of the present invention will be readily understood by the following detailed description in conjunction with the accompanying drawings. To facilitate this description, like reference numerals designate like structural elements. Embodiments of the invention are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings.

[0008] FIG. 1 illustrates a perspective view of a patient transport device in accordance with an embodiment of the present invention;

[0009] FIGS. 2A-2D illustrate a transport device responding to an external energy input in accordance with an embodiment of the present invention;

[0010] FIGS. 3A and 3B illustrate graphs comparing test results of various patient transport devices with patient transport devices in accordance with embodiments of the present invention;

[0011] FIG. 4 illustrates a control block diagram of a transport device system response in accordance with an embodiment of the present invention;

[0012] FIG. 5 illustrates a plan view of a patient transport device in accordance with an embodiment of the present invention;

[0013] FIG. 6 illustrates a plan view of a patient transport device in accordance with an embodiment of the present invention;

[0014] FIG. 7 illustrates a plan view of a patient transport device in accordance with an embodiment of the present invention; and

[0015] FIG. 8 illustrates a block diagram of a method of reducing accelerations of a patient being transported in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0016] In the following detailed description, reference is made to the accompanying drawings which form a part hereof wherein like numerals designate like parts throughout, and in which is shown by way of illustration embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present invention. Therefore, the
following detailed description is not to be taken in a limiting sense, and the scope of embodiments in accordance with the present invention is defined by the appended claims and their equivalents.

[0017] Embodiments of the present invention relate to the reduction of external energy inputs, such as vibrations, step, and impulse inputs, that are transmitted to something being transported, such as a patient, through the transport device, by implementing an Active Control System (ACS). The ACS may include both passive suspension components and an active controller adapted to input energy into the system, wherein they work in cooperation to reduce the impact of external energy inputs on a patient or item being transported. Embodiments in accordance with the present invention may include a controller that may input a force in a direction required to cause the patient support to track back to a position that is a predetermined distance away from a portion of the frame of the patient transport device. This action may have the overall effect of reducing the acceleration of a patient as a result of the external energy input. Embodiments of the present invention may include altering the magnitude and direction of the force input by the controller based on the direction and magnitude of the external energy input.

[0018] Active control systems in accordance with embodiments of the present invention may be configured to reduce the amount and/ or effect of an external energy input to the transport device that may be transmitted to the item or patient being transported. A number of different external energy inputs may be encountered, including vibrations (high-frequency, low-magnitude input) that may be caused for example rolling a gurney over rough surfaces such as aggregate, elevator threshold, and the like. Another external energy input may be caused by a step input, which may occur when an ambulance hits a curb, for example, such that the overall position of the patient transport device steps up or down from a first elevation to a second elevation. Yet another external energy input may be caused by an impulse input, which may result from an ambulance hitting a speed bump or pothole, for example, where the patient transport device is temporarily displaced from a first elevation to a second elevation and then returns to the first elevation.

[0019] FIG. 1 illustrates a perspective view of a patient transport device in accordance with an embodiment of the present invention. A patient transport device 10 may include a support reference 12, such as a support dock, that may be removable coupled to the patient transport device 10. In one embodiment, the support reference 12 may be coupled to and/or part of frame 14 that may be adapted for transport via wheels 16. A patient support 13 may be dynamically coupled to the support reference 12 through an ACS 21. In the case of neonatal transport, for example, an incubator 15 may be coupled to the patient support 13, and the incubator controls 17 and support components 18 may also be coupled to the support reference 12. The support reference may generally be any portion of a patient transport device that will be susceptible to generally uncompensated positional changes as a direct result of an external energy input and that acts as a reference point for which the patient support can move relative to.

[0020] In one embodiment, the ACS 21 may include guide members 30 configured to positionally couple patient sup-
port 13 to support reference 12 and allow limited movement in one or more desired directions. While the degrees of movement may be enabled as desired, in the illustrated embodiment, guide members 30 are configured to allow for linear movement of the patient support 13 vertically with respect to the substantially horizontal position of the support reference 12.

[0021] The ACS 21 may also include one or more passive suspension devices 18 actively coupled between the patient support 13 and the support reference 12. Passive suspension devices 18 may include a spring 32 configured to absorb energy stemming from the positional change of the support reference 12 caused by the external energy input. Passive suspension devices 18 may also include one or more dampeners 34 configured to dampen the absorption and/or release of energy through springs 32. While the passive suspension devices illustrated show separate components, such devices may be a single component, and may include other spring mechanisms such as elastomers.

[0022] Given an external energy input to the support reference 12, which may be caused, for example, by the patient transport device 10 crossing a sliding door threshold or encountering a curb, the magnitude of the energy input may be initially at least partially absorbed by the one or more passive suspension devices 18, and thus result in a reduced energy input being conveyed to the patient support 13. This may in part result in a decrease in the position, velocity, and/or acceleration of the patient support 12 as a result. Passive suspension devices 18 may include a variety of energy absorption and dampening devices and/or vibration/shock absorption devices, including, but not limited to, springs and dampers, electromagnetic fields, pneumatic systems, and the like.

[0023] The ACS 21 may also include a force generator 20 controllably coupled between the patient support 13 and the support reference 12. Force generator 20 may be adapted to input a second energy or force into the system aimed at offsetting some or all of the effects (positional, velocity, and acceleration) on the patient support 13 that could result due to the external energy input. Input of the second energy by force generator 20 may help to counteract the positional movement of the patient support 13, and in turn reduce the acceleration observed by the patient as a result of the external energy input. The direction and magnitude of the second energy input may be varied as required to minimize the positional change of the patient support with respect to the support reference 12.

[0024] As illustrated in FIGS. 2A-2D, the direction and magnitude of the second energy input may vary depending on the required dynamic response. For example, the second energy input may be at time in a direction opposite to the direction the support reference is traveling, and at times in the same direction as the movement of the support reference. FIG. 2A illustrates support reference 12 at a position P1 and the patient support 13 at a position of P1' prior to any external energy input. The distance between P1 and P1' may be a desired static separation distance D1.

[0025] When an external energy is applied to the system, a step input in the illustrated case of FIG. 2B, the support reference 12 will move from a first position P1 to a second position P2. Due to the passive suspension of the ACS, the patient support 13 may substantially remain at P1', thereby
resulting in a separation distance of $D_2$. At that time, the patient support $13$ may be considered as traveling with a negative velocity with respect to the support reference $12$. To counteract the negative velocity, the force generator may input a second energy $F_1$ in an upward direction, thereby urging patient support $13$ upward in an attempt to urge $D_2$ to equal $D_1$.

[0026] Once the energy stored in the springs of the passive suspension components, along with the second energy input $F_1$, begins to move the patient support $13$ vertically upward with respect to the support reference $12$, a positive velocity of the patient support will result. The patient support may also move from $P_1'$ to $P_2''$, resulting in a separation distance $D_3$, as illustrated in FIG. 2C. To counteract the positive velocity, force generator may input a second energy $F_2$ in a downward direction, directly opposing the movement of the patient support in an upward direction, until the velocity of the patient support again becomes negative.

[0027] This cycle may repeat until the velocity of the patient support $13$ is substantially zero with respect to the support reference $12$ and the separation distance is substantially back to the static distance of $D_1$. As shown by FIG. 2D, the separation distance of support reference $12$ with respect to patient support $13$ is back to $D_1$, where the support reference is at the new elevation $P_2$ as a result of the step input and the patient support is at $P_2''$. The same process may occur when other sources of external energy are encountered by the system, including, but not limited to step inputs, vibrations, and the like.

[0028] FIGS. 3A & 3B show a comparison of the dynamic response (position and acceleration) of a patient support to a step input in uncompensated, passively compensated, and actively compensated systems, with 3A representing position response comparison and 3B representing acceleration response comparisons. Lines 44 (position) & 44' (acceleration) are the system response of the uncompensated system; that is, the system with virtually no energy absorption components. Lines 42 & 42' show the system response of the passively controlled system; that is, the system without the internal energy device, or force generator. Lines 40 & 40' show the system response using the ACS in accordance with embodiments of the present invention. These figures illustrate a typical response of the patient support as the result of the movement illustrated in FIGS. 2A through 2D, when the step input is, for example, 0.1 meters.

[0029] As can be seen from FIGS. 3A and 3B, the ACS in accordance with embodiments of the present invention can significantly reduce the relative positional movement and the accelerations that the patient support experiences due to an external input to the system, which in turn minimizes the accelerations transmitted to a patient being transferred. It was found in both theoretical modeling and in testing of a proof of concept device, there was a reduction of the peak acceleration of the patient support (thus the patient) from approximately 13 m/s² (uncompensated) to approximately 2 m/s². As can be seen in the comparison charts, not only is the peak acceleration less in the ACS, the acceleration encountered by the patient attenuates in a shorter time interval. It was also found in the tests that there was an average overall reduction in the frequency weighted RMS acceleration seen by the patient across a range of 0 to 10 Hz from 0.67 m/s² to 0.11 m/s². It was further found that use of ACS in accordance with the present invention resulted in close to an 85% reduction in accelerations transmitted to the patient over the relative to existing systems.

[0030] Testing was also conducted where the energy input was the result of an impulse input, such as hitting a speed bump in an ambulance or turbulence in an airplane. Again, there was found to be a significant reduction in the position movement and acceleration of the patient. Likewise, the accelerations attenuated more rapidly than current systems not using ACS.

[0031] The force generator 20 may be configured in a variety of ways that may, allow for the controllable supply of a second energy input into the system. In one embodiment, for example, one or more rotary motors may be used in conjunction with a rack and pinion system to control the magnitude and direction of the second energy input, as shown in FIG. 1. In another embodiment, one or more linear motors, such as an MTS system 2000 series motor, may be coupled between the support reference and the patient support, and adapted to generate the second energy input in a desired direction and a desired magnitude. Other sources of linear motion generation and control may be used, which include, but are not limited to electromagnetic field manipulators, pneumatic and/or hydraulically controlled actuators, and the like.

[0032] Embodiments of the present invention may also include sensors 19 that may be adapted to sense the direction and magnitude of a response characteristic of the patient support 13 as a result of the external energy input. Sensor 19 may be in communication with a controller 23 adapted to apply a control law based on an input from sensor 19. Controller 23 may send a signal to force generator 20, such that the force generator may input a second energy of a magnitude of and direction appropriate to offset some of the effects of the external energy input, and ultimately reduce the acceleration of the patient support and, as a result, the patient. Sensor 19 may be, for example, a position, velocity, and/or acceleration based sensor.

[0033] The ACS in accordance with embodiments of the present invention may be a closed loop system employing negative feedback. Generally, when there is a disturbance to the system, e.g., an external energy input, the system dynamically responds, the response is sensed/measured, the force generator is sent a signal and the system responds dynamically to the second energy input, thus changing the sensed/measured characteristic. The total system response is again measured by the sensor and the force generator is again sent a signal causing the system to again respond. This is repeated until the system returns to an equilibrium state, e.g., zero input to the sensor measuring the response characteristic.

[0034] In one embodiment, the magnitude and direction of the second energy input may be determined and controlled via a negative feedback control loop, an example of which is illustrated in FIG. 4 in block diagram form. The overall system response $G_{SYS}$ (i.e., position, velocity, and acceleration) of the patient transport device may be characterized by the summation of the system response to the external energy input $R$, referred to as $G_{SYS,R}$ and the system response to the second energy input $F$ (i.e., by the force generator), referred to as $G_{SYS,F}$. In terms of the measured system
response characteristic or variable (e.g., position, velocity, and acceleration), overall system response characteristic \( Y_r \) will be equal to the sum of \( Y_e \), which is the system characteristic as a result of the external energy input \( R \), and \( Y_f \), which is the system characteristic as a result of the second energy input \( F \).

[0035] Sensor 19 may be adapted to sense \( Y_1 \) and generate a representative signal \( S_r \), such as a voltage or current that characterizes the response characteristic being sensed. A controller 23 may be in electrical communication with the sensor 19 and adapted to receive the sensor signal \( S_r \). The controller may compare the sensor signal \( S_r \) to a reference point to determine the variation of the response characteristic from a desired state. For example, the reference point may be a specific position of the patient support relative to the rest of the transport device; or a zero velocity indicating that the patient support is not moving relative to the rest of the transport device. The controller may then process the sensor signal using a predetermined control law, and generate a control signal \( S_c \). The force generator 20, which may be in electrical communication with the controller, may be adapted to receive the control signal \( S_c \) and generate a second energy input \( F \). Second energy input \( F \) will result in the system response \( G_{Y_2Y_1F} \), and generate \( Y_f \) as a result.

[0036] In one embodiment of the present invention, sensor 19 may be a velocity-based sensor adapted to measure the velocity of the patient support 13. The velocity sensor may be may be coupled to a controller, such that when a negative velocity is sensed, for example, the controller 17 generates a control signal to the force generator 20 to generate a force of a certain magnitude in positive direction to offset the negative velocity. The sensor may continue to measure the velocity of the patient support and generate sensor signals representing the response characteristic.

[0037] Periodic generation of sensor signals and thus generation of control signals may cause the force generator to vary and alter the direction and magnitude of the second energy input until the velocity of the patient support is substantially zero. This periodic measurement of sensor signals and subsequent generation of appropriate control signals that are in turn sent to the force generator creates a feedback loop. This feedback loop constantly adjusts the force generated as the response characteristic changes over time. The control law is formulated to return the system to its original state (i.e., the state prior to the external input \( Y_e \) acting on the system) as quickly as possible while minimizing the accelerations transmitted to the patient support as well as the overall movement of the system. This may in turn result in quicker attenuation of the accelerations of the patient support than would normally occur with only passive suspension components.

[0038] In one embodiment, where the sensor is a position sensor, and the external energy input is a step input directed to the patient transport device (e.g., hitting a curb) the support reference dynamically responds by raising to a second position. The position sensor will sense such second position and generate a sensor signal representative of the new position. The controller may process the signal using a control law and generate a corresponding control signal that will cause the force generator to provide a second energy input in the system to try and maintain a desired distance between the support reference and the patient support, while minimizing the relative velocity and overall acceleration of the patient support.

[0039] FIG. 5 illustrates a plan view of a patient transport device 200 in accordance with an embodiment of the present invention. Incubator 215 may be coupled to patient support 213, which in turn may be coupled to support reference 212 through an ACS 221 in accordance with embodiments of the present invention. ACS 221 may be in electrical communication with sensor 219 and controller 223. Incubator controls 217 and support components 218 may also be coupled to the support reference 212. Support reference 212 may be removably coupled to a frame 214, which may be adapted for movement on wheels 216. Support reference 214 may be removed along with patient support 213, incubator 215, ACS 221, sensor 219, controller 223, and support controls and components 217 and 218, and loaded into a transport vehicle, such as a helicopter. In such a case, the ACS 221 may continue to operate to reduce effects of external energy inputs to the patient transport device through the inconsistencies encountered by the transport vehicle on the patient support and thus the patient.

[0040] FIGS. 6 and 7 illustrate plan views of patient transport devices in accordance with embodiments of the present invention. Patient transport devices 310A and 310B may be adapted for transporting patients of all sizes. Both may include a support reference 314 and a patient support 312. A removable interposer 315 may be disposed between patient and the patient support 312. Interposer 315 may be rigid enough to support the patient, such as a backboard, and adapted to allow personnel to move the patient to and from the patient support 312. In other embodiments, the interposer may be a comfort item, such as a mattress. The patient transport devices 310A and 310B may include an ACS 321A and 321B configured to reduce the effects of an external energy input to the patient, as a result of position, velocity and/or acceleration changes.

[0041] The ACS 321A of FIG. 6 may include passive suspension components 318A coupled between the support reference 312 and the patient support 314, and a force generator 320A configured to input a second energy into the system. Force generator 320A may include a rotary motor that may be coupled to the support reference 312 and patient support 314 through a rack and pinion system 321A. The rotary motor and the rack and pinion coupling may enable control of the linear movement of the support reference 312 based on a control signal resulting from the sensor signals of sensors 319.

[0042] FIG. 7 illustrates a similar patient transport device 3103, but may be adapted for larger and heavier patients. The ACS 321B may include a force generator 3203 coupled between the support reference 312 and the patient support 314 in multiple areas through rack and pinion connections 3213. Such a configuration may enable a greater degree of local control as well as support patients having greater mass.

[0043] FIG. 8 illustrates a block diagram of a method of reducing the effects of external energy inputs observed by a patient during transport in accordance with embodiments of the present invention. A patient transport device may be provided that includes an ACS in accordance with embodiments of the present invention and which includes a sensor in electrical communication with a controller that is in
electrical communication with a force generator, and adapted to generate and control linear motion of the patient support with respect to the support reference (100). A response characteristic of the patient support device as a result of an external energy input may be sensed/measured (110). A sensor signal representative of the response characteristic may be generated and sent to the controller (120). The controller may generate and send a control signal to the force generator that is representative of a required amount of a second energy input (130). The force generator may then input a second energy of a magnitude necessary to reduce the amount of the external energy input transmitted to a patient on the patient transport device (140).

Embodiments of the present invention may be used with a variety of different patient transport device configurations, including those adapted for transport in vehicles configured for transportation over the roadways, such as ambulances, transportation via the airways, such as helicopters and airplanes, and/or vehicles adapted for other surfaces such as snow, rough terrain, and the like. Embodiments of the present invention may also be used with other transport devices, where the accelerations transmitted to an item being transported need to be reduced.

The active control system in accordance with embodiments of the present invention may be operated by a power source that is portable (e.g., battery powered) or may otherwise be adapted to interface with electrical system on board the transport vehicle. Further, the ACS may be adapted to run on either DC or AC systems.

Although certain embodiments have been illustrated and described herein for purposes of description of the preferred embodiment, it will be appreciated by those of ordinary skill in the art that a wide variety of alternate and/or equivalent embodiments or implementations calculated to achieve the same purposes may be substituted for the embodiments shown and described without departing from the scope of the present invention. Those with skill in the art will readily appreciate that embodiments in accordance with the present invention may be implemented in a very wide variety of ways. This application is intended to cover any adaptations or variations of the embodiments discussed herein. Therefore, it is manifestly intended that embodiments in accordance with the present invention be limited only by the claims and the equivalents thereof.

What is claimed is:

1. A patient transport device, comprising:
   a patient support;
   one or more passive energy devices coupled to the patient support and adapted to absorb at least a portion of an external energy input to the patient transport device; and
   a force generator controllably coupled to the patient support and configured to provide a second energy input into the device to reduce the effect of the external energy input on the patient support.

2. The patient transport device of claim 1, wherein the force generator is adapted to generate and control linear movement of the patient support with respect to a support reference.

3. The patient transport device of claim 2, wherein the force generator includes an electrically driven motor.

4. The patient transport device of claim 3, wherein the motor is a linear motor coupled to the support reference and having an actuator coupled to the patient support.

5. The patient transport device of claim 3, wherein the motor is a rotary motor coupled to the support reference and is coupled to the patient support through a rack and pinion interface.

6. The patient transport device of claim 1, further comprising a sensor in electrical communication with the force generator, the sensor adapted to detect a response characteristic of the patient support to an external energy input, and adapted to generate a sensor signal representative of the characteristic.

7. The patient transport device of claim 6, wherein the sensor is adapted to sense a selected one of the following response characteristics: position, velocity, acceleration, and force.

8. The patient transport device of claim 6, further comprising a controller in electrical communication with the force generator and the sensor, the controller adapted to receive the sensor signal and apply a control law to generate a control signal.

9. The patient transport device of claim 8, wherein the sensor, controller, and force generator are part of the same component.

10. The patient transport device of claim 1, wherein the patient support is adapted to couple to an incubator for neonatal transport.

11. The patient transport device of claim 1, wherein the patient support is adapted to couple to a transport bed for juvenile and adult transport.

12. The patient transport device of claim 1, further comprising a support reference removable coupled to a frame of the patient transport device such that the patient support device may be removed from the frame.

13. The patient transport device of claim 1, wherein the force generator is adapted to dynamically generate the second energy input based on a negative feedback control loop.

14. A method for reducing the effect of an external energy input to a patient during transport, comprising:
   providing a patient transport device having a patient support coupled to an active control system that includes a sensor in electrical communication with a controller that is in electrical communication with a force generator, the force generator adapted to at least generate and control linear motion of the patient support;
   sensing a response characteristic of the patient support as a result of the external energy input;
   sending a sensor signal representative of the response characteristic to the controller;
   generating a control signal based on the sensor signal that is representative of a second energy input required;
   sending the control signal to a force generator; and
   inputting a second energy into the patient transport device to reduce the amount of the external energy that is transmitted to the patient support.
16. The method of claim 15, wherein sensing a response characteristic includes sensing the position of the patient support with respect to a support reference, and the inputting second energy input includes generating a force input of an amount and direction sufficient to cause the distance between the patient support and the support reference to remain constant.

17. The method of claim 15, wherein sensing a response characteristic includes sensing either position, velocity, or acceleration of the patient support.

18. The method of claim 15, wherein the sensing a response characteristic includes sensing position, and further includes determining the velocity of the patient support.

19. The method of claim 15, wherein the second energy input is proportional to the position and velocity of the patient support.

20. A transport device adapted to reduce the impact of an external energy transmitted to the device on an item being transported, comprising:
   a support member;
   one or more passive energy devices coupled to the support member and adapted to absorb at least a portion of the external energy; and
   a force generator controllably coupled to the support member and configured to provide a second energy input into the device to reduce the effect of the external energy input on the support member, the force generator being controlled through a feedback control loop.

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