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(54) Title: PITCH-PROPELLED VEHICLE

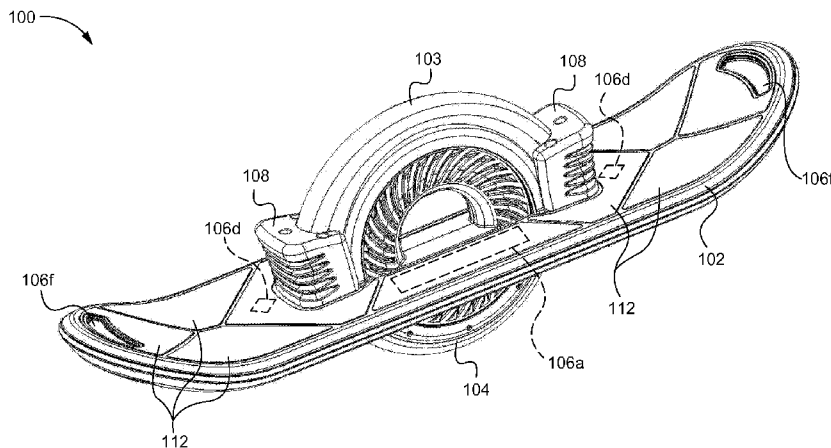


Fig. 1B

(57) Abstract: A method, system and apparatus for carrying a user including a board for supporting the user, a ground-contacting member coupled with the board, a motorized drive assembly coupled with the ground-contacting member and one or more sensors coupled with the drive assembly. In operation, the drive assembly adjusts the velocity of the ground-contacting member based on one or more distances of the board from a surface below the board as detected by the sensors. As a result, the system is able to maintain a desired velocity when ascending, descending or traversing uneven ground without the need for excessive and sometimes impossible tilting of the board.

## PITCH-PROPELLED VEHICLE

### Field of the Invention:

5 The present invention relates to the field of vehicles. More specifically, the present invention relates to the field of vehicles having pitch-sense based motion.

### Background of the Invention:

10 There are many known types of commercial and recreational vehicles for transporting people. Most of these vehicles are designed to be stable with respect to tipping by incorporating three or four wheels that balance and support the user and the remainder of the vehicle. For example, a skateboard is a well known vehicle that uses four wheels that are positioned to create a stable platform for the board and the user in all directions. However, many users enjoy the challenge of riding at least partially unstable vehicles. A scooter is an example of such a partially unstable vehicle because it is stable in the direction of the  
15 alignment of the wheels, but can tip side to side perpendicular to the alignment. Similarly, a unicycle, which uses a single wheel, is unstable with respect to tipping in all directions.

20 Recently, vehicles, such as a segway, have been created that utilize balance assisting systems to not only help stabilize an otherwise unstable vehicle, but also utilize the tipping of the vehicle to control its movement. Although this stabilization and movement control works well on even surfaces, it is unable to adequately operate on or adjust to uneven surfaces which are often encountered when riding such a vehicle. Further, they are able to be both complicated and expensive in design, which increases the likelihood of breaking down, the cost of repairs and the overall cost of manufacture.

### Summary of the Invention:

25 A vehicle for carrying a user including a board for supporting the user, a ground-contacting member coupled with the board, a motorized drive assembly coupled with the ground-contacting member and one or more sensors coupled with the drive assembly. In operation, the drive assembly adjusts the velocity of the ground-contacting member based on  
30 one or more distances of the board from a surface below the board as detected by the sensors.

As a result, the system is able to maintain a desired velocity when ascending, descending or traversing uneven ground without the need for excessive and sometimes impossible tilting of the board.

In one aspect the present application relates to a vehicle for carrying a user. The vehicle comprises a board for supporting the user, a ground-contacting member coupled with the board, a motorized drive assembly coupled with the ground-contacting member and one or more sensors coupled with the drive assembly, wherein the drive assembly adjusts the velocity of the ground-contacting member based on one or more distances of the board from a surface below the board as detected by the sensors. In some embodiments, the board is elongated along a dimension in a fore-aft plane that aligns with the forward and reverse directions of travel of the vehicle. In some embodiments, one or more fore sensors of the sensors are positioned at the fore end of the elongated dimension of the board and one or more aft sensors of the sensors are positioned at the aft end of the elongated dimension of the board. In some embodiments, the drive assembly adjusts the velocity of the ground-contacting member based on the one or more distances by using the distances to calculate a pitch of the board with respect to the surface and applying a force to the ground-contacting member in order to achieve a predefined velocity of the ground-contacting member that corresponds to the pitch. In some embodiments, the pitch is calculated by determining a difference between one or more distances and an average of two or more of the distances such that the drive assembly adjusts for unevenness in the surface. In some embodiments, the board as balanced by the ground-contacting member is unstable with respect to tipping along the fore-aft plane when the motorized drive assembly is not in operation, and the motorized drive assembly is configured to automatically balance the board with respect to tipping along the fore-aft plane when the motorized drive assembly is in operation. The vehicle is able to further comprise a vehicle locking module operatively coupled with the drive assembly, wherein the vehicle locking module prevents operation of the drive assembly when locked. In some embodiments, the ground-contacting member comprises one of the group consisting of a wheel, a ball, a tread and arcuate sections of a discontinuous wheel. The vehicle is able to further comprise one or more locking fasteners coupled to the board, wherein the ground-contacting member is able to selectively couple and decouple from the board via the fasteners

by locking or unlocking the fasteners. The vehicle is able to further comprise one or more grips coupled to the top of the board such that the grips protruding above the board for a user to lift the board with their feet. In some embodiments, the sensors are acoustic sensors and the drive assembly comprises a direct drive motor that drives the ground-contacting member.

5 In some embodiments, the drive assembly delays each adjustment of the velocity of the ground-contacting member for a period, wherein the length of the period for each adjustment is based on a calculated time that the ground-contacting member will contact a point on the surface on which the adjustment was based. In some embodiments, the vehicle further comprises one or more rider sensors coupled to the ground-contacting member, wherein the

10 rider sensors sense when a user or payload is on the board based on a force on the board by the ground-contacting member detected by the rider sensors.

Another aspect of the present application relates to a method of carrying a user. The method comprises assuming a position on a vehicle comprising a board for supporting the user, a single ground-contacting member coupled with the board, a motorized drive assembly

15 coupled with the ground-contacting member and one or more sensors coupled with the drive assembly, wherein the drive assembly adjusts the velocity of the ground-contacting member based on one or more distances of the board from a surface below the board as detected by the sensors and operating the vehicle by causing the board to tilt with respect to the surface. In some embodiments, the board is elongated along a dimension in a fore-aft plane that aligns

20 with the forward and reverse directions of travel of the vehicle. In some embodiments, one or more fore sensors of the sensors are positioned at the fore end of the elongated dimension of the board and one or more aft sensors of the sensors are positioned at the aft end of the elongated dimension of the board. In some embodiments, the drive assembly adjusts the velocity of the ground-contacting member based on the one or more distances by using the

25 distances to calculate a pitch of the board with respect to the surface and applying a force to the ground-contacting member in order to achieve a predefined velocity of the ground-contacting member that corresponds to the pitch. In some embodiments, the pitch is calculated by determining a difference between one or more distances and an average of two or more of the distances such that the drive assembly adjusts for unevenness in the surface. In

30 some embodiments, the board as balanced by the ground-contacting member is unstable with

respect to tipping along the fore-aft plane when the motorized drive assembly is not in operation, and the motorized drive assembly is configured to automatically balance the board with respect to tipping along the fore-aft plane when the motorized drive assembly is in operation. In some embodiments, the vehicle further comprises a vehicle locking module operatively coupled with the drive assembly, wherein the vehicle locking module prevents operation of the drive assembly when locked. In some embodiments, the ground-contacting member comprises one of the group consisting of a wheel, a ball, a tread and arcuate sections of a discontinuous wheel. The method is able to further comprise selectively coupling or decoupling the ground-contacting member from the board via one or more locking fasteners coupled to the board by locking or unlocking the fasteners. In some embodiments, the vehicle further comprises one or more grips coupled to the top of the board such that the grips protruding above the board for a user to lift the board with their feet. In some embodiments, the sensors are acoustic sensors and the drive assembly comprises a direct drive motor that drives the ground-contacting member. In some embodiments, the drive assembly delays each adjustment of the velocity of the ground-contacting member for a period, wherein the length of the period for each adjustment is based on a calculated time that the ground-contacting member will contact a point on the surface on which the adjustment was based. In some embodiments, the vehicle further comprises one or more rider sensors coupled to the ground-contacting member, wherein the rider sensors sense when a user or payload is on the board based on a force on the board by the ground-contacting member detected by the rider sensors.

In yet another aspect, the present application relates to a vehicle for carrying a user. The vehicle comprises an elongated board for supporting the user, wherein the board is elongated along a dimension in a fore-aft plane that aligns with the forward and reverse directions of travel of the vehicle, a single ground-contacting member coupled with the board, one or more sensors coupled to the board and a motorized drive assembly operatively coupled with the ground-contacting member and the sensors, wherein the drive assembly adjusts the velocity of the ground-contacting member based on a pitch of the board as indicated by one or more distances of the board from a surface below the board detected by the sensors, wherein the motorized drive assembly automatically stabilizes the board about the ground-contacting member such that desired distances between the surface and the fore end and the surface and

the aft end of the board are maintained, wherein the desired distances are dynamically determined as an average current distance detected between the fore end of the board and the surface and the aft end of the board and the surface. In some embodiments, the pitch is defined as a degree of deviation from an angle of the board about the ground-contacting member when automatically stabilized by the drive assembly.

#### Brief Description of the Drawings:

Figure 1A illustrates a side view of a pitch propelled vehicle according to some embodiments.

Figure 1B illustrates a top perspective view of a pitch propelled vehicle according to some embodiments.

Figure 1C illustrates a bottom perspective view of a pitch propelled vehicle according to some embodiments.

Figure 1D illustrates a top view of a pitch propelled vehicle according to some embodiments.

Figure 1E illustrates a bottom view of a pitch propelled vehicle according to some embodiments.

Figure 2 illustrates a block diagram of an exemplary controller according to some embodiments.

Figure 3 illustrates a flow chart of a method of carrying a user according to some embodiments.

#### Detailed Description:

Embodiments of a system, device and method of a pitch-propelled vehicle including a board for supporting the user, a ground-contacting member coupled with the board, a motorized drive assembly coupled with the ground-contacting member and one or more sensors coupled with the drive assembly. In operation, the drive assembly adjusts the velocity of the ground-contacting member based on one or more distances of the board from a surface below the board as detected by the sensors. As a result, the vehicle provides the advantage of altering the pitch/velocity relationship when traveling uphill, downhill or on uneven surfaces

that make a pitch/velocity relationship with respect to gravity untenable. As used herein the term “ground” is able to be the earth, the floor or any other surface over which the vehicle 100 is able to travel.

5 Figures 1A-1E illustrate a pitch-propelled vehicle 100 according to some embodiments. As shown in Figures 1A-1E, the vehicle 100 comprises a platform or board 102, a guard 103, a ground-contacting member 104, a drive assembly 106(a-g), one or more grips 108 and one or more scrapers 109 all operatively coupled together. Alternatively, one or more of the above components are able to be omitted. The board 102 is able to be rigid and detachably coupled to the ground-contacting member 104 such that when balanced the  
10 ground-contacting member 104 is able to hold/support the board 102 and the board 102 is able to support the rider(s) above the ground. In some embodiments, the board 102 comprises a member fastener assembly 105 that detachably couples the ground-contacting member 104 and/or some or all of the drive assembly 106(a-g) to the board 102. As a result, the ground-contacting member 104 is able to be selectively separated from or coupled to the  
15 board 102 by unlocking or locking the member fastener 105. This locking/unlocking mechanism of the member fastener 105 is able to be a key lock, a snap-fit connection, screw on/off or other types of fasteners that are able to hold the ground-contacting member 104 and/or some or all of the drive assembly 106(a-g) in a locked position with respect to the board 102. Thus, the vehicle 100 provides the advantage of easily replacing or repairing the  
20 board 102 and/or the ground-contacting member 104 using the member fastener 105.

As shown in Figure 1A, the guard 103 shields a rider from the top of the ground-contacting member 104 as it protrudes through the board 102. This provides the advantage of preventing a rider from being injured by stepping on or otherwise contacting the ground-contacting member 104. Although as shown, the guard 103 covers a portion of the sides of  
25 the ground-contacting member 104 as it protrudes through the top of the board 102, it is understood that more or less (e.g. all) of the ground-contacting member 104 is able to be shielded by the guard 103. As shown in Figure 1A, two scrapers 109 are positioned on either side of the ground-contacting member 104 such that the scrapers 109 are adjacent to and/or surround lower ends of the member 104. As a result, the scrapers 109 are able to protect the  
30 vehicle 100 from debris such as rocks from entering the vehicle 100 between the ground-

contacting member 104 and the board 102. In particular, the scrapers 109 are able to be sized to fill any gap between the ground-contacting member 104 and the underside of the board 102 and/or be positioned as close as possible to the ground-contacting member 104 to block debris from entering the vehicle 100 through such a gap. Further, it is contemplated that the guard 103 and/or grips 108 are able to be similarly positioned on the top of the board 102 to block debris from entering the vehicle 100 through a gap between the board 102 and the ground-contacting member 104 on the top side of the board 102. Additionally, it is contemplated that more or less than two scrapers 109 are able to be used.

The board 102 is able to have a thickness and broad and/or substantially flat top/bottom surface for receiving/supporting the feet of a rider. In some embodiments, the board 102 is able to have an oblong top surface with an elongated dimension in a fore/aft direction similar to the board of a skateboard. In particular, this elongated dimension is able to substantially align with the orientation of the ground-contacting member 104 such that a rider is able to ride the board 102 sideways to the direction of travel like one would ride a skateboard. Alternatively, the top surface of the board 102 is able to be substantially circular, ovular, rectangular, square or otherwise shaped. As shown in Figures 1A-1E, the board 102 is able to angle upwards at the fore and aft ends in order to provide better control to a rider and to prevent the feet of the rider from sliding off the board 102. Alternatively, the board 102 is able to be flat or bend downwards or upwards at one or both of the ends at the same or different angles. In some embodiments, the board 102 is at least partially hollow such that the board 102 is able to house and protect some or all of the drive assembly 106, the grips 108 and/or the ground-contacting member 104. Alternatively, the board 102 is able to be solid. As shown in Figures 1B and 1D, the board 102 is able to have a textured surface 112 and/or include textured pads 112 coupled to the top surface of the board 102 in order to improve traction between the feet of the rider and the surface of the board 102.

As shown in Figures 1A-1E, the vehicle 100 comprises two grips 108 positioned adjacent to the member fastener 105 on the fore and aft ends of the board 102. Alternatively, any number of grips 108 are able to be used and positioned on any portion of the board 102. For example, the board 102 is able to have multiple coupling locations configured to releasably couple to one or more grips 108 such that a user is able to select an ideal location



and number of grips to releasably attach to the board 102. Alternatively or in addition, the coupling locations are able to be adjustable such that for each coupling location (and/or grip 108) a user is able to adjust the position of the grip from a range of positions enabled by the coupling location. Thus, the board 102 and grips 108 provide the advantage of enabling a user to adjust the width, orientation, number and/or other characteristics of the grips 108 in order to best grip the vehicle 100 with their feet. In the same manner, one or more of the grips 108 are able to be replaced on the board 102 with grips 108 of different sizes, colors, shapes and other characteristics as desired. In some embodiments, as shown in Figures 1A-1E, one or more of the grips 108 are able to be wholly or partially textured in order to increase the ability of a user to hold onto the grips 108 with their feet. Alternatively, the grips 108 are able to be omitted.

As shown in Figures 1A-1E, the ground-contacting member 104 is able to comprise a single wheel. In some embodiments, the ground-contacting member is able to be a wheel or wheels that have a small width such as 1.5 inches or less, or 1/5th the width of the board 102 or less, which enables the vehicle 100 to more easily be turned by tilting the board 102 and the wheel 104 to the left or the right side. Additionally, because the member 104 is detachably coupled to the board 102 as described above, members 104 having different widths and/or other dimensions are able to be interchanged as desired to adjust the characteristics of the balance and turning of the ground-contacting member 104 and thereby the vehicle 100. Alternatively, the ground-contacting member 104 is able to comprise, individually or in combination, wheels, balls, arcuate sections of a wheel or ball, clusters of wheels, tracks, treads or other types of ground-contacting members well known in the art. Further, although only a single ground-contacting member 104 is shown, a plurality of ground-contacting members 104 are contemplated. In some embodiments, the ground-contacting member 104 is able to comprise a plurality of grooves for operable coupling to the drive assembly 106 in order to be rotated and/or otherwise driven by the drive assembly 106. In such embodiments, the member 104 is able to be off-center with respect to the board 102,

which enables the board 102 to be closer to the ground when supported above the ground by the member 104. Alternatively or in addition, other power transfer mechanisms are able to be used such as an axle wherein the board 102 is centered about the axle and/or other mechanisms well known in the art.

5 As shown in Figures 1A-1E, the drive assembly 106 comprises one or more motors 106a, batteries 106b, controllers 106c, rider sensors 106d, ground sensors 106e and/or user displays 106f, safety elements 106g all operably coupled together in order to operate the vehicle 100. Alternatively, the drive assembly 106 is able to comprise more or less components and/or more or less quantities of each component. Although shown in particular  
10 positions within Figures 1A-1E, it is understood that one or more of the components of the drive assembly 106 are able to be positioned anywhere on or within the board 102. For example, in some embodiments only a single user display 106f is able to be used or the user displays 106f are able to be omitted. The drive assembly 106 is housed by the board 102. As a result, the board 102 is able to protect the drive assembly 106 from damage. Alternatively,  
15 one or more components of the drive assembly 106 are able to be fully or partially exposed. Although as shown in Figures 1C and 1E the vehicle 100 comprises a finite number of motors 106a, batteries 106b, controllers 106c, rider sensors 106d, ground sensors 106e, user displays 106f and/or safety elements 106g, it is understood that more or less of each are contemplated including the omission of one or more of the components.

20 The one or more motors 106a are operably and/or mechanically coupled to the ground-contacting member 104 in order to cause the ground-contacting member 104 to rotate and thereby stabilize and move the vehicle 100. In some embodiments, the motors 106a are able to engage or couple with the plurality of grooves within the ground-contacting member 104 in order to translate motion/power of the motors 106a to the ground-contacting member  
25 104. For example, one or more of the motors 106a are able to be electric and/or direct drive motors (e.g. motors with a direct drive mechanism that couples to the member without any reductions such as a gearbox) that directly mechanically couple with the grooves of the member 104 in order to cause the member 104 to rotate/actuate as controlled by the controllers 106c. As a result, in such embodiments the vehicle 100 is able to provide the  
30 advantages of increased efficiency due to no intermediary power loss, reduced noise and

longer lifetime due to less/simpler parts, high torque at lower revolutions per minute and faster/precise positioning by eliminating mechanical backlash, hysteresis and elasticity. Alternatively, one or more of the motors 106a are able to be non-direct drive and/or electric motors such as combustion, hydraulic or other types of direct or indirect drive motors.

5           The one or more batteries 106b are able to be coupled with and provide power to the motors 106a, controllers 106c, rider sensors 106d, ground sensors 106e, user displays 106f and/or safety elements 106g. In some embodiments, the batteries 106b are able to be rechargeable batteries that provide electrical power to the vehicle 100. In such embodiments, the vehicle 100 is able to comprise a port or plug from receiving electrical power from an  
10 outside source such as a power outlet. Alternatively in such embodiments, the vehicle 100 is able to comprise one or more solar arrays that are able to recharge the one or more batteries 106a. Alternatively, the batteries are able to be non-rechargeable such that they must be replaced periodically. In some embodiments, the batteries 106b are able to be positioned  
15 across from the motors 106a within the board 102 such that they balance the weight of the motors 106a within the board 102 about the ground-contacting element 104. Alternatively, the batteries 106b are able to be positioned anywhere on or within the board 102.

          The rider sensors 106d are able to be coupled to the ground-contacting member 104 and/or the board 102 such that the sensors 106d are able to sense when a user (or payload) is on the board 102. For example, one or more of the rider sensors 106d are able to be  
20 positioned on the top surface of the board 102 in order to sense when the feet of a rider or other payload is on the surface of the board 102. Alternatively, the rider sensors 106d are able to be positioned at other points on the vehicle 100. For example, one or more of the rider sensors 106d are able to be positioned at the coupling point (e.g. the member fastener 105) between the board 102 and the ground-contacting member 104 in order to measure the  
25 force applied to ground-contacting member 104 via the board 102 due to the weight of a user on the board 102. In some embodiments, the rider sensors 106d are able to comprise resistance sensors, force sensors, acoustic sensors, visual sensors, capacitive sensors or other types of sensors as are well known in the art. The force sensors are able to measure weight or the force at a point on the board 102 and/or the ground-contacting member 104, wherein a  
30 user or payload is determined to be present when the force measures exceeds a predefined

threshold. The acoustic sensors (e.g. sonar) are able to output an acoustic signal and based on any echo of the signal input by the sensors determine whether a user or payload is on the board 102. Similarly, the visual sensors (e.g. infrared) are able to output a visual signal (or simply utilize external visual signals) and determine if a user or payload is on the board 102 based on measured input light signals. Also, the capacitive sensors are able to detect a change in capacitance between the elements coupled to the board 102, wherein a user or payload is determined to be present when the capacitance between the elements is increased above a predefined threshold.

The ground sensors 106e are operatively (e.g. electrically) coupled with the controllers 106c in order to transmit signals to the controllers 106c based on their input. As shown in Figures 1C and 1E, the ground sensors 106 are able to be partially housed within and positioned on the bottom of the board 102 on either end (fore and aft) of the ground-contacting member 104. As a result, the ground sensors 106e are able to measure the distance between the board 102 and the ground on both ends of the board 102. Therefore, as described below with reference to the controllers 106c, based on these measured distances (and the preset distances of the sensors 106e from the ground-contacting member 104) the controllers 106c are able to determine the pitch of the board 102 relative to the ground. Alternatively, ground sensors 106e are able to be positioned on other portions of the board 102. In some embodiments, the ground sensors 106e are only positioned on a single end (fore or aft) of the board 102.

The ground sensors 106e are able to be acoustic sensor (e.g. sonar based sensors) that output an acoustic signal and then determine a distance between the sensor and the ground or another object based on the echo or reflection of the acoustic signal as received by the sensor 106e. Alternatively, the ground sensors 106e are able to be light sensors that, for example, output a light signal (e.g. infrared) and then determine a distance between the sensor and the ground or another object based on the reflection of the light signal as received by the sensor 106e. Alternatively, the ground sensors 106e are able to comprise acoustic sensors, light sensors, radio frequency sensors, force sensors, pressure sensors or a combination thereof.

The user displays 106f are operatively (e.g. electrically) coupled with the controllers 106c in order to receive display commands from the controllers 106f. As a result, the user

displays 106f are able to display information to the user about the vehicle 100 based on data received from the controllers 106c. For example, the displays 106f are able to display a charge level of the batteries 106b, a current speed of the vehicle 100, revolutions per minute of the ground-contacting member 104, a pitch level and direction of the board 102, a warning or repair message if the vehicle is in an unsafe or damaged condition, a current time and/or other types of information as are well known in the art. As shown in Figures 1B and 1D, the displays 106f are positioned at the fore and aft ends of the board 102. Alternatively, the displays 106f are able to be positioned on other portions of the board 102.

The safety elements 106g are able to comprise lights and/or speakers that output light and/or sound from the vehicle 100. For example, the safety elements 106g are able to comprise lights that light an area around the vehicle 100 such as the front path of the vehicle 100 like headlights on a car and/or the back of the vehicle 100 like tail lights on a car. In some embodiments, the safety element 106g closest to the direction of travel displays a white light to illuminate the upcoming road/surface. In some embodiments, the safety element 106g closest to the rear of the direction of travel displays a red light to indicate the back of the vehicle 100 and/or is able to be controlled by the controller 106c to light up when the vehicle 100 is decelerating/braking like car tail lights. In some embodiments, the color and/or operation of the safety elements 106g are able to switch based on the direction of travel of the vehicle 100. For example, a safety element 106g acting as a tail light is able to switch operation to act as a head light and vice versa when direction of the vehicle 100 is reversed. In some embodiments, the safety elements 106g are configured to sense ambient light and only activate when ambient light detected is less than a threshold level. Alternatively or in addition, the safety elements 106g are able to be activated or de-activated manually.

In some embodiments, the safety elements 106g are able to output a warning noise that warns people that the vehicle 100 is near. In some embodiments, the noise is able to change in tune, frequency or otherwise based on the acceleration, deceleration or other operations of the vehicle 100. In some embodiments, the safety elements 106g are able to couple with an audio source via the controller or separately such that they are able to produce audio based on the signal received from the audio source. For example, the safety elements 106g are able to play music from a radio or antenna and/or from another audio source device

(e.g. telephone, ipod). The safety elements 106g are operatively (e.g. electrically) coupled with the controllers 106c in order to receive commands from the controllers 106f. As a result, the user displays 106f are able to operate based on data received from the controllers 106c. As shown in Figures 1B and 1D, the safety elements 106g are positioned at the fore and aft ends of the board 102. Alternatively, the safety elements 106g are able to be positioned on other portions of the board 102.

The controllers 106c are operably coupled to the motors 106a, the rider sensors 106d, the ground sensors 106e, the user displays 106f and/or safety elements 106g in order to control their operation according to a predefined operation protocol module as described below. In some embodiments, the controllers 106c and one or more other components of the vehicle 100 are able to be coupled together by a controller area network (CAN) bus. Alternatively, other networks are able to be used. Figure 2 illustrates a block diagram of an exemplary controller 106c according to some embodiments. As shown in Figure 2, the controller 106c comprises a network interface 202, a memory 204, a processor 206, I/O device(s) 208, a bus 210 and a storage device 212. Alternatively, one or more of the illustrated components are able to be removed or substituted for other components well known in the art. The choice of processor is not critical as long as a suitable processor with sufficient speed is chosen. The memory 204 is able to be any conventional computer memory known in the art. The storage device 212 is able to include a hard drive, CDROM, CDRW, DVD, DVDRW, flash memory card or any other storage device. The controller 106c is able to include one or more network interfaces 202. An example of a network interface includes a network card connected to an Ethernet or other type of LAN. The I/O device(s) 208 are able to include one or more of the following: keyboard, mouse, monitor, display, printer, modem, touchscreen, button interface and other devices. The operation protocol 230 used to operate the vehicle 100 is able to be stored in the storage device 212 and memory 204 and processed as programs are typically processed. More or less components shown in Figure 2 are able to be included in the controller 106c. In some embodiments, operation protocol hardware 220 is included, wherein the hardware implements a portion or all of the operation protocol. Although as shown in Figure 2, the controller 106c includes software 230 and hardware 220 for implementing the operational protocol, the operation protocol is able to be implemented

in hardware, firmware, software or any combination thereof. Additionally, the controller 106c is able to comprise one or more components not shown in Figure 2 that enable the controller 106c to perform commutation and other calculations. For example, the controller 106c is able to comprise an encoder for encoding the position of the ground-contacting member 104 relative to the board 102 or another static marker. These components are well known in the art and not described herein for the sake of brevity.

In operation, when implementing the operation protocol, the controller 106c determines the distance between one or both the fore and aft ends of the board 102 and the ground (or surface below the board 102) based on the input from one or more of the ground sensors 106e. Subsequently, based on the determined distance(s), the controller 106c calculates a pitch of the board 102 relative the ground and causes the motors 106a to apply a force to the ground-contacting member 104 based on the determined board pitch. For example, if the controller 106c determines that the board 102 is pitched at a first level, the controller 106c causes the ground-contacting member 104 (via the motors 106a) to slow down, speed up and/or reverse direction in order to approach and eventually match a desired velocity, acceleration and/or torque associated with the pitch of the first level. As a result, in general, when a user leans to pitch the board 102 in the aft or fore directions relative to the ground, the controller 106c will cause the ground-contacting member 104 and thus the vehicle 100 to move (or reverse direction and then move) in the aft or fore directions, respectively. As a result, the vehicle 100 provides the advantage of compensating for changes in ground level when determining the pitch of the board because the board pitch is determined relative to the ground. This is important when the vehicle 100 is traversing uneven surfaces as they can limit the ability of the board to pitch. For example, in systems where pitch is based on a deviation of the board angle with respect to gravity, when going up hill it can become difficult or impossible to keep the board pitched forward because the hill/ground blocks further pitching. In contrast, the pitch-propelled vehicle 100 described herein is able to determine the pitch relative to the hill/ground such that less forward pitch is still able to cause the vehicle 100 to move forward at the desired rate.

In some embodiments, the board pitch is dynamically determined based on an average of the current distance detected between the fore end of the board 102 and the surface and the

current distance detected between the aft end of the board 102 and the surface as detected by one or more of the ground sensors 106e. Alternatively, the board pitch is able to be dynamically determined by the distance detected between only one end of the board 102 and the surface. Alternatively, the board pitch is able to be dynamically determined based on the difference between the current distance detected between the fore end of the board 102 and the surface and the current distance detected between the aft end of the board 102 and the surface.

In some embodiments, the controller 106c takes into consideration detected changes in the surface that are about to be traversed by the ground-contacting member 104 when adjusting the force applied to the ground-contacting member 104 in order to achieve the desired velocity, acceleration and/or torque. In particular, because the sensors 106e are a distance in front (and behind) the ground-contacting member 104, they are able to detect (or map) characteristics of and changes in the ground/surface before the ground-contacting member 104 reaches the changes. As a result, the controller 106c is able to adjust the command signals sent to the ground-contacting member 104 based on the characteristics/changes in the ground before the ground-contacting member 104 has encountered the characteristics/changes. In such embodiments, the controller 106c is able to determine a time in the future when the ground-contacting member 104 is expected to reach the characteristics/changes and adjust the timing of the control signals associated with the characteristics/changes to correspond to the determined time. The time is able to be determined based on the current position of the ground-contacting member 104 relative to the characteristics/changes and the velocity, acceleration and/or torque of the ground-contacting member 104.

For example, if the controller 106c detects an upcoming inclination of the surface (based on the current direction of travel, a previously determined distance and the currently determined distance between the surface and one or more of the ground sensors 106e on leading side of the direction of travel), the controller 106c is able to increase the amount of force applied to the ground-contacting member 104 to compensate for the anticipated upcoming inclination. Similarly, the force is able to be decreased to compensate for anticipated upcoming declination. In other words, even if the current detected pitch



corresponds to a first force level, a higher or lower force level is able to be applied in anticipation of the detected or mapped characteristics/changes. As a result, the vehicle 100 provides the advantage of providing predictive control of the ground-contacting member 104 to compensate for incoming obstacles and terrain.

5           In order to adjust the actuation of the motors 106a (and therefore the ground-contacting member 104), the controller 106c finely encodes (e.g. greater than 1,000 counts per revolution granularity) and monitors the position of the ground-contacting member 104 relative to the board 102. Using this detected current position as feedback, the controller 106c is able to utilize sinusoidal commutation to control the actuation of the motors 106a and thus the force applied to the ground-contacting member 104. This provides the advantage of creating smoother riding experience by eliminating the cogging produced by other commutation method especially at lower speeds. Alternatively, other types of commutation, such as trapezoidal (or “six-step”) commutation, are able to be used. In some embodiments, the controller 106c is able to incorporate a control loop feedback mechanism in order to  
10 analyze and adjust/compensate the control of the motors 106a based on the feedback (i.e. the detected current position of the ground-contacting member 104). For example, the controller 106c is able to incorporate a closed loop proportional-integral-derivative (PID) control feedback loop that receives the feedback, and based on the feedback transmits one or more error corrections signals that the controller 106c uses to adjust the commutation and/or  
15 control of the motors 106a. Alternatively, the PID controller is able to be open loop and/or other types of control loop feedback mechanisms are able to be used as are well known in the art. Alternatively, the controller 106c is able to control operation of the vehicle 100 without feedback.

25           Further, instead of equating pitch (relative to ground) to a desired torque, the controller 106c is able to be configured to equate pitch (relative to ground) to a desired acceleration. For example, the PID control feedback loop is able to be configured to determine acceleration error compensation instead of torque error compensation. As a result, the PID control feedback loop and the controller 106c provides the advantage of being able to devote greater bandwidth to adjusting for incoming surface changes such as bumps, holes or  
30 other inclines/declines. Alternatively, the PID control feedback loop is able to be otherwise

configured as desired in order to fine tune the compensation of the control signal as desired. Additionally, in some embodiments, the vehicle 100 is able to comprise one or more gyroscopic and/or acceleration sensors that transmit signals to the controllers 106c such that the controllers 106c are able to smooth or otherwise further process information received  
5 from the ground sensors 106e.

Figure 3 illustrates a flow chart of a method of carrying a user according to some embodiments. As shown in Figure 3, a user/rider assumes a position on the board 102 of the vehicle 100 at the step 302. The user/rider operates the vehicle 100 by causing the board 102 to tilt or pitch with respect to the surface such that the motors 106a cause the ground-  
10 contacting member 104 to propel the vehicle in the direction of the tilt/pitch at the step 304. In some embodiments, the user selectively couples or decouples the ground-contacting member 104 from the board 102 via one or more member fasteners 105 coupled to the board 102 by locking or unlocking the fasteners 105. In some embodiments, the user selectively couples or decouples the grips 108 from the board 102 via one or more fasteners coupled to  
15 the board 102 by locking or unlocking the fasteners. As a result, the method provides the advantage of compensating the board pitch determination to account for changes in the level of the ground or surface below the board 102.

The pitch propelled vehicle system, device and method described herein has numerous advantages. Specifically, as described above the vehicle provides the advantage of altering  
20 the pitch/velocity relationship to correspond to the surface below the board (as detected by e.g. acoustic sensors) when traveling uphill, downhill or on uneven surfaces that make a pitch/velocity relationship with respect to gravity untenable. Further, it provides the advantage of including foot grips that enable a user to jump or lift the board with their feet when approaching a curb or other obstacle. Moreover, it provides the advantage of enabling  
25 the ground-contacting member to be selectively released/decoupled from the board/drive assembly and selectively re-coupled or replaced with a different ground-contacting member. Additionally, the vehicle provides the advantage of utilizing a direct drive motor/mechanism that more efficiently transfers power to the ground-contacting member, provides better torque

at lower speeds, and conserves battery life. Also, the vehicle provides the advantage of using a thin wheel or other type of ground-contacting member, which enables the vehicle to be more easily turned via tilting the board sideways to the direction of travel.

The present invention has been described in terms of specific embodiments  
5 incorporating details to facilitate the understanding of principles of construction and  
operation of the invention. Such reference herein to specific embodiments and details thereof  
is not intended to limit the scope of the claims appended hereto. It will be readily apparent to  
one skilled in the art that other various modifications may be made in the embodiment chosen  
for illustration without departing from the spirit and scope of the invention as defined by the  
10 claims. For example, in some embodiments the drive assembly 106 is able to comprise a  
locking module or mechanism that enables a user to lock the vehicle in order to prevent theft.  
In particular, the controller 106c is able to be configured to prevent the vehicle 100 from  
operating unless a password is received via a user input, a RF signal is received that matches  
a predetermined signal, bluetooth connection is made to a mobile computing device having an  
15 identifier that is recognized, and/or other appropriate locking/unlocking methods.

## C L A I M S

What is claimed is:

1. A vehicle for carrying a user comprising:  
a board for supporting the user;  
a ground-contacting member coupled with the board;  
a motorized drive assembly coupled with the ground-contacting member; and  
one or more sensors coupled with the drive assembly, wherein the drive assembly adjusts the velocity of the ground-contacting member based on one or more distances of the board from a surface below the board as detected by the sensors.
2. The vehicle of Claim 1, wherein the board is elongated along a dimension in a fore-aft plane that aligns with the forward and reverse directions of travel of the vehicle.
3. The vehicle of Claim 2, wherein one or more fore sensors of the sensors are positioned at the fore end of the elongated dimension of the board and one or more aft sensors of the sensors are positioned at the aft end of the elongated dimension of the board.
4. The vehicle of Claim 1, wherein the drive assembly adjusts the velocity of the ground-contacting member based on the one or more distances by using the distances to calculate a pitch of the board with respect to the surface and applying a force to the ground-contacting member in order to achieve a predefined velocity of the ground-contacting member that corresponds to the pitch.
5. The vehicle of Claim 4, wherein the pitch is calculated by determining a difference between the one or more distances and an average of two or more of the distances such that the drive assembly adjusts for unevenness in the surface.

6. The vehicle of Claim 2, wherein the board as balanced by the ground-contacting member is unstable with respect to tipping along the fore-aft plane when the motorized drive assembly is not in operation, and the motorized drive assembly is configured to automatically balance the board with respect to tipping along the fore-aft plane when the motorized drive assembly is in operation.
7. The vehicle of Claim 1, further comprising a vehicle locking module operatively coupled with the drive assembly, wherein the vehicle locking module prevents operation of the drive assembly when locked.
8. The vehicle of Claim 1, wherein the ground-contacting member comprises one of the group consisting of a wheel, a ball, a tread and arcuate sections of a discontinuous wheel.
9. The vehicle of Claim 1, further comprising one or more locking fasteners coupled to the board, wherein the ground-contacting member is able to selectively couple and decouple from the board via the fasteners by locking or unlocking the fasteners.
10. The vehicle of Claim 1, further comprising one or more grips coupled to the top of the board such that the grips protruding above the board for a user to lift the board with their feet.
11. The vehicle of Claim 1, wherein the sensors are acoustic sensors and the drive assembly comprises a direct drive motor that drives the ground-contacting member.
12. The vehicle of Claim 1, wherein the drive assembly delays each adjustment of the velocity of the ground-contacting member for a period, wherein the length of the period for each adjustment is based on a calculated time that the ground-contacting member will contact a point on the surface on which the adjustment was based.

13. The vehicle of Claim 1, further comprising one or more rider sensors coupled to the ground-contacting member, wherein the rider sensors sense when a user or payload is on the board based on a force on the board by the ground-contacting member detected by the rider sensors.
14. A method for carrying a user comprising:  
assuming a position on a vehicle comprising:
  - a board for supporting the user;
  - a single ground-contacting member coupled with the board;
  - a motorized drive assembly coupled with the ground-contacting member; and
  - one or more sensors coupled with the drive assembly, wherein the drive assembly adjusts the velocity of the ground-contacting member based on one or more distances of the board from a surface below the board as detected by the sensors; andoperating the vehicle by causing the board to tilt with respect to the surface.
15. The method of Claim 14, wherein the board is elongated along a dimension in a fore-aft plane that aligns with the forward and reverse directions of travel of the vehicle.
16. The method of Claim 15, wherein one or more fore sensors of the sensors are positioned at the fore end of the elongated dimension of the board and one or more aft sensors of the sensors are positioned at the aft end of the elongated dimension of the board.
17. The method of Claim 14, wherein the drive assembly adjusts the velocity of the ground-contacting member based on the one or more distances by using the distances to calculate a pitch of the board with respect to the surface and applying a force to the ground-contacting member in order to achieve a predefined velocity of the ground-contacting member that corresponds to the pitch.

18. The method of Claim 17, wherein the pitch is calculated by determining a difference between the one or more distances and an average of two or more of the distances such that the drive assembly adjusts for unevenness in the surface.
19. The method of Claim 15, wherein the board as balanced by the ground-contacting member is unstable with respect to tipping along the fore-aft plane when the motorized drive assembly is not in operation, and the motorized drive assembly is configured to automatically balance the board with respect to tipping along the fore-aft plane when the motorized drive assembly is in operation.
20. The method of Claim 14, wherein the vehicle further comprises a vehicle locking module operatively coupled with the drive assembly, wherein the vehicle locking module prevents operation of the drive assembly when locked.
21. The method of Claim 14, wherein the ground-contacting member comprises one of the group consisting of a wheel, a ball, a tread and arcuate sections of a discontinuous wheel.
22. The method of Claim 14, further comprising selectively coupling or decoupling the ground-contacting member from the board via one or more locking fasteners coupled to the board by locking or unlocking the fasteners.
23. The method of Claim 14, wherein the vehicle further comprises one or more grips coupled to the top of the board such that the grips protruding above the board a user to lift the board with their feet.
24. The method of Claim 14, wherein the sensors are acoustic sensors and the drive assembly comprises a direct drive motor that drives the ground-contacting member.

25. The method of Claim 14, wherein the drive assembly delays each adjustment of the velocity of the ground-contacting member for a period, wherein the length of the period for each adjustment is based on a calculated time that the ground-contacting member will contact a point on the surface on which the adjustment was based.
26. The method of Claim 14, wherein the vehicle further comprises one or more rider sensors coupled to the ground-contacting member, wherein the rider sensors sense when a user or payload is on the board based on a force on the board by the ground-contacting member detected by the rider sensors.
27. A vehicle for carrying a user comprising:  
an elongated board for supporting the user, wherein the board is elongated along a dimension in a fore-aft plane that aligns with the forward and reverse directions of travel of the vehicle;  
a single ground-contacting member coupled with the board;  
one or more sensors coupled to the board; and  
a motorized drive assembly operatively coupled with the ground-contacting member and the sensors, wherein the drive assembly adjusts the velocity of the ground-contacting member based on a pitch of the board as indicated by one or more distances of the board from a surface below the board detected by the sensors;  
wherein the motorized drive assembly automatically stabilizes the board about the ground-contacting member such that desired distances between the surface and a fore end and the surface and an aft end of the board are maintained, wherein the desired distances are dynamically determined as an average current distance detected between the fore end of the board and the surface and the aft end of the board and the surface.
28. The vehicle of claim 27, wherein the pitch is defined as a degree of deviation from an angle of the board about the ground-contacting member when automatically stabilized by the drive assembly.



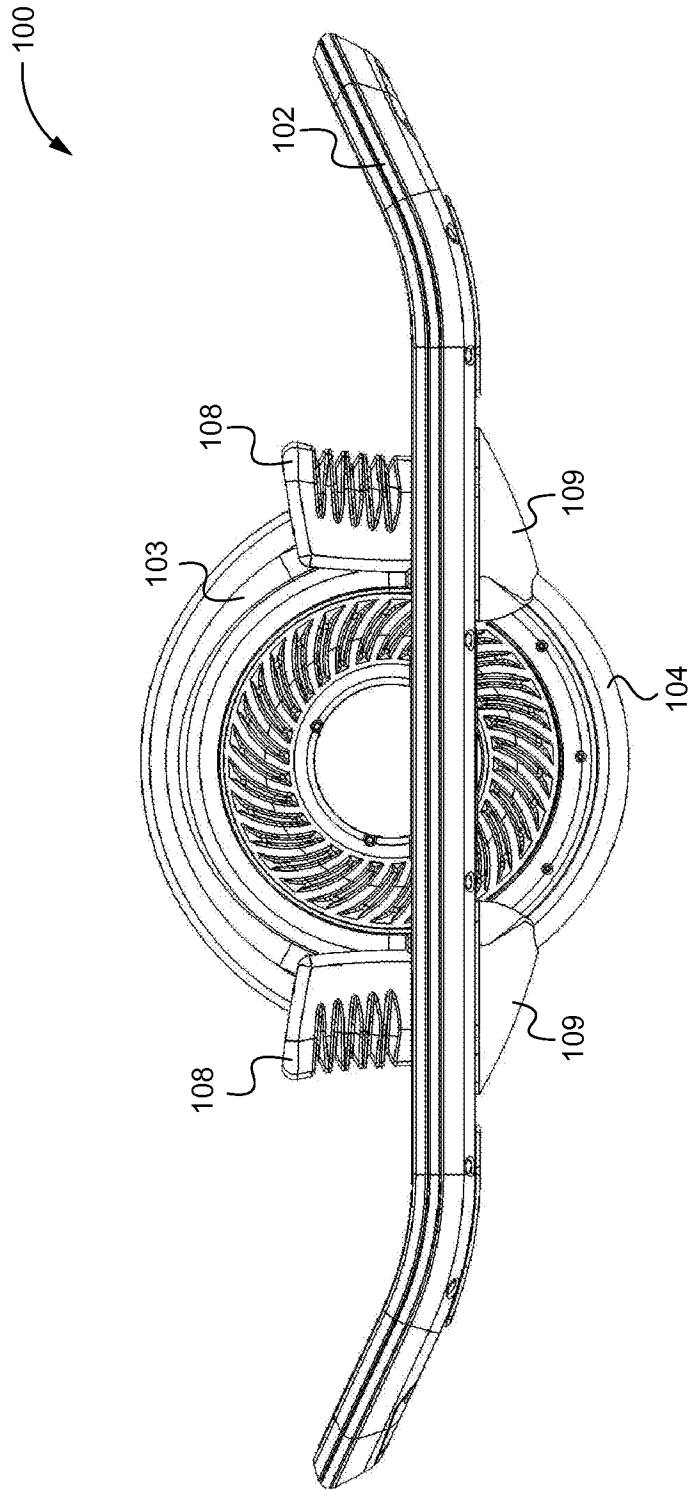
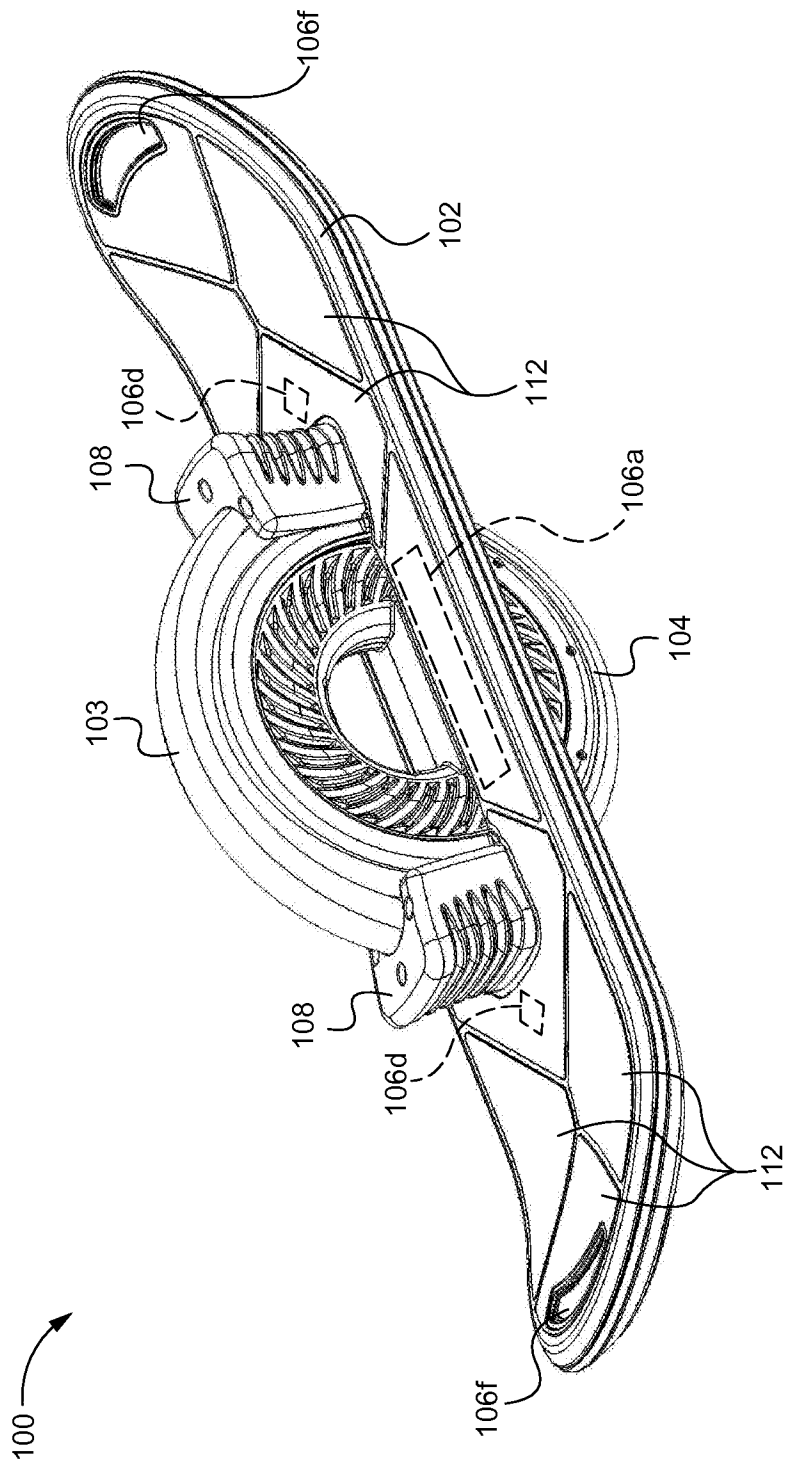
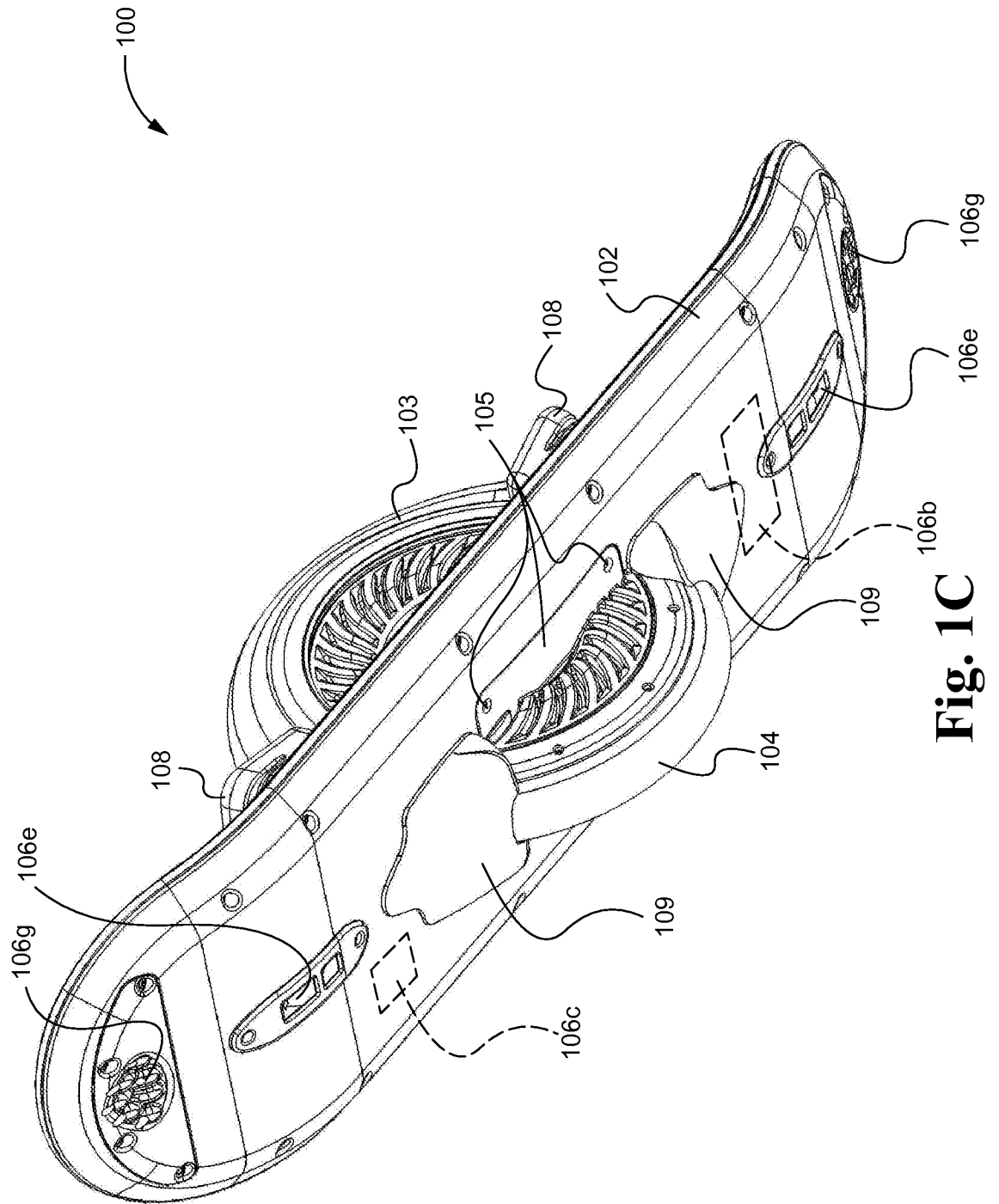


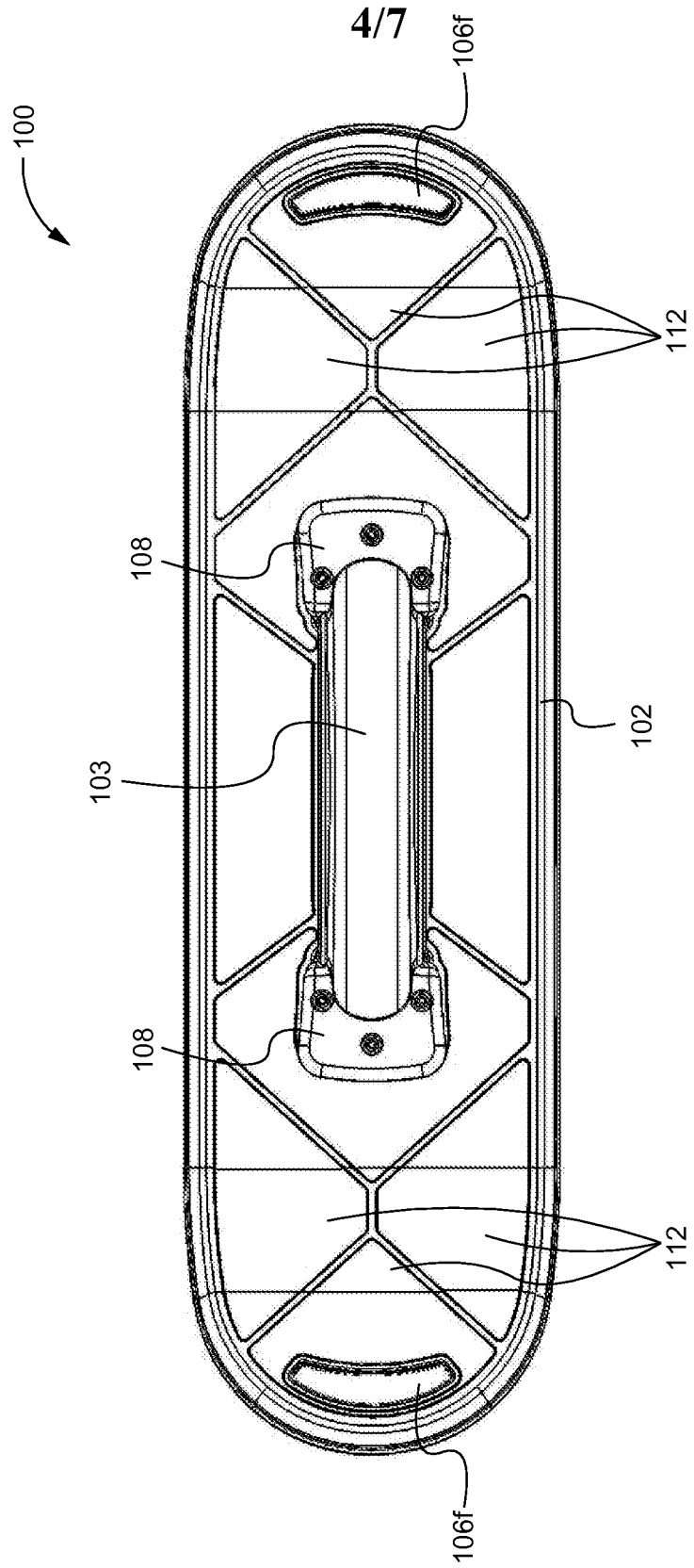
Fig. 1A



**Fig. 1B**

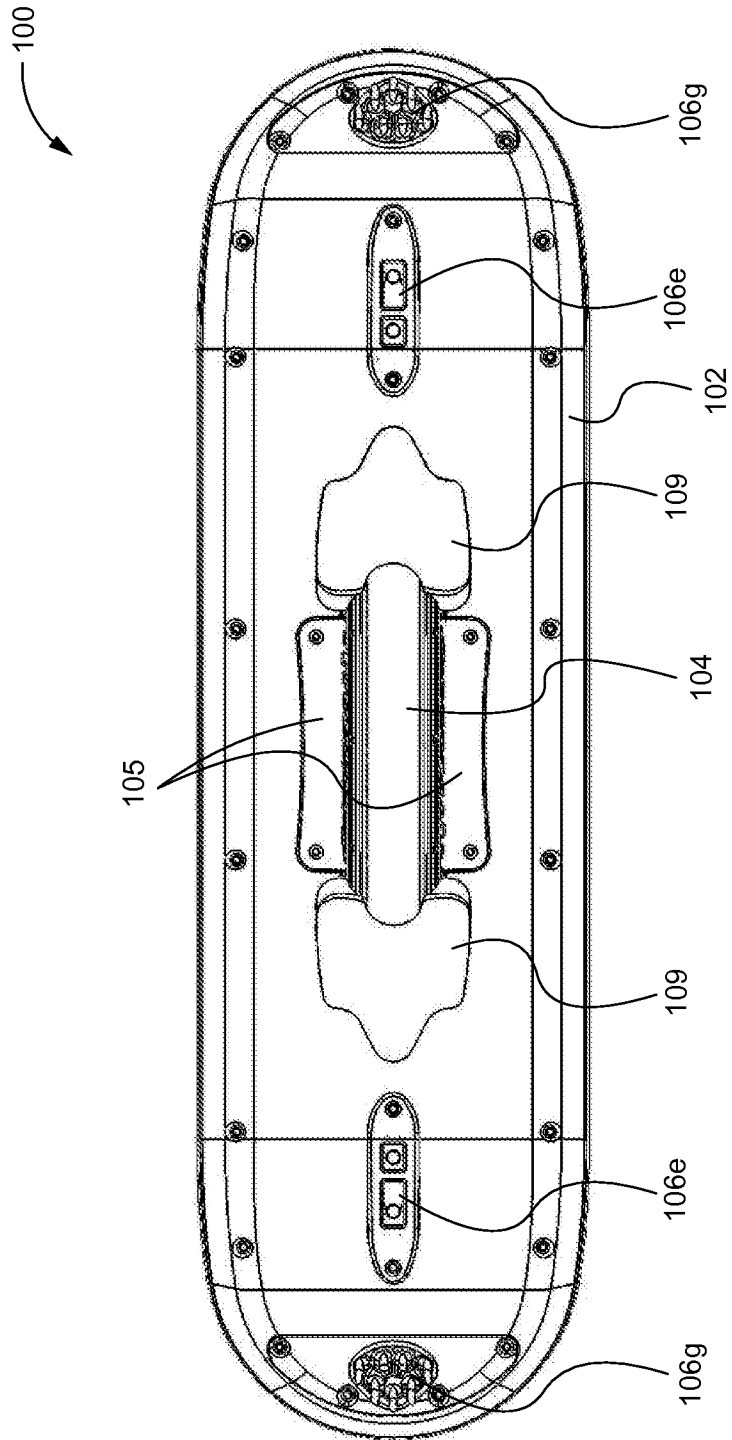


**Fig. 1C**

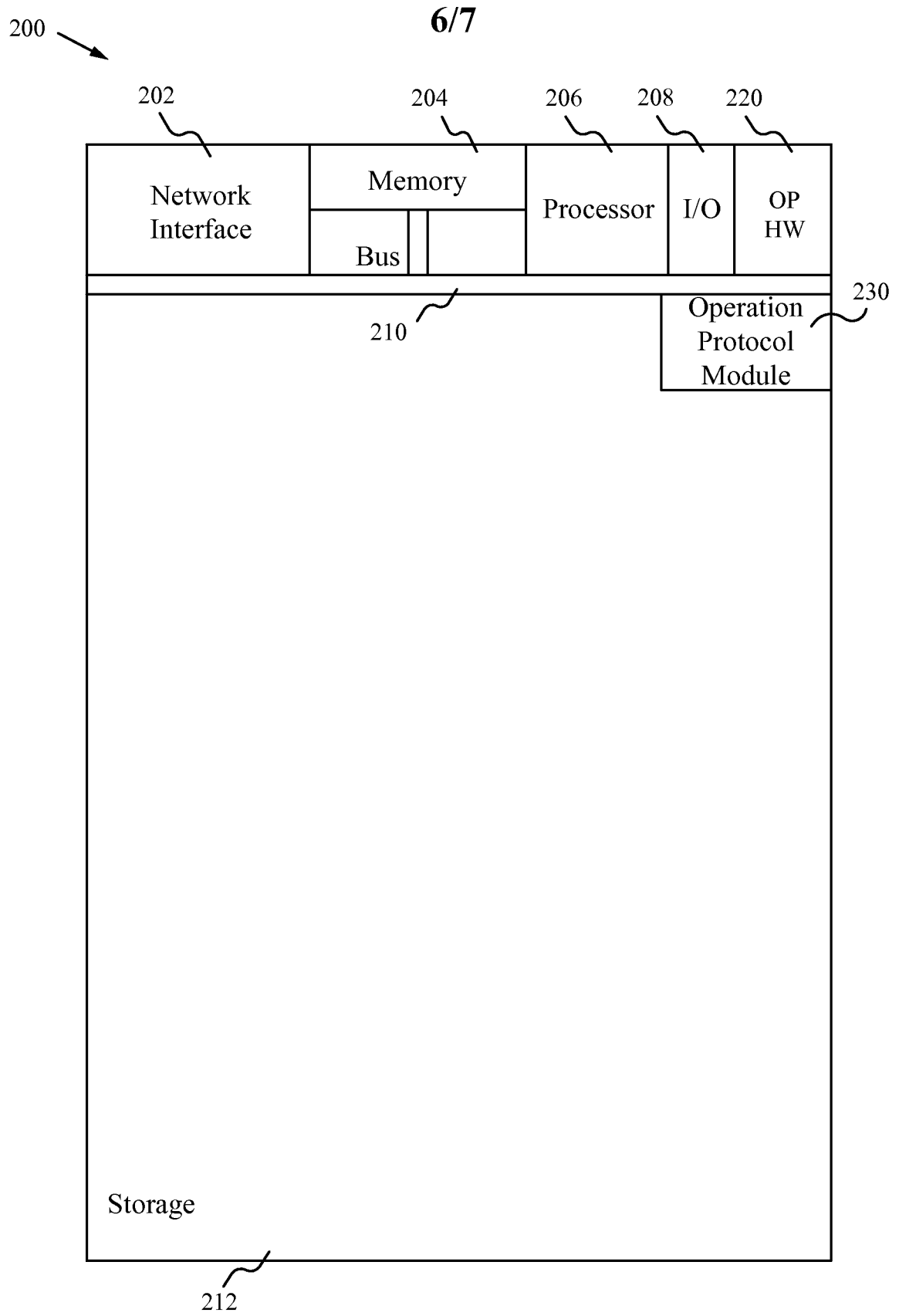


**Fig. 1D**

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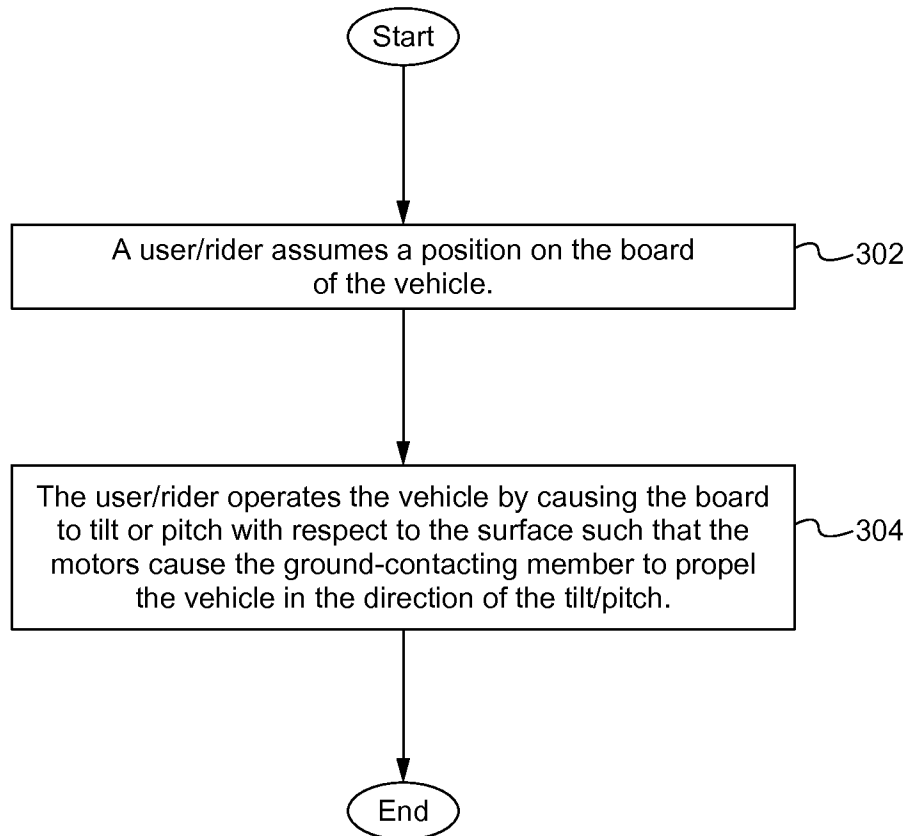


**Fig. 1E**



**Fig. 2**

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**Fig. 3**

**INTERNATIONAL SEARCH REPORT**

International application No.  
PCT/US2014/058912

**A. CLASSIFICATION OF SUBJECT MATTER**  
 IPC(8) - A63C 17/12 (2014.01)  
 CPC - A63C 17/12 (2014.09)  
 According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**  
 Minimum documentation searched (classification system followed by classification symbols)  
 IPC(8) - A63C 17/12, A63C 17/26, B60K 28/14 (2014.01)  
 USPC - 180/all, 21, 170-181, 186, 188, 282, 280/all, 6.15, 6.151-6.154, 11.24, 29, 78, 79.11, 87.01, 87.041-87.042

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  
 CPC - A63C 17/12, A63C 17/26, B60K 28/14 (2014.09) (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
 Orbit, Google Patents, Google Scholar.  
 Search terms used: velocity, speed, tilt, pitch, board, sense, detect, distance, ground, floor

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No.  |
|-----------|--|------------------------|
| X         | US 7,467,681 B2 (HIRAMATSU) 23 December 2008 (23.12.2008) entire document          | 1-8, 12, 14-21, 25     |
| ---       |  |                        |
| Y         |  | 9-11, 13, 22-24, 26-28 |
| Y         | US 6,311,795 B1 (SKOTNIKOV et al) 06 November 2001 (06.11.2001) entire document    | 27-28                  |
| Y         | WO 2012/113011 A1 (MORTON) 30 August 2012 (30.08.2012) entire document             | 9, 22                  |
| Y         | US 2006/0012141 A1 (BOUVET) 19 January 2006 (19.01.2006) entire document           | 10, 23                 |
| Y         | US 2011/0295454 A1 (MEYERS) 01 December 2011 (01.12.2011) entire document          | 11, 24                 |
| Y         | US 6,050,357 A (STAELIN et al) 18 April 2000 (18.04.2000) entire document          | 13, 26                 |

Further documents are listed in the continuation of Box C.

\* Special categories of cited documents:

|   |  |
|---|--|
| "A" document defining the general state of the art which is not considered to be of particular relevance  | "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention  |
| "E" earlier application or patent but published on or after the international filing date   | "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone   |
| "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) | "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art |
| "O" document referring to an oral disclosure, use, exhibition or other means  | "&" document member of the same patent family  |
| "P" document published prior to the international filing date but later than the priority date claimed  |  |

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| Date of the actual completion of the international search<br>10 December 2014 | Date of mailing of the international search report<br><b>07 JAN 2015</b> |
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| Name and mailing address of the ISA/US<br>Mail Stop PCT, Attn: ISA/US, Commissioner for Patents<br>P.O. Box 1450, Alexandria, Virginia 22313-1450<br>Facsimile No. 571-273-3201 | Authorized officer:<br>Blaine R. Copenheaver<br>PCT Helpdesk: 571-272-4300<br>PCT OSP: 571-272-7774 |
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