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(54) WHEELCHAIR MOBILITY SYSTEM AND METHOD

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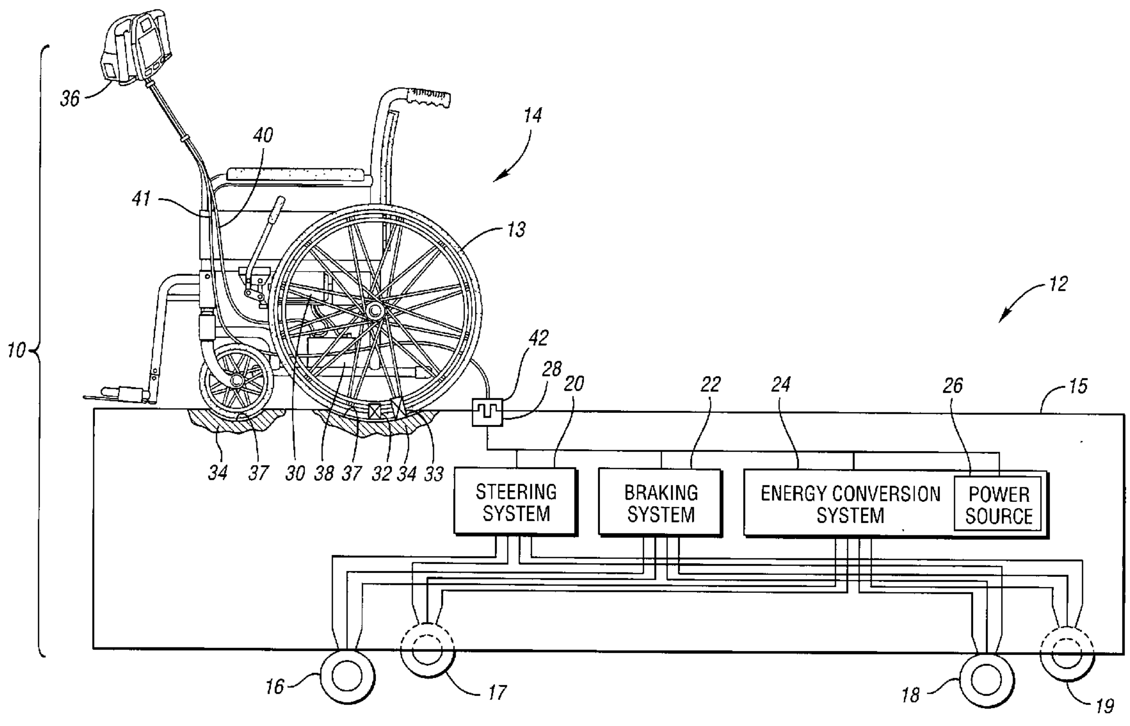
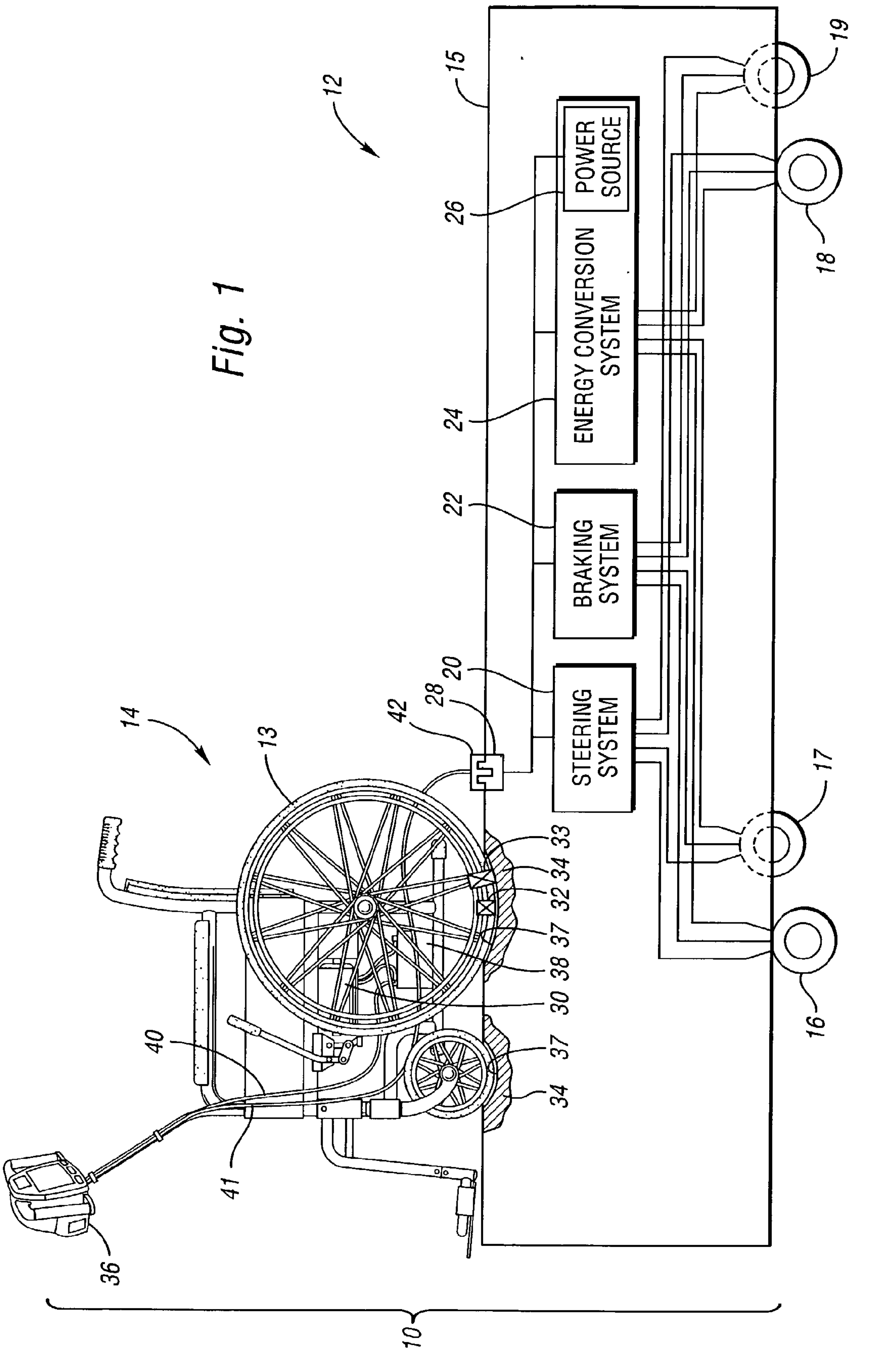
(52) **U.S. Cl.** **180/65.1**

(57) **ABSTRACT**

A wheelchair mobility system includes a wheelchair with an operator interface that controls the wheelchair and is connectable to a vehicle controllable through a drive-by-wire control so that it controls the vehicle. The wheelchair has a battery that may be recharged by the vehicle when the interface is connected. A method for enabling a wheelchair-bound person to drive a vehicle includes providing an operator-interface on a wheelchair usable for driving the wheelchair, providing access on the vehicle for receiving the wheelchair onboard the vehicle and providing a connector for connecting the operator interface and the vehicle so that the operator interface is usable for driving the vehicle. A method for the wheelchair-bound to drive includes driving a wheelchair through an operator interface, accessing a vehicle while wheelchair-bound and connecting the operator interface to the vehicle for controlling the vehicle.





POWER SOURCE
ENERGY CONVERSION SYSTEM
BRAKING SYSTEM
STEERING SYSTEM
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13
14
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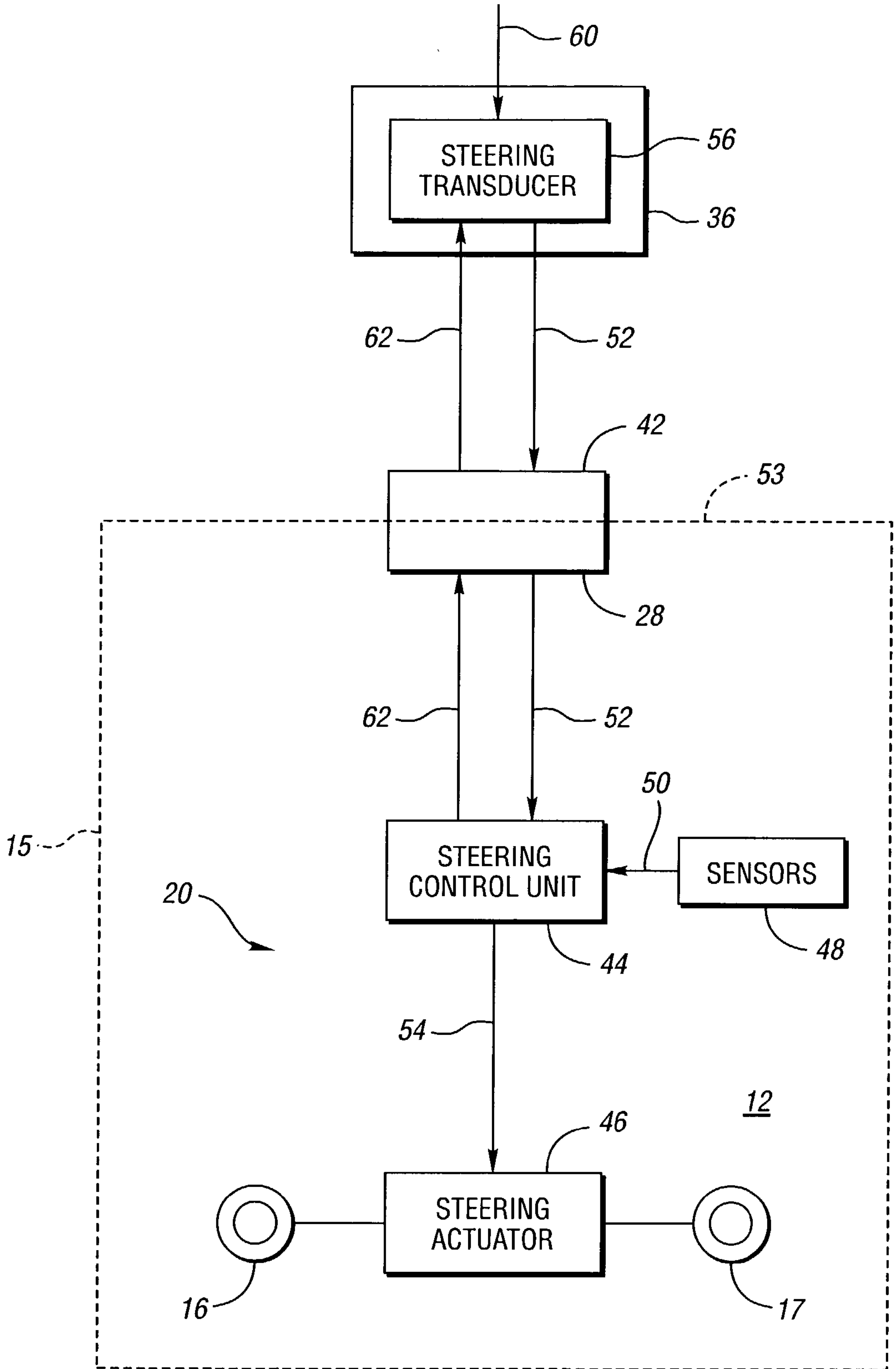
42

Fig. 1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STEERING
TRANSDUCER
56
36
62
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42
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28
62
52
50
15
STEERING
CONTROL UNIT
SENSORS
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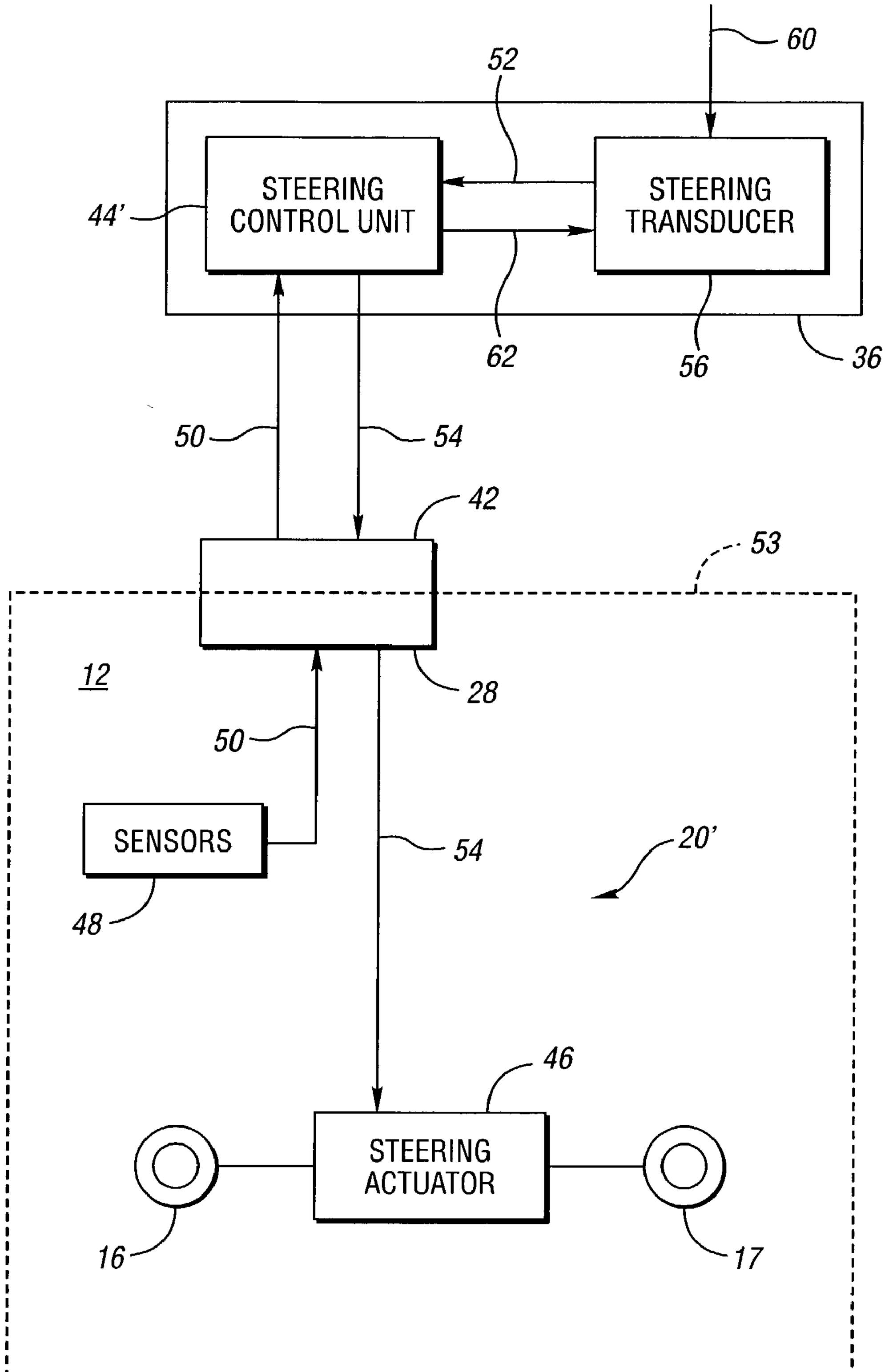
44
48
54
12
46
STEERING
ACTUATOR
16
17

Fig. 2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STEERING
ACTUATOR
16
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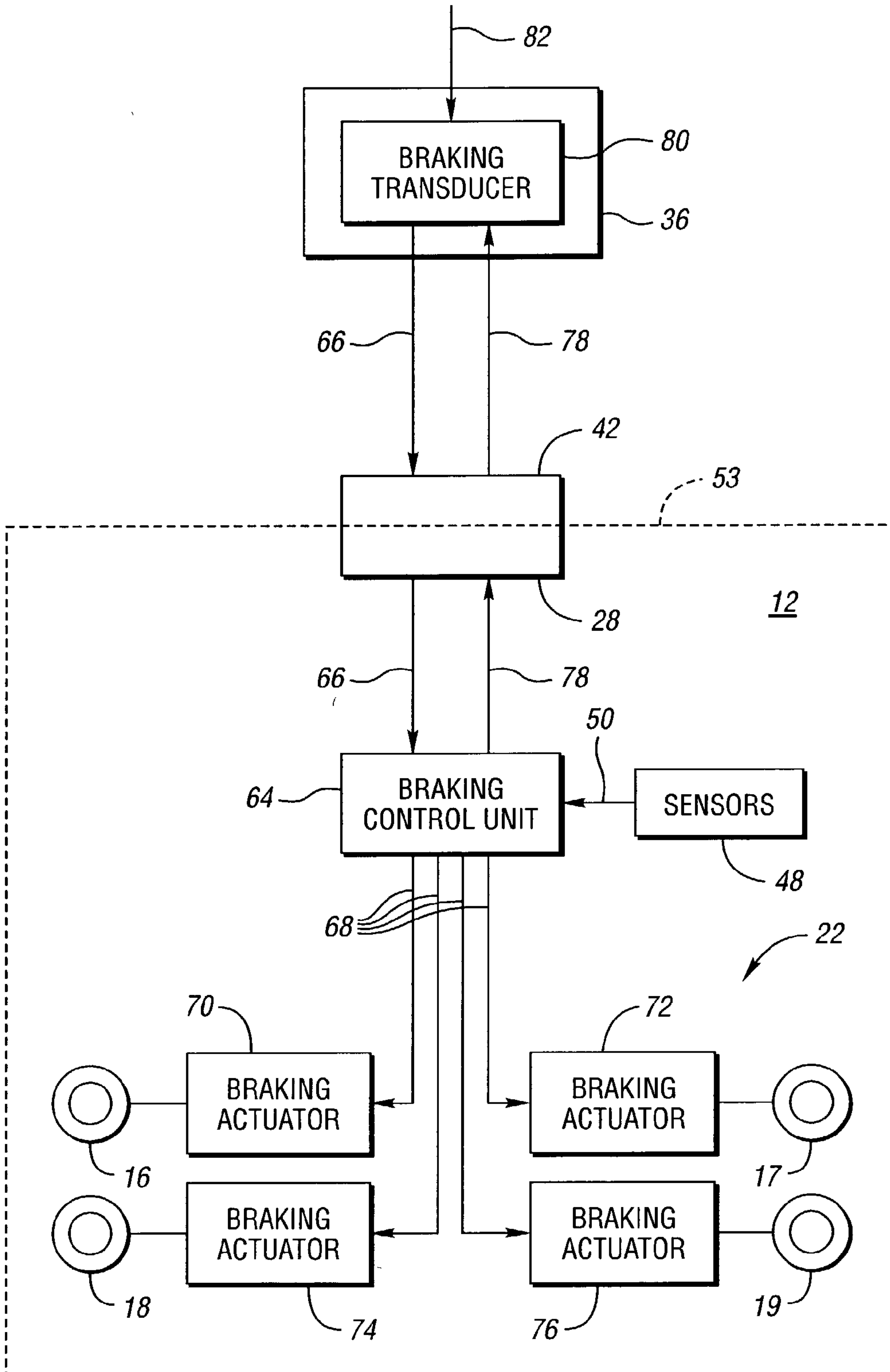
Fig. 3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BRAKING TRANSDUCER
80
36
66
78
42
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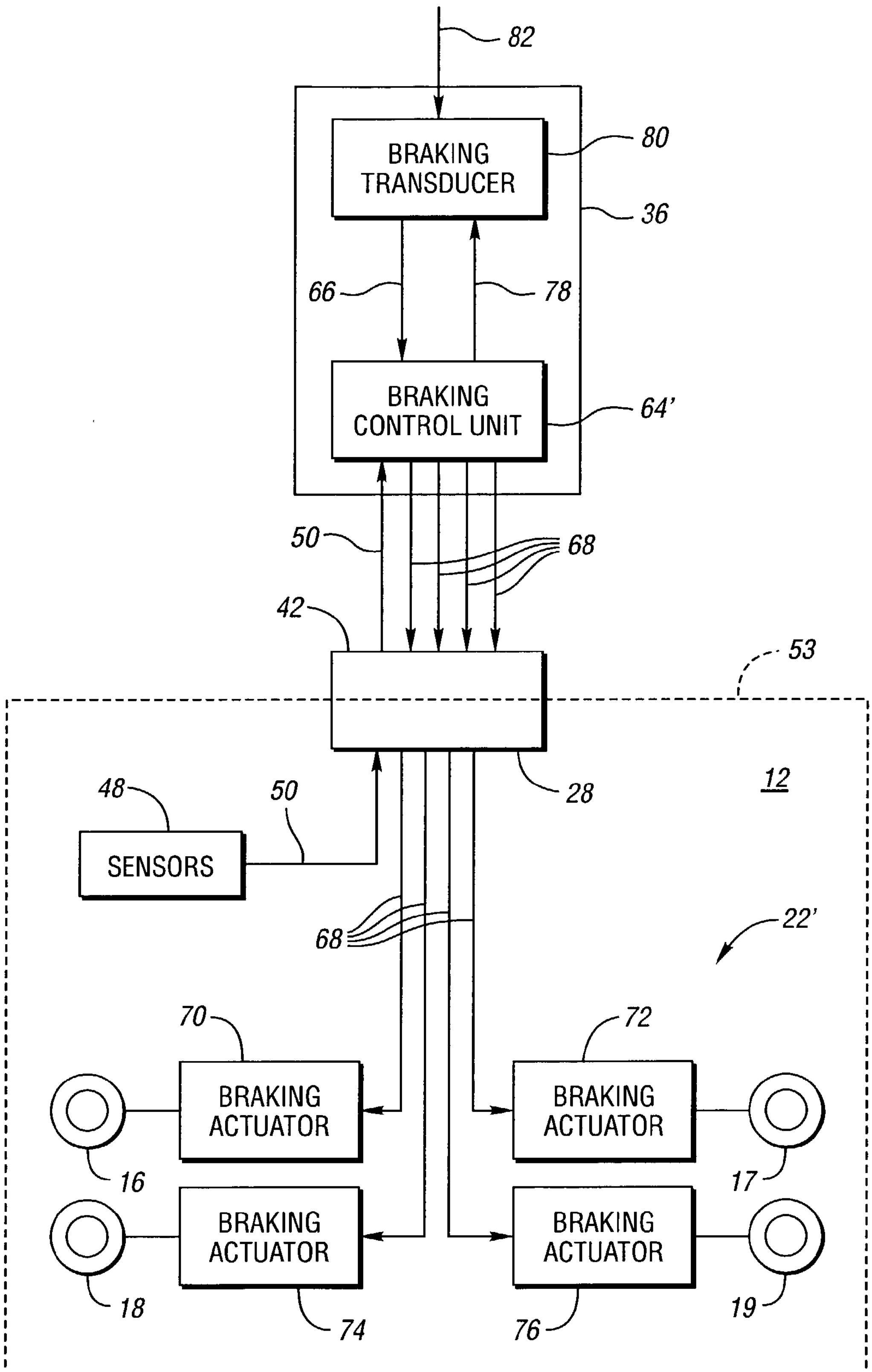
28
12
66
78
50
BRAKING CONTROL UNIT
64
SENSORS
48
68
22
70
72
BRAKING ACTUATOR
BRAKING ACTUATOR
16
17
BRAKING ACTUATOR
BRAKING ACTUATOR
18
74
76
19

Fig. 4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BRAKING TRANSDUCER
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BRAKING CONTROL UNIT
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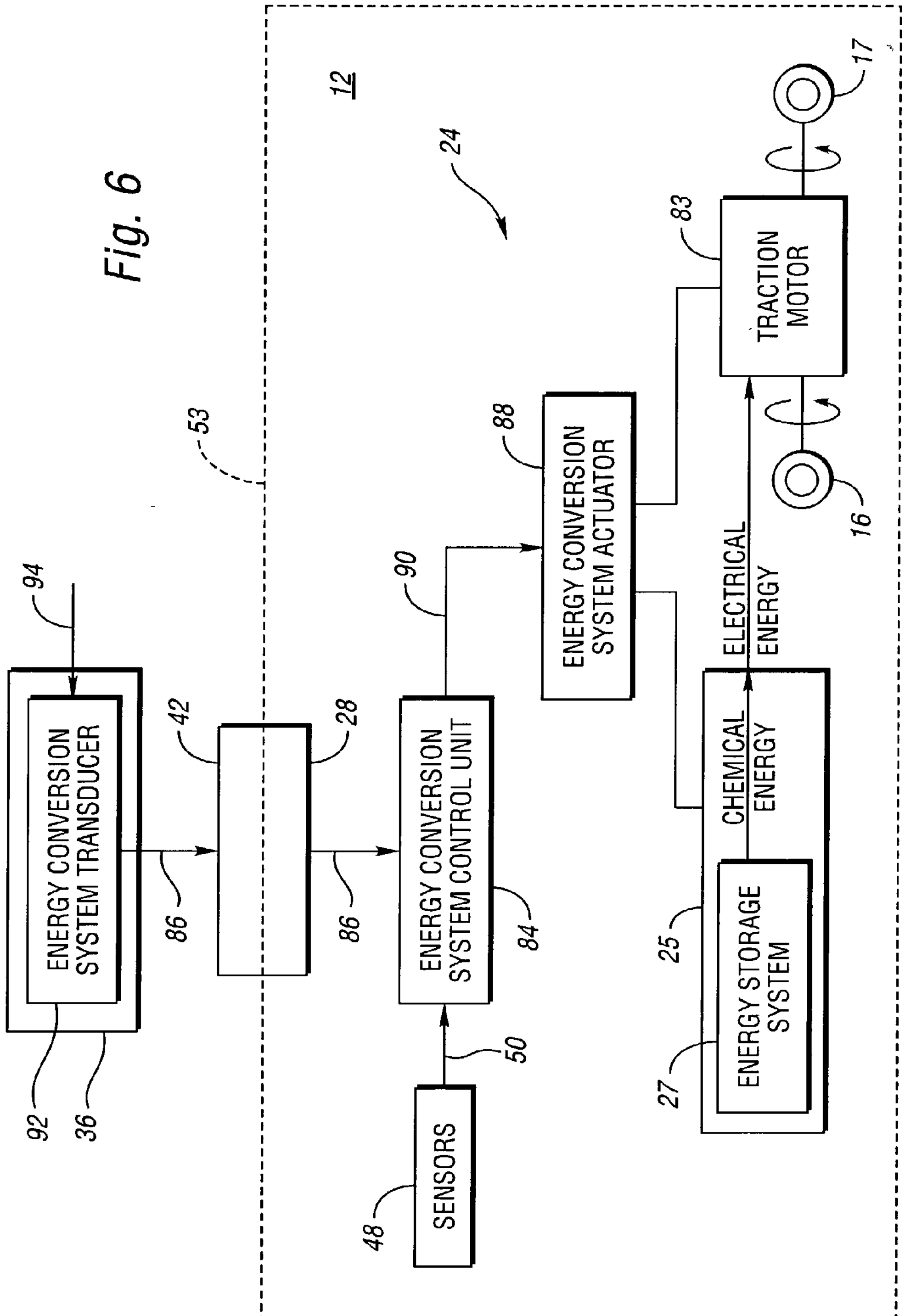
48
50
SENSORS
68
22'
70
72
BRAKING ACTUATOR
BRAKING ACTUATOR
16
17
BRAKING ACTUATOR
BRAKING ACTUATOR
18
19
74
76

Fig. 5



ENERGY CONVERSION SYSTEM TRANSDUCER
94
92
36
86
42
28
86
ENERGY CONVERSION SYSTEM CONTROL UNIT
84
50
SENSORS
48
90
ENERGY CONVERSION SYSTEM ACTUATOR
88
53
12
24
TRACTION MOTOR
83
17
16
ELECTRICAL ENERGY
CHEMICAL ENERGY
ENERGY STORAGE SYSTEM
25
27

Fig. 6

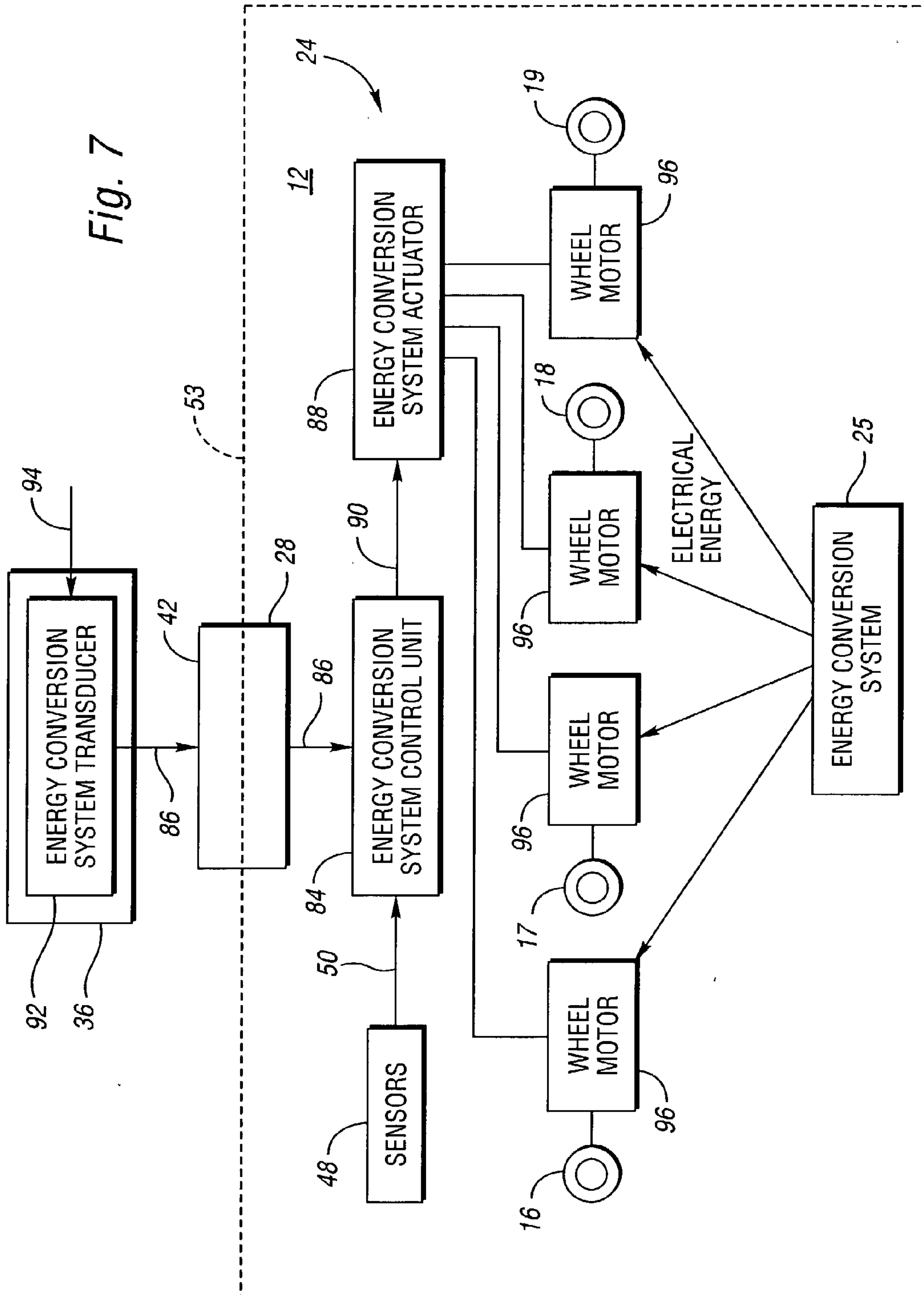

ENERGY CONVERSION SYSTEM TRANSDUCER
ENERGY CONVERSION SYSTEM CONTROL UNIT
ENERGY CONVERSION SYSTEM ACTUATOR
SENSORS
WHEEL MOTOR
WHEEL MOTOR
WHEEL MOTOR
WHEEL MOTOR
ELECTRICAL ENERGY
ENERGY CONVERSION SYSTEM
12
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Fig. 7

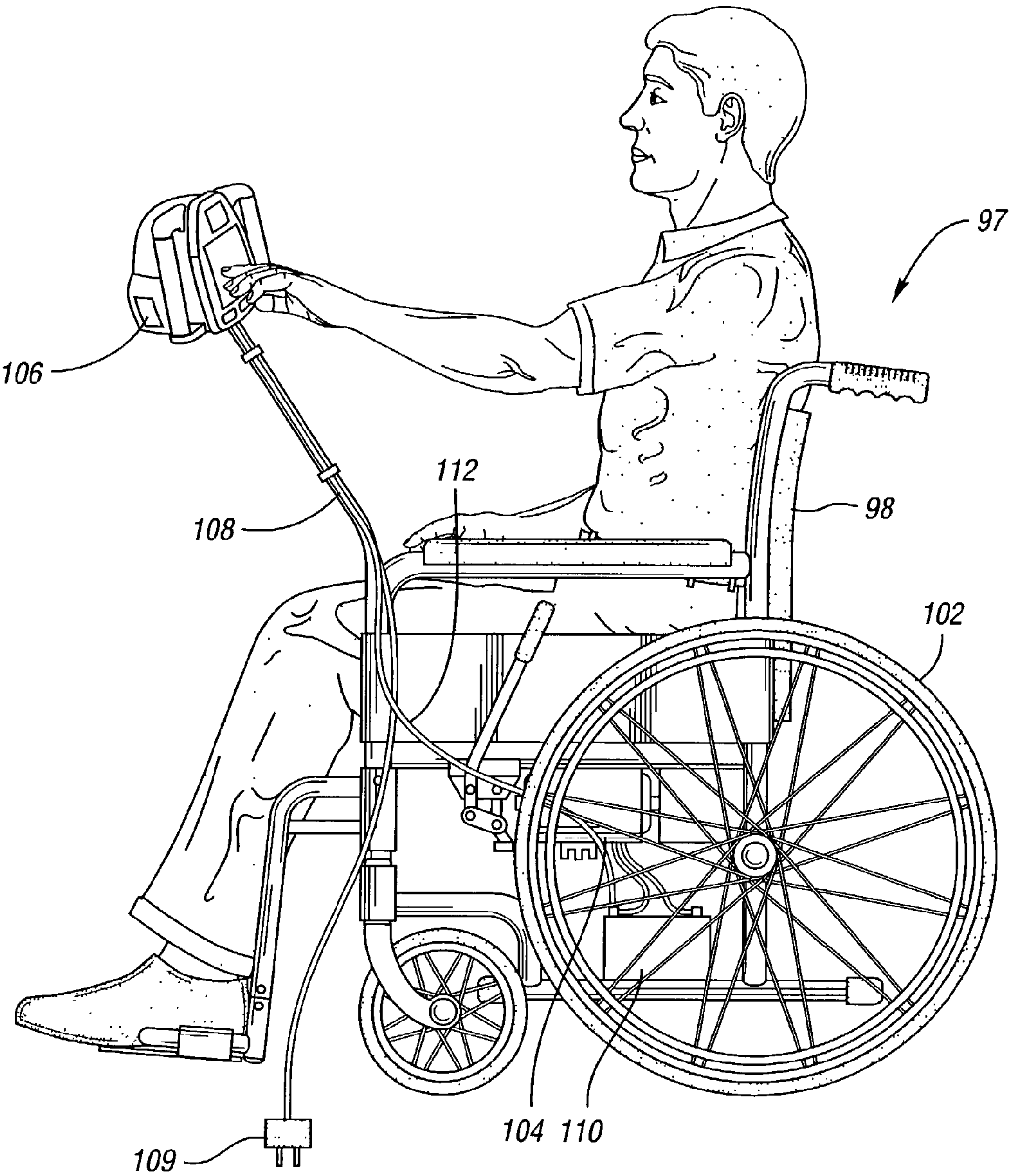

Fig. 8

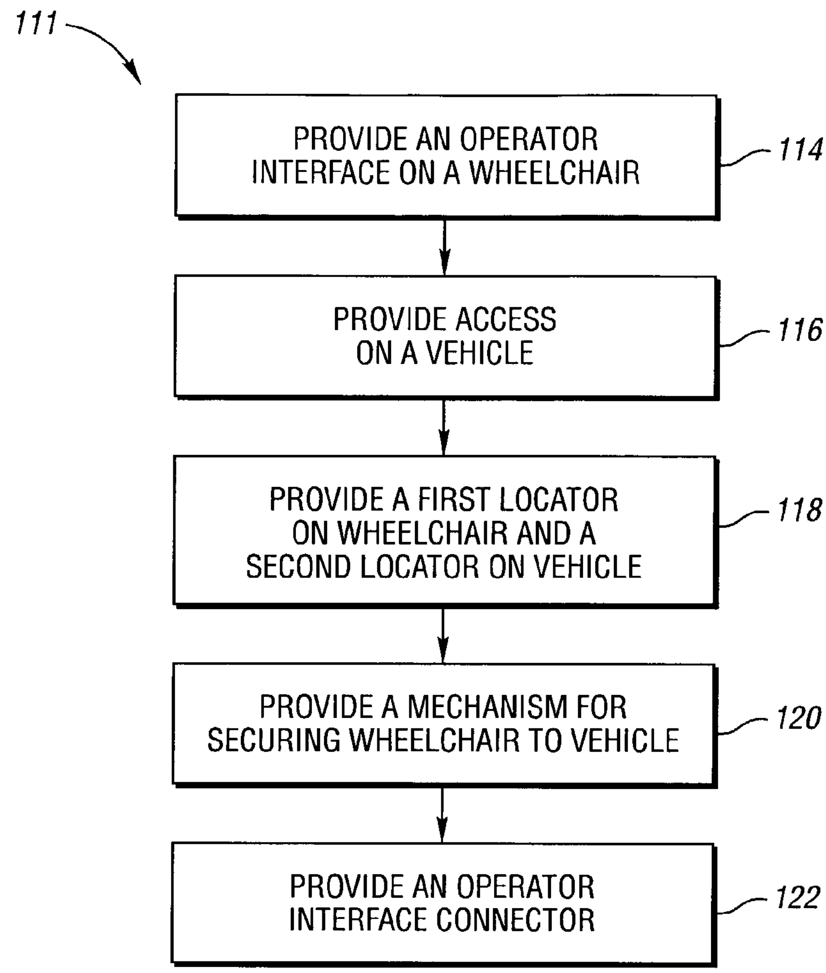
111
PROVIDE AN OPERATOR INTERFACE ON A WHEELCHAIR
114
PROVIDE ACCESS ON A VEHICLE
116
PROVIDE A FIRST LOCATOR ON WHEELCHAIR AND A SECOND LOCATOR ON VEHICLE
118
PROVIDE A MECHANISM FOR SECURING WHEELCHAIR TO VEHICLE
120
PROVIDE AN OPERATOR INTERFACE CONNECTOR
122

Fig. 9

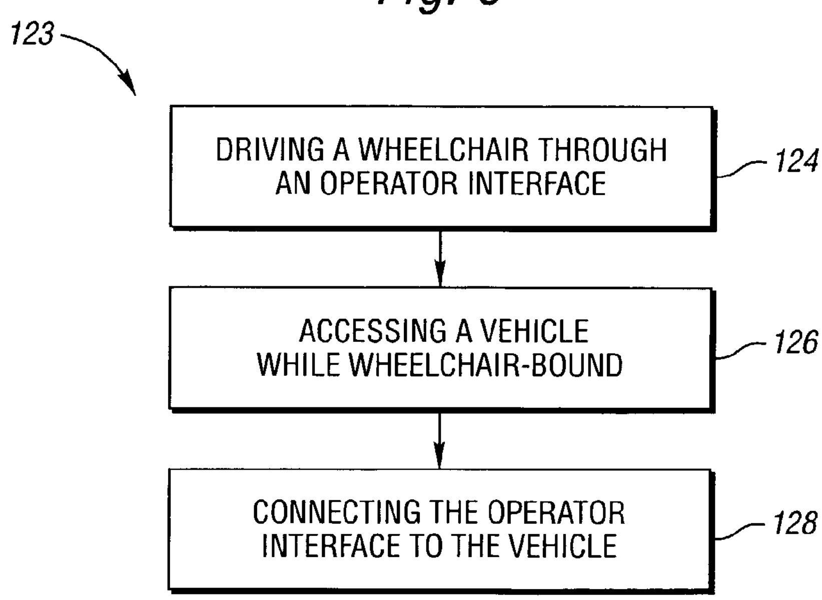
123
DRIVING A WHEELCHAIR THROUGH AN OPERATOR INTERFACE
124
ACCESSING A VEHICLE WHILE WHEELCHAIR-BOUND
126
CONNECTING THE OPERATOR INTERFACE TO THE VEHICLE
128

Fig. 10

WHEELCHAIR MOBILITY SYSTEM AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application 60/337,994 filed Dec. 7, 2001, which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] This invention relates to the adaptation of a wheelchair for use as a driver's seat in a vehicle, wherein the wheelchair includes non-mechanical controls adaptable for driving the vehicle.

BACKGROUND OF THE INVENTION

[0003] Persons confined to wheelchairs face many obstacles to mobility. Enabling a wheelchair-bound person to drive a vehicle, such as an automobile, has proven to be a challenge. Wheelchair controls typically must be custom designed, often at significant cost to the user. Significant time and effort may be expended by the user in learning to master the use of such controls. Even with the most technologically advanced wheelchair and wheelchair controls that permit a user to remain in the wheelchair and position him or her self in a vehicle as a driver, the user must then maneuver a separate set of the vehicle's own controls in order to then drive the vehicle. These separate controls may need to be modified to accommodate specific physical limitations of the wheelchair bound person. The wheelchair controls may interfere with the person's ability to utilize the separate vehicle controls.

SUMMARY OF THE INVENTION

[0004] This invention serves the primary purpose of increasing the mobility of a wheelchair bound person by allowing him to utilize his wheelchair and its controls as a driver's seat and controls of a separate vehicle.

[0005] The invention eliminates the challenge of exiting a wheelchair and repositioning into a separate driver's seat. The person is able to drive a vehicle, such as an automobile, with the wheelchair essentially becoming the driver's seat.

[0006] The invention eliminates the cost of purchasing, customizing and training to use separate specialized controls for the wheelchair-bound person in the vehicle. The wheelchair controls are able to control and drive both the wheelchair independently of the vehicle and the vehicle when the wheelchair is mounted thereon.

[0007] The invention permits recharging of the wheelchair battery by the vehicle battery, the alternator or the vehicle power system when the wheelchair is connected to the vehicle. This convenient feature saves time by eliminating the need for connecting to a separate charging mechanism.

[0008] Accordingly, a mobility system of a vehicle has a drive-by-wire control apparatus, including a drive-by-wire connector port, and a wheelchair that is removably mountable to the vehicle and has a connector that is operatively connectable to an operator interface and operably and removably connectable with the connector port. When the connector is interfitted with the connector port, the operator interface may be used to drive the vehicle when the wheelchair is mounted in the vehicle. When the connector is disconnected from the connector port and the wheelchair is removed from the vehicle, the operator interface may be used to drive the wheelchair. In the above mobility system wherein the vehicle has a power source and the wheelchair has a battery that may be engaged with the power source so that the power source recharges the battery when the wheelchair is mounted in the vehicle with the connector connected to the connector port.

[0009] A more specific embodiment of the mobility system is a vehicle and a wheelchair wherein the vehicle has a frame, at least three wheels that are operable with respect to the frame, and steering, braking and energy conversion systems that are mounted with respect to the frame and that are responsive to non-mechanical control signals. A connector port is also mounted with respect to the frame and operably connected to the steering, braking and energy conversion systems. The vehicle has structure forming a groove that is substantially fixed with respect to the frame. The wheelchair has a motor and a locator that is interfittable with the structure forming a groove to position the wheelchair with respect to the vehicle as a driver's seat. The wheelchair has an operator interface that allows the wheelchair to be driven independently of the vehicle through the motor. The operator interface also drives the vehicle through the connector port when the locator on the vehicle is interfitted with the structure forming a groove on the vehicle. The wheelchair has a battery for powering the wheelchair when the operator interface is operable for driving the wheelchair independently of the vehicle. The battery has a connector for interconnecting the battery with a power source in the energy conversion system of the vehicle to recharge the battery when the operator interface is operable for driving the vehicle.

[0010] The invention also provides a wheelchair that is adapted for multiple uses as a wheelchair and as a driver's seat for a drivable vehicle. The wheelchair has a chair for supporting a person, a wheel that is connected to the chair and that supports and motivates the chair, and a motor for driving the wheel. The wheelchair also has an operator interface in a drivable relationship by a person in the chair and a controllable relationship to the motor. The wheelchair has a connector that is selectively connectable with the motor to control the wheelchair or with the vehicle to drive the vehicle. The invention also includes the wheelchair described above wherein it has a battery for powering the motor and the battery has a connector that is selectively interconnectable with the vehicle to recharge the battery when the operator interface is interconnected with the vehicle.

[0011] The invention also includes a method of enabling a vehicle to be driven from a wheelchair. An operator interface is provided on the wheelchair that is usable for driving the wheelchair. Another step of the method is providing access on the vehicle for receiving the wheelchair onboard the vehicle. A further step of the method is providing an operator interface connector configured to be connectable between the operator interface and the vehicle when the wheelchair is onboard the vehicle so that the operator interface is usable for driving the vehicle. The invention also contemplates the above method with the additional step of providing a locator on the wheelchair and a second locator on the vehicle for sufficiently intermitting the wheelchair and the vehicle when the wheelchair is received onboard the vehicle so that the wheelchair is located with respect to the vehicle. The invention further contemplates that the locators may be accessible to the user of the wheelchair, permitting the user to interfit the wheelchair and the vehicle with the locators. Finally, the method contemplates the above steps with the additional step of providing a mechanism for securing the wheelchair to the vehicle. The invention contemplates that the mechanism may be accessible to the user of the wheelchair, permitting the user to secure the wheelchair to the vehicle.

[**0012**] The invention also includes a method for the wheelchair-bound to drive a vehicle. One step of the method is driving a wheelchair through an operator interface that controls at least one of the wheelchair's steering, accelerating, decelerating and braking functions. Another step of the method is accessing the vehicle while wheelchair-bound. This step may include controlling structure on the vehicle that facilitates the access. It may also include affixing the wheelchair in a fixed relation to the vehicle. Another step of the method is connecting the operator interface to the vehicle in a manner for controlling at least one of the vehicle's steering, accelerating, decelerating and braking.

[**0013**] The above objects, features, and advantages, and other objects, features, and advantages, of the present invention are readily apparent from the following detailed description of the best mode for carrying out the invention when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[**0014**] **FIG. 1** is a side schematic illustration of a mobility system in accordance with an embodiment of the invention, the wheelchair having a battery connectable to a power source in the vehicle and a first locator on the vehicle being in the form of structure forming a groove.

[**0015**] **FIG. 2** is a schematic illustration of a steering system for use with the mobility system of **FIG. 1**;

[**0016**] **FIG. 3** is a schematic illustration of an alternative steering system for use with the mobility system of **FIG. 1**;

[**0017**] **FIG. 4** is a schematic illustration of a braking system for use with the mobility system of **FIG. 1**;

[**0018**] **FIG. 5** is a schematic illustration of an alternative braking system for use with the mobility system of **FIG. 1**;

[**0019**] **FIG. 6** is a schematic illustration of an energy conversion system for use with the mobility system of **FIG. 1**;

[**0020**] **FIG. 7** is a schematic illustration of an alternative energy conversion system for use with the mobility system of **FIG. 1**;

[**0021**] **FIG. 8** is a side schematic illustration of a wheelchair in accordance with another embodiment of the invention, the wheelchair having a battery attached to a connector;

[**0022**] **FIG. 9** is a flow diagram illustrating a method of enabling a vehicle to be driven from a wheelchair in accordance with an embodiment of the invention, the method including the step of providing a locator on the wheelchair and another locator on the vehicle for interfitting the wheelchair and the vehicle; and

[**0023**] **FIG. 10** is a flow diagram illustrating a method for the wheelchair-bound to drive a vehicle through an interface on the wheelchair that also controls the wheelchair in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[**0024**] Referring to **FIG. 1, a** mobility system **10** in accordance with the invention includes a vehicle **12** and a wheelchair **14**. The vehicle **12** includes a frame **15** having four wheels **16, 17, 18, 19** that are operable with respect to the frame **15**. The vehicle **12** is preferably an automobile but the invention also contemplates that the vehicle may be a tractor, forklift, or other industrial vehicle. Those skilled in the art will recognize materials and fastening methods suitable for attaching the wheels **16**, **17**, **18** and **19** to the frame **15**.

[**0025**] The vehicle **12** further includes a steering system **20**, a braking system **22** and an energy conversion system **24**, each of which is mounted with respect to the frame **15** and responsive to non-mechanical control signals. The energy conversion system **24** is connected to a power source **26**. Embodiments of such systems are described subsequently with respect to **FIG. 4** through **FIG. 9**.

[**0026**] The structural frame **15** provides a rigid structure to which the steering system **20**, braking system **22** and energy conversion system **24** as well as the wheels **16, 17, 18, 19** are mounted, as shown in **FIG. 1**, and is configured to support an attached body such as an automotive body. A person of ordinary skill in the art will recognize that the structural frame **15** can take many different forms. For example, the structural frame **15** can be a traditional automotive frame having two or more longitudinal structural members spaced a distance apart from each other, with two or more transverse structural members spaced apart from each other and attached to both longitudinal structural members at their ends. Alternatively, the structural frame may also be in the form of a "belly pan," wherein integrated rails and cross members are formed in sheets of metal or other suitable material, with other formations to accommodate various system components. The structural frame may also be integrated with various vehicle components.

[**0027**] The vehicle **12** includes a connector port **28**, also referred to as a drive-by-wire connector port, that is mounted with respect to the frame **15** and operably connected to the steering system **20**, the braking system **22**, and the energy conversion system **24**. Persons skilled in the art will recognize various methods for mounting the connector port **28** to the frame **15**. In the preferred embodiment, the connector port is located on the top face of the frame **15**, in close proximity to the wheelchair **14**. Various embodiments of the manner for operably connecting the connector port **28** to the steering system **20**, the braking system **22**, and the energy conversion system **24** are described subsequently with respect to **FIG. 2** through **FIG. 7**.

[**0028**] The wheelchair **14** shown in **FIG. 1** includes a motor **30** for driving the wheelchair **14**. Prior art includes many representations of motorized wheelchairs; those skilled in the art will recognize many methods of attaching a motor **30** to the wheelchair **14** such that the motor **30** will power the wheelchair **14** when the wheelchair **14** is independent of the vehicle **12**.

[**0029**] The wheelchair **14** includes a locator **32**, also referred to herein as a second locator. The locator **32** is designed to be interfittable with a first locator **34** that is substantially fixed with respect to the frame **15**. The location and design of the locator **32** on the wheelchair **14** and the first locator **34** on the frame **15** are such that, once interfitted, the wheelchair **14** is positioned with respect to the vehicle **12** as a driver's seat. The first locator **34** is structure forming a groove **37** in the embodiment depicted in **FIG. 1**. When the first locator **34** is structure forming a groove **37**, the locator **32** could be a portion of the wheel **13** on the wheelchair **14**. Ideally, the width, length and depth of the groove **37** are designed to permit a large enough part of the wheel **13** to rest in the groove **37** such that the wheelchair **14** is secured to the frame **15**. Those skilled in the art will recognize various other designs for a locator **32** on the wheelchair capable of interfitting with the first locator **34** to securely position the wheelchair **14** on the vehicle as a driver's seat. A locking clamp attached to the frame **15** that secures to a portion of the wheelchair **14**, one or more magnets attached to the wheelchair **14**, aligned with a number of magnets of opposing polar forces on the frame **15**, or a releaseably locking belt, similar to a seatbelt, attached to the frame **15** and designed to secure a portion of the wheelchair **14**, are examples of locator and second locator designs that may be feasible. Another embodiment would include a first locator in the form of a seat on the vehicle with the second locator being the chair portion of the wheelchair such that when the wheelchair is onboard the vehicle, the chair portion fits on top of the seat to secure the chair. This embodiment would permit the wheelchair wheels to be designed to disengage from the chair portion once it is positioned on the seat. In this embodiment, the operator interface would be affixed to the chair portion of the wheelchair such that it is readily accessible to control the vehicle once the chair portion is engaged with the seat.

[**0030**] A secondary restraining device, such as a clamp attached to the frame **15** may be employed in conjunction with the groove **37** to afford greater securement. In the embodiment depicted in **FIG. 1, a** locking clamp **33** is attached to the frame. When the locator **32** is interfitted with the first locator **34**, the locking clamp **33** automatically locks the wheel **13** to the frame **15**.

[**0031**] The wheelchair includes an operator interface **36**, that is operable for driving the wheelchair **14** independently of the vehicle **12** through the motor **30** and operable for driving the vehicle **12** through the connector port **28** when the locator **32** on the wheelchair **14** is interfitted with the first locator **34** on the frame **15**. The invention may also include a wheelchair that has no motor but has a vehicle attachment interface only for steering purposes. The operator interface **36** may be fixed with respect to the wheelchair **14** or movable in relation thereto. In the preferred embodiment of **FIG. 1**, it is represented as being fixed to the wheelchair **14**. In **FIG. 1**, the operator interface **36** is depicted as being selectively connected to the connector port **28** via a connector wire **41** for transmitting electrical signals from the operator interface **36** to a connector **42** and to the connector port **28** when the connector **42** is interfitted therewith. Although the operator interface **36** is shown as connected only to the steering system **20**, the braking system **22** and the energy conversion system **24**, it could conceivably be connected to control a multitude of vehicle systems such as climate control systems, and video or audio systems.

[**0032**] Those skilled in the art will recognize various designs for an operator interface **36** capable of transforming directional input from a wheelchair occupant into an electrical signal to be transmitted either to the motor **30** of the wheelchair or to the connector port **28** of the vehicle if the operator interface is operably connected to the connector port **28**. The operator interface **36** could include one or more manual joysticks, and may further include a touch screen or keyboard design. A touch screen and keyboard design employed in combination could conceivably be converted to an Internet access device when the interface is not being used with either the wheelchair **14** or the vehicle **12** in drive mode. Prior art teaches controls for various devices that are responsive to head movements, eye movements or breathing motions of a disabled person. The interface may include any of these designs and other designs.

[**0033**] The wheelchair **14** includes a battery **38** designed for powering the wheelchair **14** when the operator interface **36** is operable for driving the wheelchair **14** independently of the vehicle **12** through the motor **30**. The battery **38** has a connector wire **40** for interconnecting the battery through the connector **42** and the connector port **28** to the power source **26** in the energy conversion system **24**. In **FIG. 1**, the connector wire **40** is depicted as connecting the connector **42** through the operator interface **36** and the connector wire **41**. When the connector wire **40** is operably connected to the power source **26**, the battery is recharged by the power source **26**.

[**0034**] The connector port **28** of the preferred embodiment may perform multiple functions, or select combinations thereof. First, the connector port **28** may function as an electrical power connector, i.e., it may be configured to transfer electrical energy generated by components on the vehicle **12** to the operator interface **36** or other non-frame destination. Second, the connector port **28** may function as a control signal receiver, i.e., a device configured to transfer non-mechanical control signals from a non-vehicle source, such as the operator interface **36**, to controlled systems including the steering system **20**, the braking system **22**, and the energy conversion system **24**. Third, the connector port **28** may function as a feedback signal conduit through which feedback signals are made available to a vehicle driver. Fourth, the connector port **28** may function as an external programming interface through which software containing algorithms and data may be transmitted for use by controlled systems. Fifth, the connector port **28** may function as an information conduit through which sensor information and other information is made available to a vehicle driver. The connector port **28** may thus function as a communications and power "umbilical" port through which all communications between the vehicle **12** and the attached operator interface **36** and other attachments to the frame are transmitted. The connector port **28** is essentially an electrical connector. Electrical connectors include devices configured to operably connect one or more electrical wires with other electrical wires. The wires may be spaced a distance apart to avoid any one wire causing signal interference in another wire operably connected to an electrical connector or for any reason that wires in close proximity may not be desirable.

[**0035**] The steering system **20** is housed in the vehicle **12** and is operably connected to the front wheels **16, 17**. Preferably, the steering system **20** is responsive to non-mechanical control signals. In the preferred embodiment, the steering system **20** is by-wire. A by-wire system is characterized by control signal transmission in electrical form. In the context of the present invention, "by-wire" systems, or systems that are controllable "by-wire," include systems configured to receive control signals in electronic form via a control signal receiver, and respond in conformity to the electronic control signals.

[**0036**] **FIG. 2** is a schematic illustration of a steering system for use with the mobility system of **FIG. 1**. The by-wire steering system **20** of the preferred embodiment includes a steering control unit **44**, and a steering actuator **46**. Sensors **48** are located on the vehicle **12** and transmit sensor signals **50** carrying information concerning the state or condition of the vehicle **12** and its component systems. The sensors **48** may include position sensors, velocity sensors, acceleration sensors, pressure sensors, force and torque sensors, flow meters, temperature sensors, etc. The steering control unit **44** receives and processes sensor signals **50** from the sensors **48** and electrical steering control signals **52** from the connector port **28**, and generates steering actuator control signals **54** according to a stored algorithm. A control unit typically includes a microprocessor, ROM and RAM and appropriate input and output circuits of a known type for receiving the various input signals and for outputting the various control commands to the actuators. Sensor signals **50** may include yaw rate, lateral acceleration, angular wheel velocity, tie-rod force, steering angle, chassis velocity, etc.

[**0037**] The steering actuator **46** is operably connected to the front wheels **16, 17** and configured to adjust the steering angle of the front wheels **16, 17** in response to the steering actuator control signals **54**. Actuators in a by-wire system transform electronic control signals into a mechanical action or otherwise influence a system's behavior in response to the electronic control signals. Examples of actuators that may be used in a by-wire system include electromechanical actuators such as electric servomotors, translational and rotational solenoids, magnetorheological actuators, electrohydraulic actuators, and electrorheological actuators. Those skilled in the art will recognize and understand mechanisms by which the steering angle is adjusted. In the preferred embodiment, the steering actuator **46** is an electric drive motor configured to adjust a mechanical steering rack.

[**0038**] Referring to **FIG. 2**, the preferred embodiment of the vehicle **12** is configured such that it is steerable by any source of compatible electrical steering control signals **52** connected to the connector port **28**. The connector port **28** interfits with the connector **42** at the connector interface **53**. **FIG. 2** depicts a steering transducer **56** located within the operator interface **36** and connected to a complementary connector **42**. Transducers convert the mechanical control signals of a vehicle driver to non-mechanical control signals. When used with a by-wire system, transducers convert the mechanical control signals to electrical control signals usable by the by-wire system. A vehicle driver inputs control signals in mechanical form by turning a wheel, gripping or turning a handle or handles, using head or eye movements, using controlled breathing movements (puffs or sucks of air), pressing a button, or the like. Transducers utilize sensors, typically position and force sensors, to convert the mechanical input to an electrical signal.

[**0039**] The complementary connector **42** is coupled with the connector port **28** of the connector interface **53**. The steering transducer **56** converts vehicle driverinitiated mechanical steering control signals **60** to electrical steering control signals **52** which are transmitted via the connector port **28** to the steering control unit **44**. In the preferred embodiment, the steering control unit **44** generates steering feedback signals **62** for use by a vehicle driver and transmits the steering feedback signals **62** through the connector port **28**. Some of the sensors **48** monitor linear distance movement of a steering rack and vehicle speed. This information is processed by the steering control unit **44** according to a stored algorithm to generate the steering feedback signals **62**.

[**0040**] In the context of the present invention, a "by-wire" system may be an actuator connected directly to the connector port **28**. An alternative by-wire steering system **20'** within the scope of the claimed invention is depicted schematically in **FIG. 3**, wherein like reference numbers refer to like components from **FIG. 2**. A steering actuator **46** configured to adjust the steering angle of the front wheels **16, 17** is connected directly to the connector port **28**. In this embodiment, a steering control unit **44'** and a steering transducer **56** may be located in the operator interface **36**. The steering transducer **56** would transmit electrical steering control signals **52** to the steering control unit **44'**, and the steering control unit **44'** would transmit steering actuator control signals **54** to the steering actuator **46** via the connector port **28**. Sensors **48** positioned on the vehicle **12** transmit sensor signals **50** to the steering control unit **44'** via the connector port **28** and the complementary connector **42**.

[**0041**] Examples of steer-by-wire systems are described in U.S. Pat. Nos. 6,176,341, issued Jan. 23, 2001 to Delphi Technologies, Inc; 6,208,923, issued Mar. 27, 2001 to Robert Bosch GmbH; 6,219,604, issued Apr. 17, 2001 to Robert Bosch GmbH; 6,318,494, issued Nov. 20, 2001 to Delphi Technologies, Inc.; 6,370,460, issued Apr. 9, 2002 to Delphi Technologies, Inc.; and 6,394,218, issued May 28, 2002 to TRW Fahrwerksysteme GmbH & Co. KG; which are hereby incorporated by reference in their entireties.

[**0042**] The steer-by-wire system described in U.S. Pat. No. 6,176,341 includes a position sensor for-sensing angular position of a road wheel, a hand-operated steering wheel for controlling direction of the road wheel, a steering wheel sensor for sensing position of the steering wheel, a steering wheel actuator for actuating the hand-operated steering wheel, and a steering control unit for receiving the sensed steering wheel position and the sensed road wheel position and calculating actuator control signals, preferably including a road wheel actuator control signal and a steering wheel actuator control signal, as a function of the difference between the sensed road wheel position and the steering wheel position. The steering control unit commands the road wheel actuator to provide controlled steering of the road wheel in response to the road wheel actuator control signal. The steering control unit further commands the steering wheel actuator to provide feedback force actuation to the hand-operated steering wheel in response to the steering wheel control signal. The road wheel actuator control signal and steering wheel actuator control signal are preferably scaled to compensate for difference in gear ratio between the steering wheel and the road wheel. In addition, the road wheel actuator control signal and steering wheel actuator control signal may each have a gain set so that the road wheel control actuator signal commands greater force actuation to the road wheel than the feedback force applied to the steering wheel.

[0043] The steer-by-wire system described in U.S. Pat. No. 6,176,341 preferably implements two position control loops, one for the road wheel and one for the hand wheel. The position feedback from the steering wheel becomes a position command input for the road wheel control loop and the position feedback from the road wheel becomes a position command input for the steering wheel control loop. A road wheel error signal is calculated as the difference between the road wheel command input (steering wheel position feedback) and the road wheel position. Actuation of the road wheel is commanded in response to the road wheel error signal to provide controlled steering of the road wheel. A steering wheel error signal is calculated as the difference between the steering wheel position command (road wheel position feedback) and the steering wheel position. The hand-operated steering wheel is actuated in response to the-steering wheel error signal to provide force feedback to the hand-operated steering wheel.

[0044] The steering control unit of the ’341 system could be configured as a single processor or multiple processors and may include a general-purpose microprocessor-based controller, that may include a commercially available off-the-shelf controller. One example of a controller is Model No. 87C196CA microcontroller manufactured and made available from Intel Corporation of Delaware. The steering control unit preferably includes a processor and memory for storing and processing software algorithms, has a clock speed of 16 MHz, two optical encoder interfaces to read position feedbacks from each of the actuator motors, a pulse width modulation output for each motor driver, and a 5-volt regulator.

[0045] U.S. Pat. No. 6,370,460 describes a steer-by-wire control system comprising a road wheel unit and a steering wheel unit that operate together to provide steering control for the vehicle operator. A steering control unit may be employed to support performing the desired signal processing. Signals from sensors in the road wheel unit, steering wheel unit, and vehicle speed are used to calculate road wheel actuator control signals to control the direction of the vehicle and steering wheel torque commands to provide tactile feedback to the vehicle operator. An Ackerman correction may be employed to adjust the left and right road wheel angles correcting for errors in the steering geometry to ensure that the wheels will track about a common turn center.

[0046] Referring again to **FIG. 1, a** braking system **22** is mounted to the frame **15** and is operably connected to the wheels **16, 17, 18, 19**. The braking system **22** is configured to be responsive to non-mechanical control signals. In the preferred embodiment, the braking system **22** is by-wire, as depicted schematically in **FIG. 4**, wherein like reference numbers refer to like components from **FIGS. 2 and 3**. Sensors **48** transmit sensor signals **50** carrying information concerning the state or condition of the vehicle **12** and its component systems to a braking control unit **64**. The braking control unit **64** is connected to the connector port **28** and is configured to receive electrical braking control signals **66** via the connector port **28**. The braking control unit **64** processes the sensor signals **50** and the electrical braking control signals **66** and generates braking actuator control signals **68** according to a stored algorithm. The braking control unit **64** then transmits the braking actuator control signals **68** to braking actuators **70, 72, 74, 76** which act to reduce the angular velocity of the wheels **16, 17, 18, 19**. Those skilled in the art will recognize the manner in which the braking actuators **70, 72, 74, 76** act on the wheels **16, 17, 18, 19**. Typically, actuators cause contact between friction elements, such as pads and disc rotors. Optionally, an electric motor may function as a braking actuator in a regenerative braking system.

[0047] The braking control unit **64** may also generate braking feedback signals **78** for use by a vehicle driver and transmit the braking feedback signals **78** through the connector port **28**. In the preferred embodiment, the braking actuators **70, 72, 74, 76** apply force through a caliper to a rotor at each wheel. Some of the sensors **48** measure the applied force on each caliper. The braking control unit **64** uses this information to ensure synchronous force application to each rotor.

[0048] Referring again to **FIG. 4**, the preferred embodiment of the vehicle **12** is configured such that the braking system **22** is responsive to any source of compatible electrical braking control signals **66**. A braking transducer **80** may be located in the operator interface **36** and connected to a complementary connector **42** interfitted with the connector port **28** at the connector interface **53**. The braking transducer **80** converts vehicle driver-initiated mechanical braking control signals **82** into electrical form and transmits the electrical braking control signals **66** to the braking control unit via the connector port **28**. In the preferred embodiment, the braking transducer **80** includes two hand-grip type assemblies. The braking transducer **80** includes sensors that measure both the rate of applied pressure and the amount of applied pressure to the hand-grip assemblies, thereby converting mechanical braking control signals **82** to electrical braking control signals **66**. The braking control unit **64** processes both the rate and amount of applied pressure to provide both normal and panic stopping.

[0049] An alternative brake-by-wire system **22'** within the scope of the claimed invention is depicted in **FIG. 5**, wherein like reference numbers refer to like components from FIGS. 2-4. The braking actuators **70, 72, 74, 76** and sensors **48** are connected directly to the connector port **28**. In this embodiment, a braking control unit **64'** may be located within the operator interface **36**. A braking transducer **80** within the operator interface **36** transmits electrical braking control signals **66** to the braking control unit **64'**, and the braking control unit **64'** transmits braking actuator signals **68** to the braking actuators **70, 72, 74, 76** via the connector **42** and to the connector port **28**.

[0050] Examples of brake-by-wire systems are described in U.S. Pat. Nos. 5,366,281, issued Nov. 22, 1994 to General Motors Corporation; 5,823,636, issued Oct. 20, 1998 to General Motors Corporation; 6,305,758, issued Oct. 23, 2001 to Delphi Technologies, Inc.; and 6,390,565, issued May 21, 2002 to Delphi Technologies, Inc.; which are hereby incorporated by reference in their entireties.

[0051] The system described in U.S. Pat. No. 5,366,281 includes an input device for receiving mechanical braking control signals, a brake actuator and a control unit coupled to the input device and the brake actuator. The control unit receives brake commands, or electrical braking control signals, from the input device and provides actuator commands, or braking actuator control signals, to control current and voltage to the brake actuator. When a brake command is first received from the input device, the control unit outputs, for a first predetermined time period, a brake torque command to the brake actuator commanding maximum current to the actuator. After the first predetermined time period, the control unit outputs, for a second predetermined time period, a brake torque command to the brake actuator commanding voltage to the actuator responsive to the brake command and a first gain factor. After the second predetermined time period, the control unit outputs the brake torque command to the brake actuator commanding current to the actuator responsive to the brake command and a second gain factor, wherein the first gain factor is greater than the second gain factor and wherein brake initialization is responsive to the brake input.

[0052] U.S. Pat. No. 6,390,565 describes a brake-by-wire system that provides the capability of both travel and force sensors in a braking transducer connected to a brake apply input member such as a brake pedal and also provides redundancy in sensors by providing the signal from a sensor responsive to travel or position of the brake apply input member to a first control unit and the signal from a sensor responsive to force applied to a brake apply input member to a second control unit. The first and second control units are connected by a bi-directional communication link whereby each controller may communicate its received one of the sensor signals to the other control unit. In at least one of the control units, linearized versions of the signals are combined for the generation of first and second brake apply command signals for communication to braking actuators. If either control unit does not receive one of the sensor signals from the other, it nevertheless generates its braking actuator control signal on the basis of the sensor signal provided directly to it. In a preferred embodiment of the system, a control unit combines the linearized signals by choosing the largest in magnitude.

[0053] **FIG. 6** is a schematic illustration of an energy conversion system **24** for use with the mobility system depicted in **FIG. 1**. The energy conversion system **24** includes an energy converter **25** that converts the energy stored in an energy storage system **27** to mechanical energy that propels the vehicle **12**. In the preferred embodiment, depicted in **FIG. 6**, the energy converter **25** is operably connected to a traction motor **83**. The energy converter **25** converts chemical energy into electrical energy, and the traction motor **83** converts the electrical energy to mechanical energy, and applies the mechanical energy to rotate the front wheels **16, 17**. Those skilled in the art will recognize many types of energy converters **25** that may be employed within the scope of the present invention.

[0054] The energy conversion system **24** is configured to respond to non-mechanical control signals. The energy conversion system **24** of the preferred embodiment is controllable by-wire, as depicted in **FIG. 6**. An energy conversion system control unit **84** is connected to the connector port **28** from which it receives electrical energy conversion system control signals **86**, and sensors **48** from which it receives sensor signals **50** carrying information about various vehicle conditions. In the preferred embodiment, the information conveyed by the sensor signals **50** to the energy conversion system control unit **84** includes vehicle velocity, electrical current applied, rate of acceleration of the vehicle, and motor shaft speed to ensure smooth launches and controlled acceleration. The energy conversion system control unit **84** is connected to an energy conversion system actuator **88**, and transmits energy conversion system actuator control signals **90** to the energy conversion system actuator **88** in response to the electrical energy conversion system control signals **86** and sensor signals **50** according to a stored algorithm. The energy conversion system actuator **88** acts on the energy conversion system **24** or traction motor **83** to adjust energy output. Those skilled in the art will recognize the various methods by which the energy conversion system actuator **88** may adjust the energy output of the energy conversion system.

[0055] An energy conversion system transducer **92** may be located in the operator interface **36** and connected to a complementary connector **42** engaged with the connector port **28** at the connector interface **53**. The energy conversion system transducer **92** is configured to convert mechanical energy conversion system control signals **94** to electrical energy conversion system control signals **86**.

[0056] In another embodiment of the invention, as shown schematically in **FIG. 7**, wherein like reference numbers refer to like components from FIGS. **2-6**, wheel motors **96**, also known as wheel hub motors, are positioned at each of the four wheels **16, 17, 18, 19**. Optionally, wheel motors **96** may be provided at only the front wheels **16, 17** or only the rear wheels **18, 19**. The use of wheel motors **96** reduces the height of the vehicle **12** compared to the use of traction motors, and therefore may be desirable for certain uses.

[0057] Referring to **FIG. 8, a** wheelchair **96** in accordance with the invention includes a chair **98** for supporting a person and wheels **102** connected to the chair **98** for supporting and motivating the chair **98**. A motor **104** is mounted on the wheelchair **96** and operably connected to the wheels **102** for driving the wheels **102**. An operator interface **106** is drivable by the person in the chair **98**. The operator interface **106** is in a controllable relationship to the motor **104**. The operator interface **106** is connectable with the motor **104** to drive the wheels **102** and control the chair **98**. Alternatively, the operator interface **106** is designed to be connectable with another vehicle to drive the vehicle. This interconnectablility is depicted in **FIG. 8** with a connector wire **108** connected at one end to the operator interface **106** and connectable at the other end through a connector plug **109** either to the motor **104** or to a vehicle. A battery **110** is mounted on the wheelchair **96**. The battery powers the motor **104** to drive the wheels **102** when the operator interface **106** is used to control the motor. The battery has a connector wire **112** that is selectively connectable to a vehicle when the operator interface **106** is used to drive such vehicle. When the connector wire **112** is connected to a vehicle, the battery is recharged. Those skilled in the art will recognize a variety of ways to accomplish recharging of the battery **110** by the vehicle. **FIG. 8** shows an embodiment wherein the connector wire **112** is connectable to a vehicle through the operator interface **106** and the connector plug **109** that connects the operator interface **106** to a vehicle. Those skilled in the art will recognize alternative means for connecting the connector wire **112** to a vehicle.

[0058] Additionally, the invention provides a multiple step process for enabling a vehicle to be driven from a wheelchair. One embodiment of this process **111** is depicted in **FIG. 9**. One step **114** is providing an operator interface on a wheelchair that is usable for driving the wheelchair. The operator interface could be one of a number of designs. It could include one or more manual joysticks, a touchscreen or keyboard design, or controls that are responsive to head movements, eye movements or breathing motions of a wheelchair-bound person. Those skilled in the art will recognize many different forms that the operator interface may take. Another step **116** is providing access on a vehicle for receiving the wheelchair onboard the vehicle. Access could include a ramp or lift. It may encompass special design features of the vehicle such as a wider door or a structural mechanism incorporated into the vehicle that enables wheelchair entry. Another optional step **118** depicted in **FIG. 9** is providing a locator on the wheelchair and a second locator on the vehicle that are accessible to the user of the wheelchair, permitting the user to interfit the wheelchair and the vehicle with the locators when the wheelchair is onboard the vehicle so that the wheelchair is located with respect to the vehicle. The invention also includes this step when the locators are not accessible to the user but may nevertheless be used, by another person or otherwise, to locate the wheelchair with respect to the vehicle. Another optional step **120** is providing a mechanism for securing the wheelchair to the vehicle that is accessible to the user of the wheelchair, permitting the user to secure the wheelchair to the vehicle. The invention also encompasses this optional step wherein the mechanism provided for securing the wheelchair to the vehicle is not accessible to the user of the wheelchair. In that case, another person or some other mechanism would be necessary to enable securement. Preferably, the mechanism would be designed to accommodate a wide variety of different wheelchair designs. Finally, **FIG. 9** depicts another step **122** of the method providing an operator interface connector connectable between the operator interface and the vehicle when the wheelchair is onboard the vehicle so that the operator interface is usable for driving the vehicle. The above discussion of the mobility system depicted in **FIG. 1** provides an example of an operator interface designed to connect to and control a vehicle that includes by-wire steering, braking and energy conversion. The connection mechanism discussed with respect to that system is an example of an operator interface connector covered by step **122**. Performing steps **114** to **122** provides a method that allows a wheelchair with an operator interface to be attached to a vehicle, with the operator interface being usable to drive the vehicle.

[**0059**] The invention also provides a method **123** for the wheelchair-bound to drive a vehicle. This method is depicted in **FIG. 10**. One step **124** of the method is driving a wheelchair through an operator interface that controls at least one of the wheelchair's steering, accelerating, decelerating and braking functions. Another step **126** of the method is accessing the vehicle while wheelchair-bound wherein there is controlling structure on the vehicle that facilitates the access and including affixing the wheelchair in a fixed relation to the vehicle. The method also includes accessing the vehicle without any controlling structure on the vehicle and where the wheelchair is not necessarily fixed in relation to the vehicle. For instance, accessing the vehicle could include simply entering the vehicle via a ramp located adjacent to the vehicle. Another step **128** of the method is connecting the operator interface to the vehicle in a manner for controlling at least one of the vehicle's steering, accelerating, decelerating and braking. The above discussion of the mobility system depicted in **FIG. 1** provides an example of a connection mechanism (connector wire **41**, connector **42** and connector port **28**) that would enable an operator interface on a wheelchair to control a vehicle. Performing steps **124** to **128** results in driving a vehicle from a wheelchair using an operator interface on the wheelchair that also drives the wheelchair.

[**0060**] While the best modes for carrying out the invention have been described in detail, those familiar with the art to which this invention relates will recognize various alternative designs and embodiments for practicing the scope of the invention within the scope of the appended claims.

1. A wheelchair mobility system comprising:

a vehicle having

a frame,

at least three wheels operable with respect to the frame,

a steering system mounted with respect to the frame and responsive to non-mechanical control signals,

a braking system mounted with respect to the frame and responsive to non-mechanical control signals,

an energy conversion system mounted with respect to the frame and responsive to non-mechanical control signals,

a connector port mounted with respect to the frame and operably connected to the steering, braking and energy conversion systems, and

a first locator mounted with respect to the frame; and

a wheelchair having

a second locator interfittable with the first locator to position the wheelchair on the vehicle as a driver's seat,

the wheelchair being interconnectable with the connector port on the vehicle and having a motor and an operator interface operable for moving the wheelchair independently of the vehicle through the motor and being operable when positioned as a driver's seat on the vehicle and interconnected with the connector port on the frame for driving the vehicle.

2. The mobility system of claim 1 wherein the first locator is structure on the vehicle forming a groove and the second locator is a portion of the wheelchair.

3. The mobility system of claim 1 wherein the vehicle has an energy source for the energy conversion system, and the wheelchair has a battery for powering the motor, said battery having a connector interconnectable with the energy source on the vehicle to recharge the battery.

4. A wheelchair adapted for multiple uses as a wheelchair and as a driver's seat for a drivable vehicle comprising, a chair for supporting a person, a wheel connected to the chair for supporting and motivating the chair, a motor for driving the wheel, an operator interface in a drivable relationship by a person in the chair and in a controllable relationship to the motor, the operator interface having a connector selectively interconnectable with the motor to control the wheelchair or with the vehicle to drive the vehicle.

5. The wheelchair of claim 4 including a battery for powering the motor wherein the battery further has a connector selectively interconnectable with the vehicle to recharge the battery when the operator interface is selectively interconnected with the vehicle to drive the vehicle.

6. A mobility system comprising:

a vehicle having drive-by-wire control apparatus including a drive-by-wire connector port; and

a wheelchair removably mountable in the vehicle including a connector operatively connected to an operator interface and operably and removably connectable with the connector port, whereby said operator interface may be used to drive the vehicle when the wheelchair is mounted in the vehicle with the connector connected to the connector port, and the operator interface may be used to drive the wheelchair when the wheelchair is removed from the vehicle and the connector disconnected from the connector port.

7. The mobility system of claim 6 wherein the vehicle has a power source and including a battery configured for engagement with the power source when the wheelchair is mounted in the vehicle with the connector connected to the connector port so that the battery may be recharged.

8. A wheelchair comprising:

an operator interface for driving the wheelchair,

mounting structure configured for mounting the wheelchair on a vehicle, and

a connector selectively operatively associated with the operator interface and configured to be operatively and removably connectable to the vehicle,

whereby said operator interface may be used to drive the vehicle when the connector is operably connected to the vehicle.

9. The wheelchair of claim 8 including:

a battery for powering the wheelchair, and

a connector configured for connecting the battery with the vehicle when the operator interface is used to drive the vehicle, whereby to recharge the battery.

10. A mobility system comprising:

a vehicle having:

a frame,

at least three wheels operable with respect to the frame,

a steering system mounted with respect to the frame and responsive to non-mechanical control signals,

a braking system mounted with respect to the frame and responsive to non-mechanical control signals,

an energy conversion system mounted with respect to the frame and responsive to non-mechanical control signals,

a connector port mounted with respect to the frame and operably connected to the steering, braking and energy conversion systems, and

structure on the vehicle forming a groove that is substantially fixed with respect to the frame; and

a wheelchair including:

a motor,

a locator on the wheelchair interfittable with the groove on the vehicle to position the wheelchair with respect to the vehicle as a driver's seat,

an operator interface operable for driving the wheelchair independently of the vehicle through the motor and operable for driving the vehicle through the connector port when the locator on the wheelchair is interfitted with the structure forming a groove on the vehicle, and

a battery for powering the wheelchair when the operator interface is operable for driving the wheelchair independently of the vehicle, said battery having a connector for interconnecting the battery with a power source in the energy conversion system of the vehicle to recharge the battery when the interface is operable for driving the vehicle.

11. A method of enabling a vehicle to be driven from a wheelchair comprising:

providing an operator interface on the wheelchair usable for driving the wheelchair;

providing access on the vehicle for receiving the wheelchair onboard the vehicle;

providing an operator interface connector connectable between the operator interface and the vehicle when the wheelchair is onboard the vehicle so that the operator interface is usable for driving the vehicle.

12. The method of claim 11 including providing a locator on the wheelchair and a second locator on the vehicle for sufficiently interfitting the wheelchair and the vehicle when the wheelchair is received onboard the vehicle so that the wheelchair is located with respect to the vehicle.

13. The method of claim 12 wherein the locator and the second locator are accessible to a user of the wheelchair, permitting the user to interfit the wheelchair and the vehicle with the locators.

14. The method of claim 12 including providing a mechanism for securing the wheelchair to the vehicle.

15. The method of claim 14 wherein the mechanism for securing the wheelchair to the vehicle is accessible to a user of the wheelchair, permitting the user to secure the wheelchair to the vehicle.

16. A method for the wheelchair-bound to drive a vehicle comprising:

driving a wheelchair through an operator interface controlling at least one of the wheelchair's steering, accelerating, decelerating and braking systems;

accessing the vehicle while wheelchair-bound; and

connecting the operator interface to the vehicle in a manner for controlling at least one of the vehicle's steering, accelerating, decelerating and braking systems.

17. The method of claim 16 wherein accessing the vehicle includes affixing the wheelchair in a fixed relation to the vehicle.

18. The method of claim 16 wherein accessing the vehicle includes controlling structure on the vehicle to facilitate the access of the wheelchair onboard the vehicle.

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