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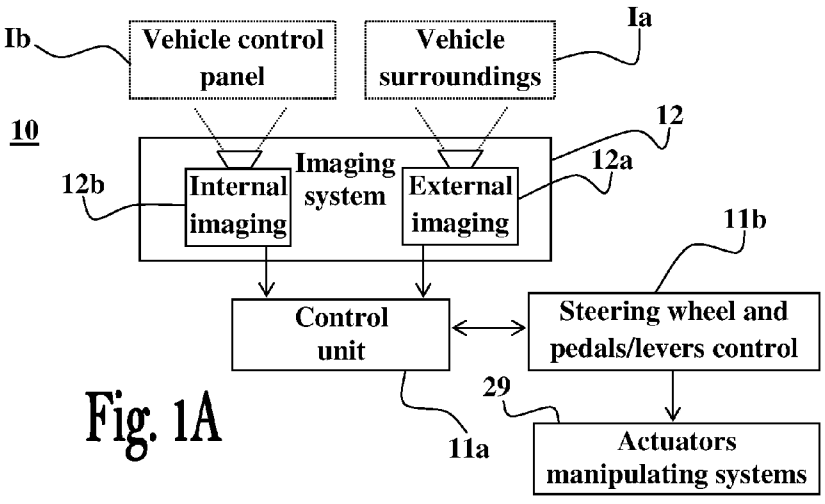


Fig. 1A

(57) Abstract: A robotic system for driving a vehicle to a destination and related methods are disclosed. The robotic system is configured for placement inside the vehicle and it utilizes an imaging system for acquiring image data of at least a part of the interior of the vehicle and image data of external surroundings of the vehicle, and a control system for processing the image data acquired by the imaging system. The control system is configured to identify in the image data of at least part of the interior of the vehicle image data of the vehicle state indicators, and determine therefrom at least vehicle status data. The control system is adapted to determine from the image data of external surroundings road status data, and analyze the at least vehicle status data and the road status data for generating control instructions for driving the vehicle along the road.

UNIVERSAL AUTONOMOUS ROBOTIC DRIVING SYSTEM

TECHNOLOGICAL FIELD

The present invention is generally in the field of robotic driving systems.

BACKGROUND

Driving a motor vehicle is a relatively tedious, repetitive, time consuming (about 250 hours annually for an average commuter according to KPMG report on "Self-driving cars: The next revolution", 2012) and costly (in terms of manpower) task. About 93% of car accidents are caused by human error, which also renders driving motor vehicles a hazardous task. Car accidents annually claim thousands of casualties and result in tremendous costs (a few hundred billion dollars every year according to the KPMG report) associated with hospitalization, medical treatment and care, and car damages.

Robotic driving systems are being developed for replacing human drivers for various different tasks and applications, such as, for testing vehicle performance, for military operations, and suchlike. The solutions proposed heretofore are usually expensive to implement and very difficult to license/authorize for operating land vehicles.

Some automated driving systems are known from the patent literature, as described in US Patent Nos. 4,742,720, 5,172,589, 5,270,628, 5,363,027, 5,394,743, 5,816,106, 5,821,718, 7,628,239 and 8,051,936, for example. These automated driving systems, however, require a human operator for providing control and instructions to the system, in order to drive the vehicle along a predetermined track/path, and are not designed to provide a universal platform that can be used with any land/motor vehicle.

GENERAL DESCRIPTION

There is a need in the art for automated driving systems that are universal, in a sense of being capable to be mechanically coupled to any type/model of land/motor vehicle and operate its actuators (steering wheel, pedals and/or levers), for driving the vehicle towards a destination. There is also a need in the art for automated driving systems that can autonomously operate a vehicle and drive it towards a desired

destination without communicating data with control and/or computerized systems of the vehicle and without human intervention in the vehicle operation tasks.

The present invention provides a low weight and low cost, easy to assemble and easy to mount, universal autonomous robotic system configured and operable to operate a land vehicle and drive it to a desired destination. The robotic system of the present invention is configured and operable to be fastened to a driver seat of any land vehicle (*e.g.*, sedan, van, truck, tractor, and the like), is mechanically coupled to pedals, steering wheel and/or levers of the vehicle (generally referred to herein as actuators), and which continuously acquires and analyzes image data of the interior of the vehicle and of its external surroundings. The robotic system processes the acquired image data, determines therefrom vehicle and road status data, and, based on the determined vehicle and road status data, determines control operators/instructions. The control operators/instructions are then used by the system to change the states of one or more actuators of the vehicle, accordingly, in order to safely drive the vehicle along a predetermined route towards the destination.

The term *actuators* as used herein generally refers to mechanical controls (*e.g.*, wheels, levers, knobs/switches, etc.) used for operating different systems of a vehicle, such as, but not limited to, a wheel steering system, a gear system, an acceleration system, a brake system, a clutch system, an engine ignition system, a vehicle lights system, a wipers system, a handbrake system, and suchlike.

The term *state indicators* as used herein generally refers to means indicative of a status of the vehicle, such as provided in a control panel of the vehicle (*e.g.*, speed meter, engine temperature indicator, engine angular velocity indicator, fuel level indicator, battery charge level indicator, and suchlike).

The road status data may be indicative of external obstacles (*e.g.*, nearby vehicles/bicycles, pedestrians, traffic islands, and suchlike) and/or traffic regulation signs/lights, identified in the acquired image of the external surroundings of the vehicle. The road status data may include additional data acquired by other sensors and/or wirelessly received (*e.g.*, over a wireless Internet communication), such as, but not limited to, traffic loads, weather conditions, speed limitations, average vehicle speed applicable over certain road sections during certain hours of the day, and suchlike.

The vehicle status data may be indicative of the vehicle speed, motor state (temperature, angular speed), fuel and/or battery state, and the like, as identified in the

acquired image of the control panel of the vehicle. Optionally, and in some embodiments preferably, some, or all, of the vehicle status data is received directly from the vehicle by connecting the robotic system to the control bus of the car (if such a bus is present) either by a wired connection, or wirelessly (*e.g.*, CAN bus, also known as controller area network bus). The vehicle status data may include additional data acquired by other sensors and/or wirelessly fetched, such as, but not limited to, the current state (angular displacement) of the steering wheel, the current state of the pedals and/or of levers of the vehicle, battery charging history and the like.

Optionally, and in some embodiments preferably, the robotic system receives the destination from the user via a suitable input device and determines a route for driving the vehicle from its current location to the indicated destination based at least in part on navigation data obtained from an internal storage of the system, and/or obtained wirelessly from a remote data storage/service accessible over a data network. The current location of the vehicle may be determined using any suitable positioning technique (*e.g.*, triangulation), or provided by the user (*e.g.*, via a smart device). Preferably, the robotic system comprises a positioning system (*e.g.*, global positioning system/GPS module), and/or an inertia measurement unit (IMU), for continuously monitoring the movement of the vehicle towards the desired destination.

In some possible embodiments visual determination techniques may be used to monitor the movement of the vehicle along the route. For example, a visual odometry process may be used to analyze a sequence of images of the external environment of the vehicle, identify one or more stationary objects in the images, determine distances of the identified stationary objects from the vehicle, and based on the determined distances determine vehicle movement as a function of time.

The route determination process may utilize additional information collected by the robotic system during the ride, such us, but not limited to, the road status data (*e.g.*, traffic loads) and/or the vehicle status data (*e.g.*, fuel and/or battery state). For example, and without being limiting, if the vehicle status data indicates that the fuel/battery state of the vehicle is low, the robotic system may determine a new route to the destination including one or more stops at petrol and/or battery charging/exchange stations to renew the energy resources of the vehicle. Similarly, if the road status data is indicative of traffic loads along the determined route, the robotic system may determine a new route to the destination using less loaded roads.

One inventive concept of the subject matter disclosed herein relates to a robotic system for driving a vehicle to a destination. The robotic system is configured for placement inside the vehicle and utilizes an imaging system and a control system for driving the vehicle to the destination. The system uses the imaging system to acquire image data of at least a part of the interior of the vehicle, and image data of external surroundings of the vehicle. The image data acquired by the imaging system is processed and analyzed by the control system.

The control system identifies, in the image, data of at least part of the interior of the vehicle image data of the vehicle state indicators and determines therefrom at least vehicle status data. The control system also determines road status data from the image data of external surroundings. The control system further analyzes at least one of the vehicle status data and the road status data, and, based on the analysis, generates control instructions for driving the vehicle along the road.

Preferably, an actuators manipulating system coupled to actuators of the vehicle is used to controllably change operational states of the actuators according to the control instructions generated by the control unit.

Optionally, and in some embodiments preferably, the control system receives location data indicative of a current location of the vehicle and road data, and determines a route for driving the vehicle to the destination based at least in part on the received location and road data. In some embodiments a positioning unit is used to determine the current location of the vehicle. The system may further comprise a wireless communication unit for communicating data with a remote computer system (server). The control system in some embodiments is adapted to receive at least the road data via the wireless communication unit.

In some embodiments a user interface unit is used for communicating data with a user. In possible applications the control system is adapted to receive at least the destination data via the user interface unit. Optionally, and in some embodiments preferably, the user interface unit comprises a data communication device usable for communicating data with a user device. In this way, the control system may use the data communication device of the user interface unit for receiving at least one of the location data and the road data. In a variant, an audio input device is used for receiving audible instructions from a user via the user interface unit. For example, and without being limiting, the audible instructions are indicative of at least one of the destination and

vehicle operating instructions. In addition, an audio output device may be used for outputting audible information to the user via the user interface unit.

Optionally, and in some embodiments preferably, the different components of the robotic system (*e.g.*, the imaging system, control system and actuators manipulating system) are mounted on a support member (*e.g.*, one or more support frames) configured and operable for securing the system to a driver seat of the vehicle.

In possible embodiments the actuators manipulating system comprises at least a brake pedal manipulating system, an accelerator pedal manipulating system, and a steering wheel manipulating system. Optionally, and in some embodiments preferably, the steering wheel manipulating system is elastically coupled to the support member to permit movement of the steering wheel manipulating system in at least one of its translational axes, while preventing angular movement thereof. In possible applications the actuators manipulating system further comprises at least one lever manipulating system usable for actuating at least a gear system of the vehicle. However, the lever manipulating system may be also used to actuate the handbrake, lights, wipers, and/or other actuating knobs/switches and levers of the vehicle.

The imaging system is used in some embodiments for acquiring image data indicative of the state indicators on a control panel of the vehicle, and for acquiring front image data indicative of front side external surroundings of the vehicle. Though the imaging system may utilize a single imager unit to acquire the needed image data, in some embodiments at least two imager units are used. For example, and without being limiting, a panel imager unit is used for acquiring the image data indicative of the state indicators on the control panel of the vehicle, and a front view imager is used for acquiring the front image data indicative of front side external surroundings of the vehicle.

Optionally, and in some embodiments preferably, the imaging system also comprises a back imager unit for acquiring rear-view image data of the external surroundings of the vehicle.

In some applications the imaging system is further configured for acquiring image data indicative of at least one of left-view of the external surroundings of the vehicle and left-side rear-view reflected by a left-side mirror of the vehicle, and for acquiring image data indicative of at least one of right-view of the external surroundings of the vehicle and right-side rear-view reflected by a right-side mirror of the vehicle.

For example, and without being limiting, the imaging system may utilize a left imager unit for acquiring the image data indicative of at least one of the left-view of the external surroundings of the vehicle and the left-side rear-view reflected by the left-side mirror of the vehicle, and a right imager unit for acquiring the image data indicative of at least one of the right-view of the external surroundings of the vehicle and the right-side rear-view reflected by the right-side mirror of the vehicle.

Another inventive concept of the subject matter disclosed herein relates to a method of autonomously driving a vehicle to a destination. In some embodiments the method comprises receiving image data indicative of at least of state indicators of the vehicle and of external surroundings of the vehicle, identifying in the received image data at least the states of the state indicators and objects in the external surroundings of the vehicle, and respectively generating the vehicle and road status data based on the identified states and objects, and generating the control instructions for driving the vehicle along the road based at least in part on the vehicle status data and the road status data.

Optionally, and in some embodiments preferably, the method comprises receiving location data indicative of a current location of the vehicle and determining a route to the destination based on the location data. The identifying step comprises in some embodiments detecting at least one of road lanes and road curves in the image data and generating lane data indicative thereof. The generated lane data is usable in possible applications for safely navigating the vehicle on the driven road.

The method comprises in possible embodiments tracking at least one of the identified objects and generating trajectory data indicative of a trajectory thereof. This trajectory data is usable in at least one of determining the route and generating the control instructions.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings. Features shown in the drawings are meant to be illustrative of only some embodiments of the invention, unless otherwise implicitly indicated. In the drawings like reference numerals are used to indicate corresponding parts, and in which:

Figs. 1A and **1B** are block diagrams of a robotic driving system according to some possible embodiments;

Figs. 2A to **Fig. 2D** schematically illustrate possible embodiments of the robotic system fastened to a driver seat of a land vehicle;

Fig. 3 is a block diagram of an imaging system according to some possible embodiments;

Fig. 4 is a block diagram exemplifying a control scheme according to some possible embodiments; and

Figs. 5A to **5C** schematically illustrate another possible embodiment of the robotic system, wherein **Fig. 5A** is a perspective view of the system, **Fig. 5B** is a sectional view of the base assembly of the system, and **Fig. 5C** is a sectional view of a vertical support assembly of the system.

DETAILED DESCRIPTION OF EMBODIMENTS

One or more specific embodiments of the present disclosure will be described below with reference to the drawings, which are to be considered in all aspects as illustrative only and not restrictive in any manner. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. Elements illustrated in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the invention. This invention may be provided in other specific forms and embodiments without departing from the essential characteristics described herein.

The present invention aims to provide a low weight and low cost, easy to assemble and easy to mount, robotic driving system, that can be quickly mounted on any land vehicle by an ordinary vehicle user/owner. The robotic driving system described herein is designed as a universal robotic navigation driver that can be fastened to a driver seat of any land vehicle. The robotic driving system is mechanically coupled to actuators of the vehicle using a steering wheel manipulating system, one or more pedal manipulating systems and/or or one or more levers and/or knobs manipulating systems, for operating the vehicle and driving it towards a predetermined destination. Accordingly, the present invention provides a universal system that can be placed in a driver seat of any land/motor vehicle and perform all functions customarily conducted by a human driver for operating the vehicle and driving it towards a desired destination.

An imaging system of the robotic system is used to continuously acquire image data of the external environment (surroundings) of the vehicle and of interior portions thereof. The image data acquired by the imaging system from the external environment and from the interior of the vehicle is processed and analyzed to respectively determine road status data and vehicle status data.

A control system of the robotic system is used to determine the road and vehicle status data from the acquired images and determine a driving route to a predetermined destination based at least in part on the road and/or vehicle status data, and/or navigation data obtained from an internal storage of the vehicle, and/or wirelessly from a remote data storage/server accessible over a data network. Correspondingly, the control system generates control operators/instructions for operating the manipulating systems of the robot in order to change the state of the steering wheel, pedals, and/or levers/knobs of the vehicle based at least in part on the road and vehicle status data, and the determined driving route, in order to safely drive the vehicle to the desired destination.

Figs. 1A and **1B** are block diagrams schematically illustrating autonomous robotic operation of a land vehicle according to some possible embodiments. **Fig. 1A** shows a simplified scheme of the autonomous robotic system **10** using a control unit **11a** to process and analyze one or more streams of image data received from an imaging system **12**. The control unit **11a** is configured and operable to determine road and vehicle status data from the received streams of image data, and based at least on the determined status data generate control operators/instructions for driving/maneuvering the vehicle towards a predetermined destination. The control operators/instructions generated by the control unit **11a** are used by an actuators manipulator controller **11b** to operate the manipulating systems **29** to change the operational state of one or more actuators of the vehicle (*e.g.*, accelerator pedal, brake pedal, hand brake, steering wheel, gear lever, blinker lever, wipers lever, and suchlike).

The control unit **11a** may also use data received from the actuators manipulator controller **11b** in the generating of the control operators/instructions. For example, and without being limiting, in some embodiments the manipulators controller **11b** is configured and operable to receive state data from sensor units (*e.g.*, encoders, not shown in **Fig. 1A**), provided in the actuators manipulating systems **29** and being indicative of operational states of the pedals, levers and/or knobs of the vehicle.

Optionally, and in some embodiments preferably, the manipulators controller **11b** is configured and operable to obtain at least part of the state data from computer/data systems of the vehicle, for example, by connecting to its data bus (*e.g.*, CAN bus). In this way a feedback loop is obtained allowing the control unit **11a** to adaptively adjust the control operators/instructions provided to the manipulators controller **11b** based on the state data the manipulators controller **11b** gathers from the sensor units, from the actuators manipulating systems **29**, and/or from the computer/data systems of the vehicle. This configuration enables using advanced drive control schemes, for example, employing fuzzy logic and neural networks techniques for generating the control operators/instructions.

In some embodiments, the communication between the control unit **11a** and the actuators manipulator controller **11b** is carried out over a universal asynchronous receive/transmit (UART) connection, for high level instructions and feedback. However, any suitable serial or parallel bus based data communication (*e.g.*, USB, CAN bus, Ethernet, WiFi) may be similarly used without departing from the scope and spirit of the present invention.

Optionally, and in some embodiments preferably, the imaging system **12** comprises at least two imaging units; an internal imaging unit **12b** and an external imaging unit **12a**. The internal imaging unit **12b** is configured and operable to acquire images of the vehicle's interior **Ib** being indicative of the vehicle status *e.g.*, comprising indicators of the control panel of the vehicle and/or showing operational states of levers, knobs and/or pedals of the vehicle. The external imaging unit **12a** is configured and operable to acquire images of the vehicle's external surroundings **Ia** being indicative of the road status *e.g.*, road direction, traffic signs, traffic lights, possible obstacles present on the road, and suchlike.

It is however noted that in some possible embodiments the images of the vehicle's external surroundings **Ia** and of the vehicle's interior **Ib** are acquired by means of a single imager unit. For example, and without being limiting, such a single imager unit may be configured to acquire a very wide field of view including the image data of both the external surroundings **Ia** and of the vehicle's interior **Ib** (*i.e.*, concurrently acquiring all needed image data). Additionally or alternatively, a movable/rotatable imager unit may be used to sequentially acquire the external surroundings **Ia** and the vehicle's interior **Ib**. Additionally or alternatively, optical means (mirrors, lenses,

splitters) can be used to combine the image data of external surroundings **Ia** and of the vehicle's interior **Ib** on different areas of the same imager sensor, so as to combine them into a single image frame.

In **Fig. 1A**, the control unit **11a** is configured and operable to determine from the images **Ib** acquired by the internal imaging unit **12b** the data indicative of the vehicle status, comprising, *inter alia*, vehicle velocity, temperature and angular velocity of the engine, fuel and/or battery state, operational state of pedals, lever and/or knobs of the vehicle, and suchlike. The road status data is determined by the control unit **11a** from the images **Ia** acquired by the external imaging unit **12a**, by identifying in the acquired images the direction of the road and/or lane, nearby vehicles and/or pedestrians, traffic signs, traffic lights, sidewalks and/or traffic islands. Based at least in part on the extracted road and vehicle status data the control unit **11a** determines if states of the vehicle actuators need to be changed, and generates the control operators/instructions accordingly, for adjusting the vehicle actuators' states by the manipulators controller **11b**.

Fig. 1B is a block diagram showing other possible embodiments of the robotic driving system **10**. In this non-limiting example the manipulators controller **11b** is coupled to the actuators manipulating systems **29** that comprises an accelerator pedal manipulating system **24**, brake pedal manipulating system **25**, steering wheel manipulating system **23**, and levers/knobs actuator **26**.

The levers/knobs actuator **26** is adapted for operating various buttons/knobs, keys, gear shaft, and/or handbrake, of the vehicle. In some possible embodiments, the robotic driving system **10** further comprises a clutch pedal manipulating system (not shown) configured and operable to operate a clutch pedal of the vehicle, if so needed.

The manipulators controller **11b** is configured and operable to receive the control operators/instructions generated by the control unit **11a** and actuate the one or more of the actuators manipulating systems **29** (**23**, **24**, **25**, and/or **26**) accordingly, receive state data (*e.g.*, angular position) from sensor units (**23e**, **24e**, **25e** and **26e**, respectively) of the actuators manipulating systems **29** and transfer the same to the control unit **11a**. As also seen in **Fig. 1B**, the data communication between the imaging system **12** and the control unit **11a** may be a bi-directional data communication to allow provision of control instructions to the imaging system **12** *e.g.*, for adjusting optical elements thereof and/or image acquisition direction of one or more imagers thereof.

A human machine interface (**HMI**) unit **16** may be used to input data from a user and/or to output data to the user. For example, and without being limiting, the HMI unit **16** may be configured and operable to receive audible data (*e.g.*, indicative of the destination and/or the location data) and/or instructions (*e.g.*, start, stop, drive, or other such instructions) from the user via an audio input device **16m** (*e.g.*, using one or more microphones), and transfer the same to the control unit **11a**. The HMI unit **16** may receive output data from the control unit **11a** and generate respective audible output to the user using an audio output device **16s** (*e.g.*, using one or more speakers). For this purpose the HMI unit **16** may employ any suitable voice recognition and voice generating techniques known in the art.

The HMI unit **16** may use a data communication unit **16c** to communicate digital data with the user using any suitable input/output device (*e.g.*, keypad/keyboard, pointing device, LCD/video display, touch screen or pad, or suchlike). Optionally, and in some embodiments preferably, the data communication unit **16c** comprises a wireless communication device **16r** for wirelessly communicating data (*e.g.*, using optical communication, such as infrared communication, and/or radio-frequency communication, such as WiFi, Bluetooth, near field communication - NFC, Zigbee) with a user device **16u** (*e.g.*, smart device such as a tablet, smart phone, or a laptop) through the HMI unit **16**. For example, and without being limiting, a smart device/phone **16u** of the user may be used to provide the robotic system **10** with the destination data, and/or location data using the positioning functionalities (*e.g.*, GPS and/or base stations triangulation) of the smart device **16u**. Similarly, the smart device **16u** may be also used to provide the system **10** with maps (*e.g.*, using Google Maps™) and/or navigation data (*e.g.*, using Waze™).

Alternatively or additionally, the data communication unit **16c** may further comprise a cable connector **16u** for communicating data with a user device (*e.g.*, smart device) over a serial or parallel data communication cable (*e.g.*, using a universal serial bus protocol - USB). The control unit **11a** may be configured to receive various types of information via the cable connector **16u**, such as, but not limited to, road data, map data, location data, one or more destinations, locations of petrol and/or battery charge stations, and such like.

Optionally, and is some embodiments preferably, the robotic system **10** comprises a wireless communication unit **15** for communicating data with one or more

remote computer systems/servers **19** (*e.g.*, using Internet access over WiFi or cellular network). The control unit **11a** may be configured and operable to fetch the maps and/or the navigation data directly through the wireless communication unit **15**. The wireless communication unit **15** may be used to fetch different types of information relevant for the driving of the vehicle to the destination, such as, but not limited to, traffic loads data, weather conditions/forecasts, locations of gasoline/charging stations, and suchlike.

Optionally, and in some embodiments preferably, as least some of the data communication (conducted through wires and/or wirelessly) performed by/with the robotic driving system **10** is encrypted in order to ensure safety and security. Any suitable encryption scheme may be utilized for this purpose, such as DES, RSA, SHA.

The robotic system **10** may also comprise a positioning system **18** using GPS and/or inertia measurement unit (IMU) for continuously determining the location of the vehicle in which the robotic system **10** is used. In this way, the control unit **11a** can determine at any given time the location of the vehicle based on position/orientation data received from the positioning system **18**, monitor the progress of the ride towards the destination and determine control operators/instructions for the actuators manipulation controller **11b**, accordingly. Alternatively or additionally, the position data obtained, or derived, from the positioning unit **18** may be communicated via the wireless communication unit **15** for processing and generating navigation data to the destination by a remote server/service **19**.

A power source **17** of the robotic system **10** is also shown in **Fig. 1B**, for powering the different units/devices of the robotic system **10**. An internal rechargeable battery (not shown) may be used for the power source **17**, or alternatively, the robotic system **10** may be configured and operable to connect to a power supply of the vehicle.

The robotic system **10** may further comprise a safety and monitoring unit **18** configured and operable to receive and process the status data determined by the control unit **11a** and the state data obtained by the actuators manipulator controller **11b** from the different actuators manipulating systems, to assure that all of the units/devices of the system **10** are operating properly and safely. In some embodiments, the safety and monitoring unit **18** analyzes the input data of each unit/device being monitored to assure its validity and quality (*e.g.*, verify the images received from the imaging system are not saturated or blocked), and assesses the output of the module to assure the obtained results are within acceptable operational ranges. If a problem is identified, the safety

and monitoring unit **18** issues respective indications/alerts to the user indicating the identified problem and and/or logs the same in the system **10**. For example, and without being limiting, the safety and monitoring unit **18** may be able to stop the vehicle if the identified problem is crucial. In some embodiments the safety and monitoring system **18** is configured and operable to monitor the operation of the motors (seen in **Figs. 2A** and **2B**) of the actuating systems and the status of the power source **17** of the system **10**.

Fig 2A and **2B** respectively show front and back perspective views of the robotic driving system **10** fastened to a driver seat **20a** of a land vehicle **20**, according to some possible embodiments. In this non-limiting example, the robotic system **10** is fastened to the driver seat **20a** by a fastening frame **22** having a base frame **22a** immovably secured to the base of the driver seat **20a**, and a support frame **22b** connected to the base frame **22a** and immovably secured to the back support portion **20b** of the driver seat **20a**. A support member **22c** carrying the steering wheel manipulating system **23** can be connected to the base frame **22a** and/or to the support frame **22b**, or to an intersection of these frames.

Optionally, and in some embodiments preferably, the base and support frames, **22a** and **22b**, are movably hinged one to the other, to allow angular movement of the frames one relative to other. The support member **22c** may be also movably hinged to one of the frames **22a** and **22b**, or to their intersection, to permit angular motion of the support member **22c** relative to at least one of the frames **22a** and **22b**. In some embodiments the support member **22c** carrying the steering wheel manipulating system **23** is attached to at least one of the frames **22a** and/or **22b** by cables and/or straps **22s**, as exemplified in **Fig. 2D**, thereby providing the steering wheel manipulating system **23** the strength required to hold the support member **22c** while providing it with freedom of movement in the translation axes (i_1, i_2, i_3) and preventing rotational/angular movement thereof. A certain orientation of the frames **22a** and **22b**, one relative to the other, and/or of the support member **22c** relative to at least one of the frames **22a** and **22b**, may be locked using a locking mechanism (*e.g.*, **22q**), to achieve a desired angle between the frames **22a** and **22b**, and a desired angle between the support member **22c** and at least one of the frames **22a** and **22b**.

In this non-limiting example the imaging system **12** is mounted on the support frame **22b**. It is however noted that in possible embodiments various imaging units of the imaging system **12** may be mounted at/on different locations of the support frame

22b, at/on different locations of the base frame **22a**, and/or of the support member **22c**. As also exemplified in **Figs. 2A** and **2B**, a control system **11** comprising the control unit **11a** and the actuators manipulator controller **11b** may be immovably secured to at least one of the frames **22a** and **22b**. However, the control units of the control system **11** may be similarly immovable attached to any one of the frames **22a** and **22b** and/or to the support member **22c**.

The steering wheel manipulation system **23** carried by the support member **22c** is attached to the steering wheel system **20w** of the vehicle **20** and configured and operable to rotate the steering wheel **23f** of the vehicle **20** by means of a motor **23m** and gear **23g** arrangements (*e.g.*, using a worm gear rotor assembly). The steering wheel manipulation system **23** may be configured to attach and rotate the steering wheel **20w** by means of a propeller structure **28** having a plurality of fin members **28p** (three such fins are shown in **Figs. 2A**, **2B** and **2D**) and is mechanically coupled to a rotatable shaft of the motor **23m** via the gear system **23g**. The propeller structure **28** is attached to a rotatable shaft **23h** of the gear system **23g**, and its fin members **28p** extend therefrom radially towards the frame **23f** of the steering wheel system **20w** and attach to the frame **23f** of the steering wheel **20w** by their free ends.

The propeller structure **28** of the fin members **28p** may be attached to the frame **23f** of the steering wheel system **20w** by any suitable clamping means *e.g.*, using U-bolts **23t** and nuts. This configuration provides a simple attachment scheme allowing the user to quickly and easily couple the wheel manipulation system **23** to the steering wheel **20w**. In addition, the use of the fin members **28p** of the propeller structure **28** to transfer rotary motion of the motor **23m** to the frame **23f** of the steering wheel system **20w** is exploited to actuate the steering wheel **20w** by the motor **23m** while providing it some freedom to move along the translation axes i_2, and i_3 (where i_1 is parallel to, or coincides with, the axis of rotations $\mathbf{W}_x$ of the wheel **23f**).

As exemplified in **Fig. 2D**, in some embodiments the support member **22c** of the steering wheel manipulating system **23** is attached to at least one of the fastening frames **22** by straps and/or cables **22s**. In this specific and non-limiting example the support member **22c** is attached to the base frame **22a** by straps **22s**, however, it may be similarly attached to the support frame **22b**, or to both of frames **22a** and **22b**. The attachment of the support member **22c** by straps/cables **22s** provides a flexible/resilient connection between the steering wheel manipulating system **23** and the fastening frame

22 providing it with some freedom to move along the translational axes i_1, i_2, and i_3 while preventing angular motion thereof. Such an attachment scheme employing cable/straps **22s** thus provides the steering wheel manipulating system **23** non-rigid connection to the fastening frame **22**, that permits limited motion of the motor **23m** of the steering wheel manipulating system **23**, and thereby resolves the problems associated with centering the rotating parts of the steering wheel system **20w** and of the motor **23m**, and enables reduction of the actuation forces applied by the motor **23m** in order to rotate the frame **23f** of the steering wheel system **20w**.

Figs. 2A and **2B** also show the accelerator pedal manipulating system **24** and the brake pedal manipulating system **25**, each immovably attached to the base frame **22a** and comprising a movable leg mechanically coupled to the respective pedal.

The accelerator pedal manipulating system **24** comprises an electric motor **24m** (*e.g.*, servo motor) immovably attached to a support beam **22p** of the base frame **22a**, a rotatable lever **24r** mechanically coupled to the shaft of the motor **24m** and to the movable leg **24f**. The movable leg **24f** is hinged to the rotatable lever **24r** at one end thereof, thereby forming a knee-like joint **24j**, and is mechanically coupled to the accelerator pedal **20c** by its free end. In this way, rotary movements of the shaft of the motor **24m**, and of the lever **24r** mechanically coupled to it, are translated to push or pull actuations of the accelerator pedal **20c** by the movable leg **24f** coupled to it.

Similarly, the brake pedal manipulating system **25** comprises an electric motor **25m** (*e.g.*, a worm gear motor) immovably attached to the support beam **22p** of the base frame **22a**, and a rotatable lever **25r** mechanically coupled to the shaft of the motor **25m** and to the movable leg **25f**. The movable leg **25f** is hinged to the rotatable lever **25r** at one end thereof, thereby forming a knee-like joint **25j**, and is mechanically coupled to the brake pedal **20k** by its free end. In this way, rotary movements of the shaft of the motor **25m**, and of the lever **25r** mechanically coupled to it, are translated to push or pull actuations of the accelerator pedal **20c** by the movable leg **25f** coupled to it.

Referring now **Fig. 2C**, in some embodiments the movable legs **24f** and **25f** are coupled to their respective pedals, **20c** and **20k**, using 'C'-shaped coupling members (or clamps), **24g** and **25g** respectively, configured to wrap around at least some portion of the pedal and be rigidly secured thereto *e.g.*, using securing bolts. As seen, in this non-limiting examples the legs **24f** and **25f** are hinged to their respective 'C'-shaped coupling members **24g** and **25g**, forming simple joint structures **24x** and **25x** for

permitting angular movement between the legs **24f** and **25f** and their respective coupling members **24g** and **25g**.

In this non-limiting example the vehicle **20** is a type of electric vehicle operable by a limited number of actuators, comprising the accelerator pedal **20c**, the brake pedal **20k**, and a steering wheel **20w**. Therefore, lever manipulating system(s) (*e.g.*, for operating a gear system of the vehicle) and clutch manipulating system, are not required, and are not shown in **Figs. 2A** and **2B**. However, such manipulating systems can be easily implemented using mechanisms such as used in the manipulating systems **24 25** and/or **23** described and illustrated herein. Similarly, the robotic driving system **10** may comprise one or more such manipulating systems for operating various buttons/knobs, keys, gear shaft, and/or handbrake, of the vehicle. Thus, the robotic driving system **10** can be easily adapted for mounting in any manual or automatic vehicle.

It is noted that the embodiments of the robotic system **10** depicted in **Figs. 2A** and **2B** are designed for use with a right-hand traffic/drive vehicle. It should be clear that this is not a limitation on the present invention, and the robotic system **10** may be similarly configured to operate the controls of a left-hand traffic/drive vehicle, as well.

Fig. 3 is a block diagram showing the imaging system **12** according to some possible embodiments. In this non-limiting example the internal imaging unit **12b** of the imaging system **12** comprises a panel imaging unit **41**, comprising one or more imagers configured and operable to acquire images of the control panel **20x** of the vehicle **20** (only one imaging unit **41** is shown in **Fig. 3**). The external imaging unit **12a** of the imaging system **12** comprises a front imaging unit **42** comprising one or more imagers configured and operable to acquire front-view images of the external surroundings of the vehicle *e.g.*, as seen through the windshield **30w** of the vehicle, a back imaging unit **43** for acquiring rear-view images of the external surroundings of the vehicle *e.g.*, as seen via the rear-view mirror (windshield mirror) **20n** of the vehicle.

Alternatively, in some embodiments, the imaging system **12** employs movable/rotatable imager units capable of sequentially acquiring image data from various different fields of view (FOV) *e.g.*, using PAN-TIL mounted cameras, Omni directional cameras, standard cameras or a combination thereof. Alternatively or additionally, the imaging system **12** may comprise optical means (*e.g.*, lenses, mirrors, splitters) for allowing it to concurrently collect and combine image data from various

different FOVs onto different areas of the same imager sensor. In this way the number of imagers of the imaging system **12** may be substantially reduced. For example, in certain embodiments a single imager unit is used to collect the images of the control panel **20x** and the front-view images of the external surroundings of the vehicle.

In some embodiments the external imaging unit **12a** of the imaging system **12** further comprises a left side imaging unit **46** for acquiring left-side-view images of the external surroundings of the vehicle *e.g.*, as seen through the driver side window **30f**, and/or left-side-rear-view images *e.g.*, as seen via the left-side-view mirror **20f** of the vehicle. Similarly, a right side imaging unit **45** may be used for acquiring right-side-view images of the external surroundings of the vehicle *e.g.*, as seen through the front passenger side window **30r**, and/or right-side-rear-view images *e.g.*, as seen via the right-side-view mirror **20r** of the vehicle.

Optionally, and in some embodiments preferably, the front imaging unit **42** utilizes stereoscopic imaging techniques using two imagers **42f** and **42r** for determining locations of objects imaged by the front imaging unit **42** in a three-dimensional space (*i.e.*, for adding depth information). In some possible embodiments, such stereoscopic imaging techniques may be employed by the other imaging units, such as the left and right sides imaging units, **46** and **45**. The imaging units of the imaging system **12** may be implemented using any type of any suitable imager such as, but not limited to, Point Grey's FLEA3 1.3 MPix 30 FPS color GigE camera. In some embodiments, however, a single imager unit is used in the imaging system **12** to acquire all needed image data (*i.e.*, of the control panel **20x**, the front-view images, the rear-view images, the left-side-view images, and the right-side-view images), utilizing a rotatable/movable imager, and/or optical means for expanding the FOV of the image and/or for concurrently combining the different image data on different sensor areas of imagers.

The imaging system **12** may include one or more control and/or processing units **12c** configured and operable to receive the images acquired by the imagers of the imaging units, **41**, **42**, **43**, **45** and/or **46**, and transfer them to the control system **11** for processing. In some possible embodiments the control/processing units **12c** of the imaging system **12** may comprise image processing hardware and/software configured and operable to process and analyze the images acquired by the imaging units and determine the external and internal status data needed by the control system **11** for generating the control operators/instructions for driving the vehicle.

Fig. 4 is a block diagram **40** exemplifying components and functions of the control unit **11a** according to some possible embodiments. In this non-limiting example the control unit **11a** utilizes a location determination module **3t** for determining the location (*e.g.*, global earth localization and/or on a road map) of the vehicle based on position/orientation data received from the positioning system **18**, and generating location data indicative thereof. If the positioning system **18** comprises both a GPS and an IMU unit, the position/orientation data from these units may be fused/combined in the location determination module **3t** for improving the accuracy and understanding of real world position of the vehicle, and thereby improving precision of the generated location data. For example and without being limiting, Kalman filters may be used at least in part for generating the location data based on the position/orientation data generated by the GPS and/or IMU units.

An image processing module **3e** of the control unit **11a** is used for determining the road and/or vehicle status data from the image data (**Ia** and **Ib**) received from the imaging system **12**. A route planning and monitoring module **3r** of the control unit **11a** is used for generating a route, monitoring the progress of the ride along the generated route, and for decision making based at least in part on the location data generated by the positioning system **18** and the road and/or vehicle status data generated by the image processing module **3e**. The route planning and monitoring module **3r** further generates driving instructions (*e.g.*, accelerate/decelerate, stop vehicle, turn left or right, change lane, and suchlike) based at least in part on the received location data and the road and/or vehicle status data. The driving instructions generated by the planning and monitoring module **3r** are used by an actuators control module **3c** of the control unit **11a** for generating the control operators/instructions used by the actuators manipulator controller **11b** to operate the manipulating systems.

The route planning and monitoring module **3r** may be configured and operable to monitor the progress of the ride along the generated route based at least in part on the location data generated by the location determination module **3t**, the road/map and/or navigation data received from a remote database/server (**19**) via the wireless communication unit **15**, the road and/or vehicle status data received from the image processing unit **3e**.

In some possible embodiments the road/map and/or navigation data is fetched from a memory/storage unit **3b** (*e.g.*, magnetic/optical disk, Flash memory, or suchlike)

of the control unit **11a**. Similarly, a predetermined destination for the ride may be fetched from the memory/storage unit **3b** and used by the route planning and monitoring module **3r** for generating the route. Accordingly, in some possible embodiments the robotic driving system **10** may be implemented without the wireless communication unit **15**.

In some possible embodiments the image processing module **3e** comprises at least an object detection (**OD**) component **m1**, an object tracking (**OT**) component **m2**, and a road/lane detection (**RD**) component **m3**, used for generating at least some portions of the road and vehicle status data (*e.g.*, utilizing vision/mapping algorithms). The object detection component **m1** is configured and operable to identify objects (*e.g.*, vehicles/bicycles, pedestrians, traffic signs/lights/islands, sidewalks, control panel indicators, and suchlike) in the image data received from the imaging system **12**, and generate object data indicative thereof. The object data generated by the object detection component **m1** is essential for driving the vehicle safely to the destination and preventing accidents and/or incidents. The object tracking component **m2** is configured and operable to anticipate the trajectory of the various objects identified by the object detection component **m1**, and generate trajectory data indicative thereof. The road/lane detection component **m3** is configured and operable to detect lanes and the road curves in the image data received from the imaging system, and generate lane data indicative thereof. The lane data generated by the road/lane detection component **m3** is used by the robotic driving system **10** to navigate safely on the driven roads, and is required in order to maintain the vehicle in a road lane, to permit lane switching, if needed, and to take road turns.

The object data, trajectory data and lane data, from the image processing unit **3e** is provided to the path planning/monitoring unit **3r**, wherein it is used for determining a safe route for the vehicle to drive in.

Fig. 5A shows a robotic system **50** according to some possible embodiment, and **Figs. 5B** and **5C** show sectional views of a base assembly **51** and of a vertical support assembly **52** of the system **50**. With reference to **Fig. 5A**, the base assembly **51** is configured to be securely attached to the driver seat, and the vertical support assembly **52** is configured to be securely attached to the back support of the driver seat. In some embodiments the vertical support assembly **52** is pivotally hinged to the base assembly **51**.

As seen in **Fig. 5A**, the vertical support assembly **52** comprises two apertures **52r** and **52f** at upper portion thereof serving as light entrance apertures for the front imaging unit **42**. Referring now to **Fig. 5C**, the vertical support assembly **52** comprises an upper compartment **52c** used for housing the imaging unit **42** and the positioning system **18**. More particularly, the imagers **42f** and **42r** of the imaging unit **42** are mounted at the sides of the upper compartment **52c** in alignment with the apertures **52r** and **52f**, and the positioning system **18** is positioned therebetween. An intermediate compartment **52i** is used for housing a computer system **55** (*e.g.*, a laptop) of the system, configured to implement functions of the control system and imaging system/DSP described hereinabove.

Fig. 5B shows a sectional view of the base assembly **51**, comprising a front support frame **51f** configured to receive and hold the electric motor **25m**, a front support frame **51r** configured to receive and hold the electric motor **24m**, and rear support frame **51e** configured to receive and hold circuitry drivers **51d** of the electric motors **24m** and **25m**, and of other elements of the system shown in **Fig. 2**.

As described hereinabove and shown in the associated figures, the present invention provides a universal robotic driving system **10/50** configured and operable for installation inside any land/motor vehicle for autonomously driving the vehicle to a desired/predetermined destination, and related methods. As will be appreciated the robotic driving system of the present invention provides a simple solution for transforming any vehicle into an autonomous vehicle, which may be advantageously utilized for various different applications, such as, but not limited to, agriculture, transportation, mining, cleaning, routine patrol, delivery, and for assisting handicapped/incapacitated, elderly, vision impaired and sleepy drivers.

The different modules of the control unit **11a** described hereinabove may be implemented in some embodiments as software and/or hardware modules, or a combination thereof. Functions of the robotic driving system **10/50** described hereinabove may be controlled through instructions executed by a computer-based control system which may be housed in the control system **11**. A control system suitable for use with embodiments described hereinabove may include, for example, one or more processors connected to a communication bus, one or more volatile memories (*e.g.*, random access memory – RAM) or non-volatile memories (*e.g.*, Flash memory). A secondary memory (*e.g.*, a hard disk drive, a removable storage drive, and/or

removable memory chip such as an EPROM, PROM or Flash memory) may be used for storing data, computer programs or other instructions, to be loaded into the computer system.

For example, computer programs (*e.g.*, computer control logic) may be loaded from the secondary memory into a main memory for execution by one or more processors of the control system **11**. Alternatively or additionally, computer programs may be received via a communication interface. Such computer programs, when executed, enable the computer system to perform certain features of the present invention as discussed herein. In particular, the computer programs, when executed, enable a control processor to perform and/or cause the performance of features of the present invention. Accordingly, such computer programs may implement controllers of the computer system.

In an embodiment where modules and/or units of the robotic driving system **10/50** are implemented using software, the software can be stored in a computer program product and loaded into the computer system using the removable storage drive, the memory chips or the communications interface. The control logic (software), when executed by a control processor, causes the control processor to perform certain functions of the invention as described herein.

In another embodiment, features of the modules and/or units of the robotic driving system **10/50** are implemented primarily in hardware using, for example, hardware components such as application specific integrated circuits (ASICs) or field-programmable gated arrays (FPGAs). Implementation of the hardware state machine so as to perform the functions described herein will be apparent to persons skilled in the relevant art(s). In yet another possible embodiment, features of the invention can be implemented using a combination of both hardware and software.

While particular embodiments of the invention have been described, it will be understood, however, that the invention is not limited thereto, since modifications may be made by those skilled in the art, particularly in light of the foregoing teachings. As will be appreciated by the skilled person, the invention can be carried out in a great variety of ways, employing more than one technique from those described above, all without exceeding the scope of the invention.

CLAIMS:

1. A robotic system for driving a vehicle to a destination, wherein the robotic system is configured for placement inside the vehicle and comprises:

an imaging system configured and operable to acquire image data of at least a part of the interior of the vehicle, and image data of external surroundings of the vehicle; and

a control system configured and operable to process and analyze the image data acquired by the imaging system, and identify in the image data of at least part of the interior of the vehicle, image data of the vehicle state indicators and determine therefrom at least vehicle status data, and determine from the image data of external surroundings, road status data, and analyze said at least vehicle status data and said road status data for generating control instructions for driving the vehicle along said road.

2. The system of claim 1, further comprising an actuators manipulating system configured and operable to couple to actuators of the vehicle and to controllably change operational states thereof according to the control instructions generated by the control unit.

3. The system of claim 1 or 2 wherein the control system is configured and operable to receive location data indicative of a current location of the vehicle and road data, and determine a route for driving the vehicle to the destination based at least in part on said location and said road data.

4. The system of claim 3 comprising a positioning unit configured and operable to determine the current location of the vehicle.

5. The system of claim 3 or 4 comprising a wireless communication unit configured and operable for data communication with a remote computer system for receiving at least the road data via said wireless communication unit.

6. The system of any one of the preceding claims, comprising a user interface unit for data communication with a user, for receiving at least the destination data.

7. The system of claim 6 wherein the user interface unit comprises a data communication device configured and operable for communicating data with a user device, for receiving at least one of the location data and the road data via the data communication device.

8. The system of claim 6 or 7, comprising an audio input device for receiving audible instructions from a user via the user interface unit, said audible instructions being indicative of at least one of the destination and vehicle operating instructions.

9. The system of any one of claims 6 to 8 comprising an audio output device for outputting audible information to the user via the user interface unit.

10. The system of any one of claims 2 to 9, wherein components of the robotic system are mounted on a support member configured and operable for securing the system to a driver seat of the vehicle.

11. The system of claim 10, wherein the actuators manipulating system comprises at least a brake pedal manipulating system, an accelerator pedal manipulating system, and a steering wheel manipulating system.

12. The system of claim 11, wherein the steering wheel manipulating system is elastically coupled to the support member to permit movement of the steering wheel manipulating system in at least one of its translational axes while preventing angular movement thereof.

13. The system of claim 11 or 12, wherein the actuators manipulating system further comprises at least one lever manipulating system configured and operable to actuate at least a gear system of the vehicle.

14. The system of any one of the preceding claims, wherein the imaging system is configured for acquiring image data indicative of the state indicators on a control panel

of the vehicle, and acquiring front image data indicative of front side external surroundings of the vehicle.

15. The system of claim 14, wherein the imaging system comprises at least two imager units, comprising: a panel imager unit for acquiring said image data indicative of the state indicators on the control panel of the vehicle, and a front view imager for acquiring said front image data indicative of front side external surroundings of the vehicle.

16. The system of Claim 14 or 15, wherein the imaging system comprises a back imager unit for acquiring rear-view image data of the external surroundings of the vehicle.

17. The system of any one of claims 14 to 16, wherein the imaging system is further configured for acquiring image data indicative of at least one of left-view of the external surroundings of the vehicle and left-side rear-view reflected by a left-side mirror of the vehicle, and for acquiring image data indicative of at least one of right-view of the external surroundings of the vehicle and right-side rear-view reflected by a right-side mirror of the vehicle.

18. The system of claim 17, wherein the imaging system comprises a left imager unit for acquiring said image data indicative of at least one of left-view of the external surroundings of the vehicle and left-side rear-view reflected by the left-side mirror of the vehicle, and a right imager unit for acquiring said image data indicative of at least one of right-view of the external surroundings of the vehicle and right-side rear-view reflected by the right-side mirror of the vehicle.

19. A method of autonomously driving a vehicle to a destination using the system of any one of the preceding claims, the method comprising:

receiving image data indicative of at least of state indicators of the vehicle and of external surroundings of the vehicle;

identifying in the received image data at least the states of said state indicators and objects in the external surroundings of the vehicle, and respectively generating the vehicle and road status data based on the identified states and objects; and

generating the control instructions based at least in part on said vehicle status data and said road status data.

20. The method of claim 19 comprising receiving location data indicative of a current location of the vehicle and determining a route to the destination based on said location data.

21. The method of claim 19 or 20 wherein the identifying comprises detecting at least one of road lanes and road curves in the image data and generating lane data indicative thereof usable for navigating the vehicle on the driven road.

22. The method of any one of claims 19 to 21 comprising tracking at least one of the identified objects and generating trajectory data indicative of a trajectory thereof, and using said trajectory data in at least one of the route determining and the generating of the control instructions.

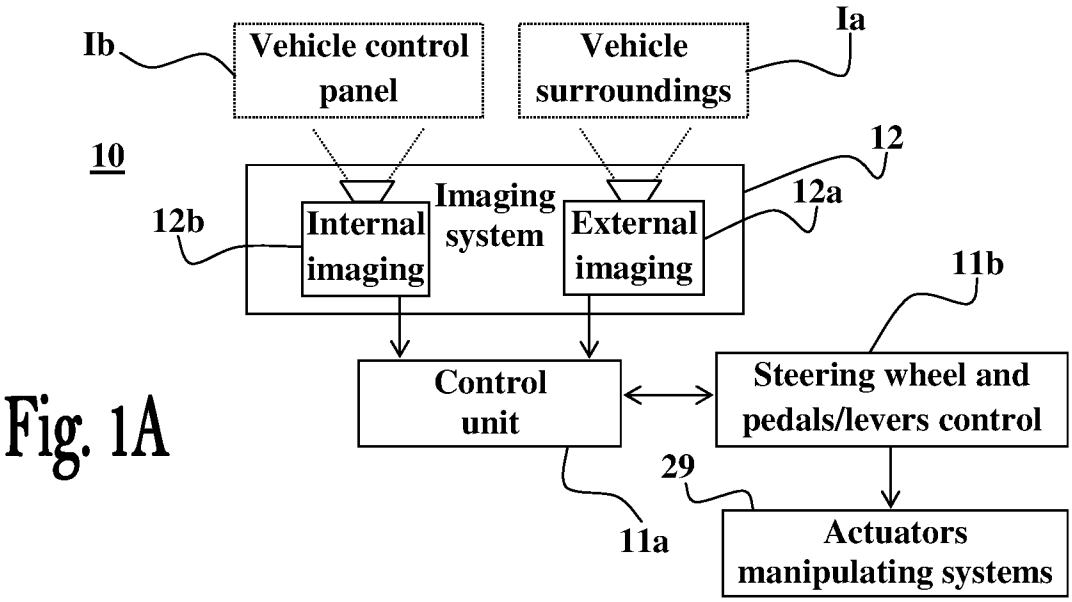

Ib
Vehicle control panel
Vehicle surroundings
Ia
10
12
12a
12b
Internal imaging
Imaging system
External imaging
11b
Control unit
Steering wheel and pedals/levers control
29
11a
Actuators manipulating systems

Fig. 1A

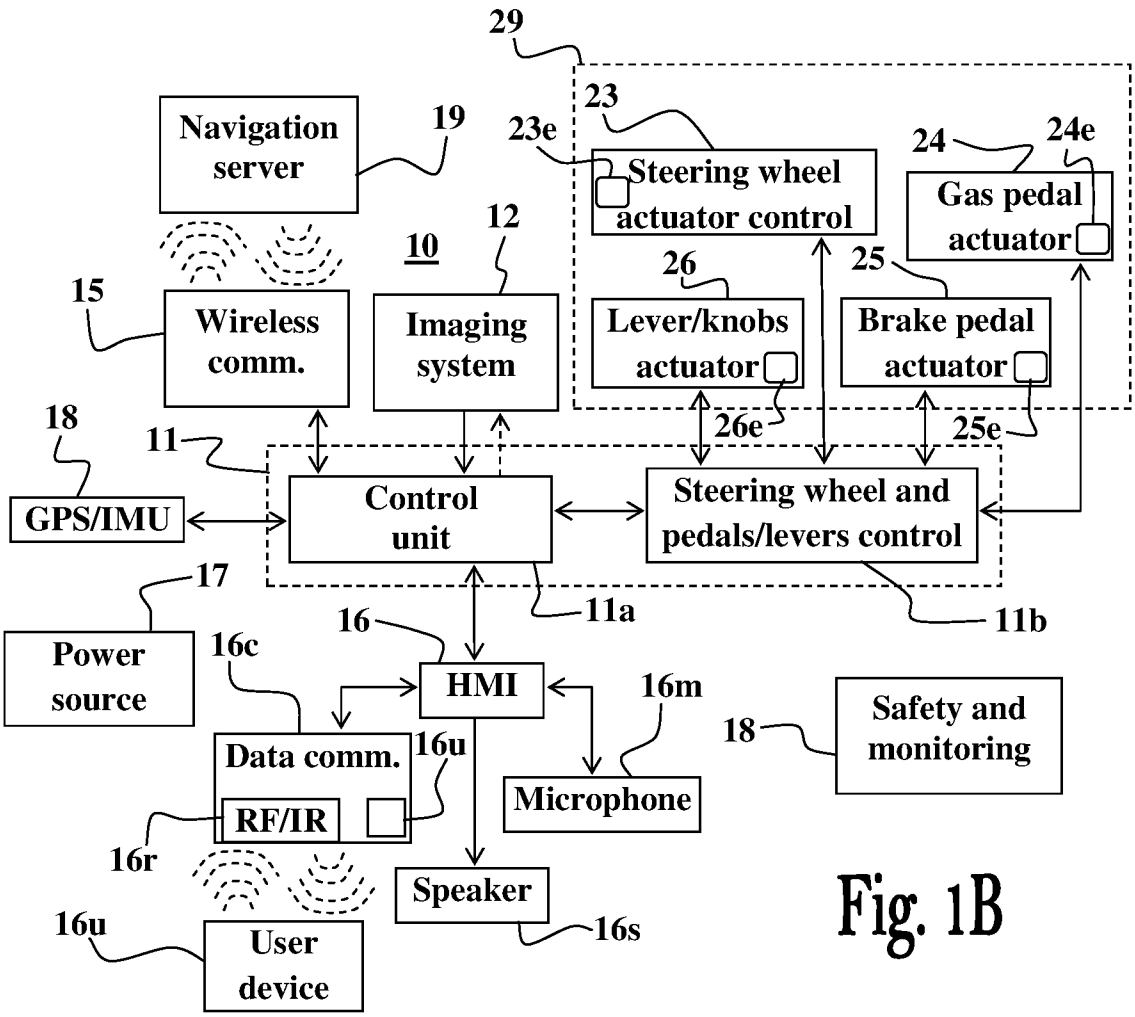

29
23
23e
24
24e
Navigation server
19
Steering wheel actuator control
Gas pedal actuator
12
10
26
25
15
Wireless comm.
Imaging system
Lever/knobs actuator
Brake pedal actuator
18
11
26e
25e
GPS/IMU
Control unit
Steering wheel and pedals/levers control
17
11a
11b
16
Power source
16c
HMI
16m
Safety and monitoring
18
Data comm.
16u
RF/IR
Microphone
16r
Speaker
16u
16s
User device

Fig. 1B

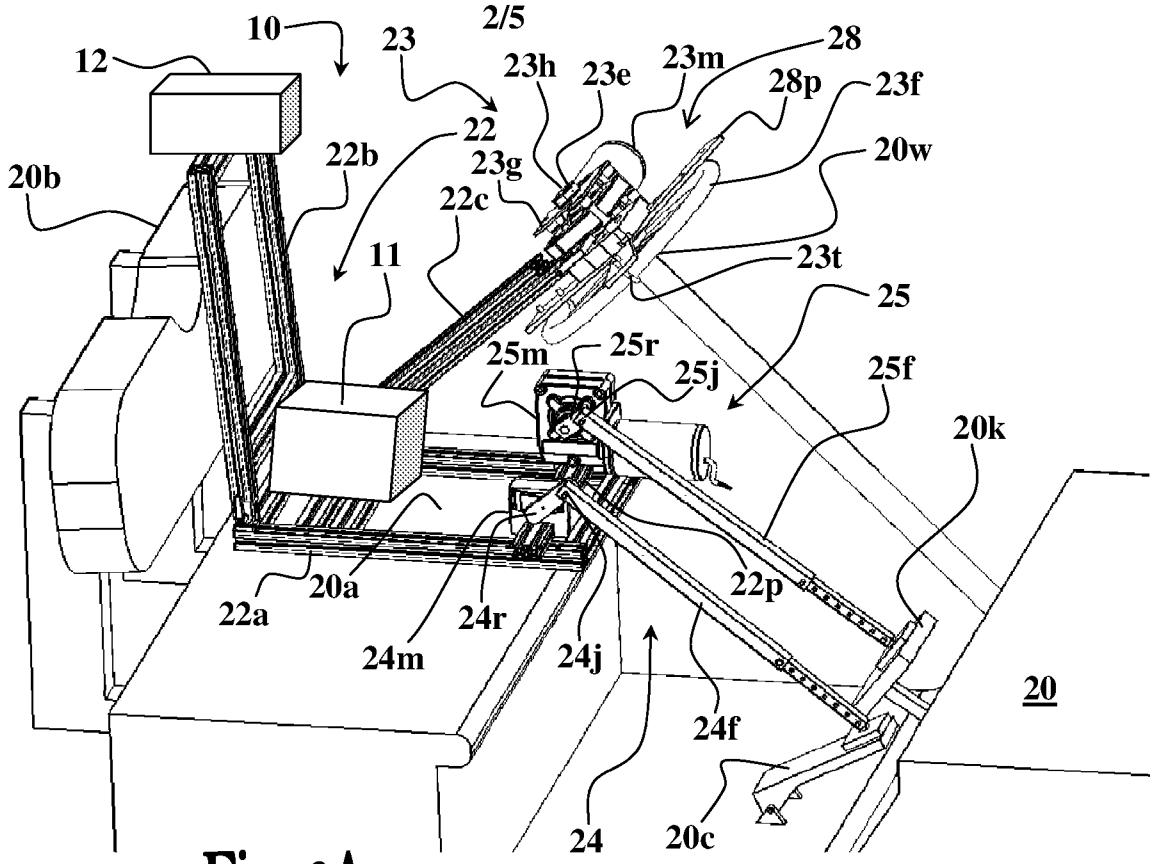

10
12
23
23h
23e
23m
28
28p
23f
20w
22
22b
23g
22c
20b
11
23t
25
25m
25r
25j
25f
20k
22a
20a
24r
22p
24m
24j
24f
20
24
20c

Fig. 2A

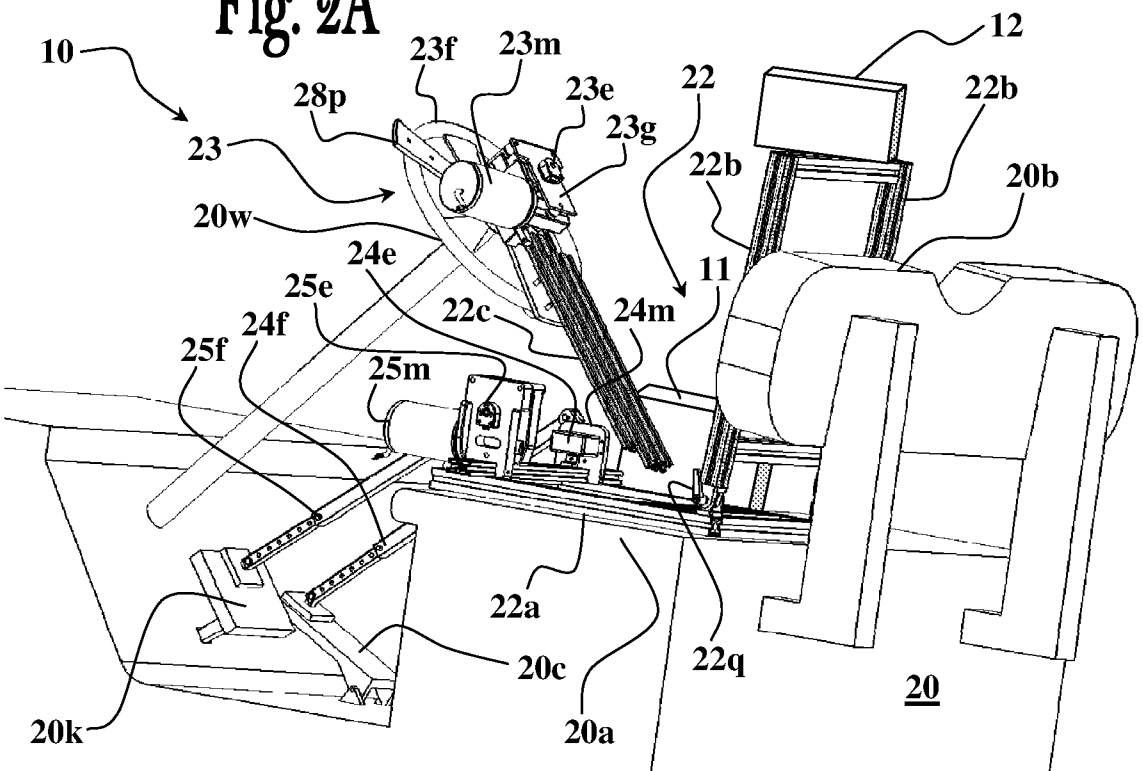

10
23f
23m
12
28p
23e
22
22b
23
23g
22b
20b
20w
24e
11
25e
22c
24m
24f
25f
25m
22a
22q
20c
20
20k
20a

Fig. 2B

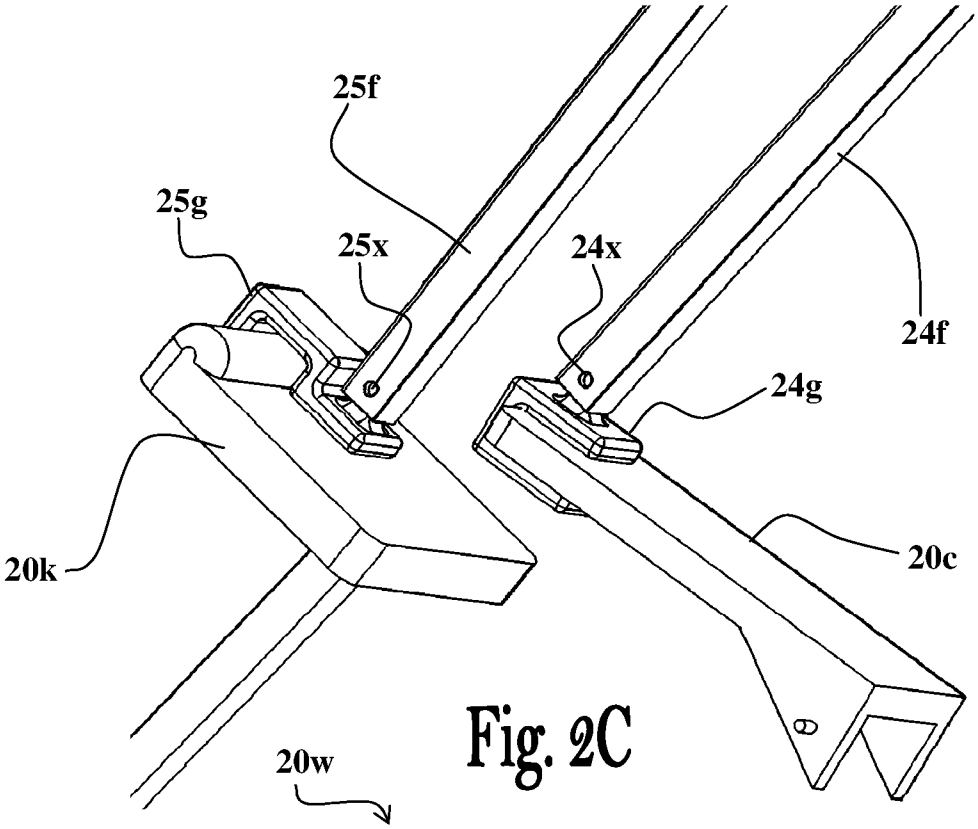

25f
25g
25x
24x
24f
24g
20k
20c

Fig. 2C

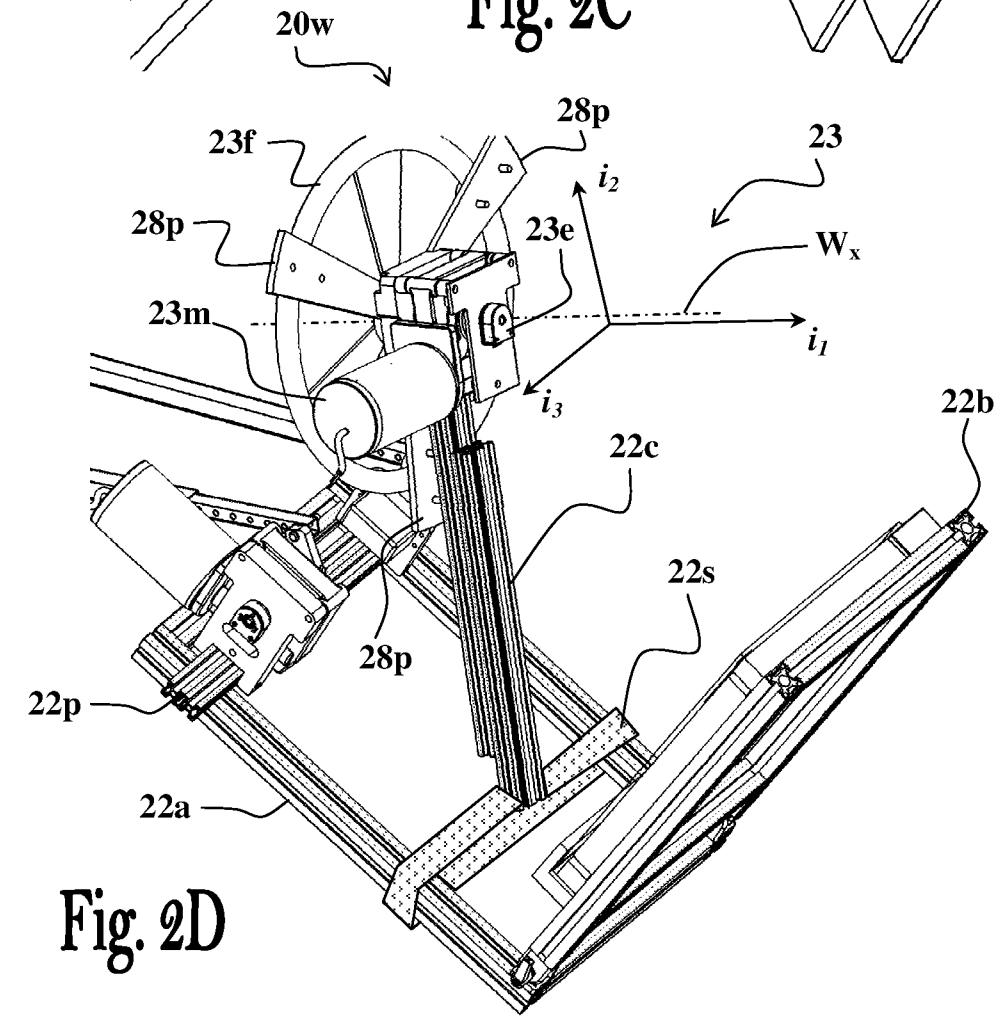

20w
28p
23f
23
i_2
28p
23e
W_x
23m
i_1
i_3
22b
22c
22s
28p
22p
22a

Fig. 2D

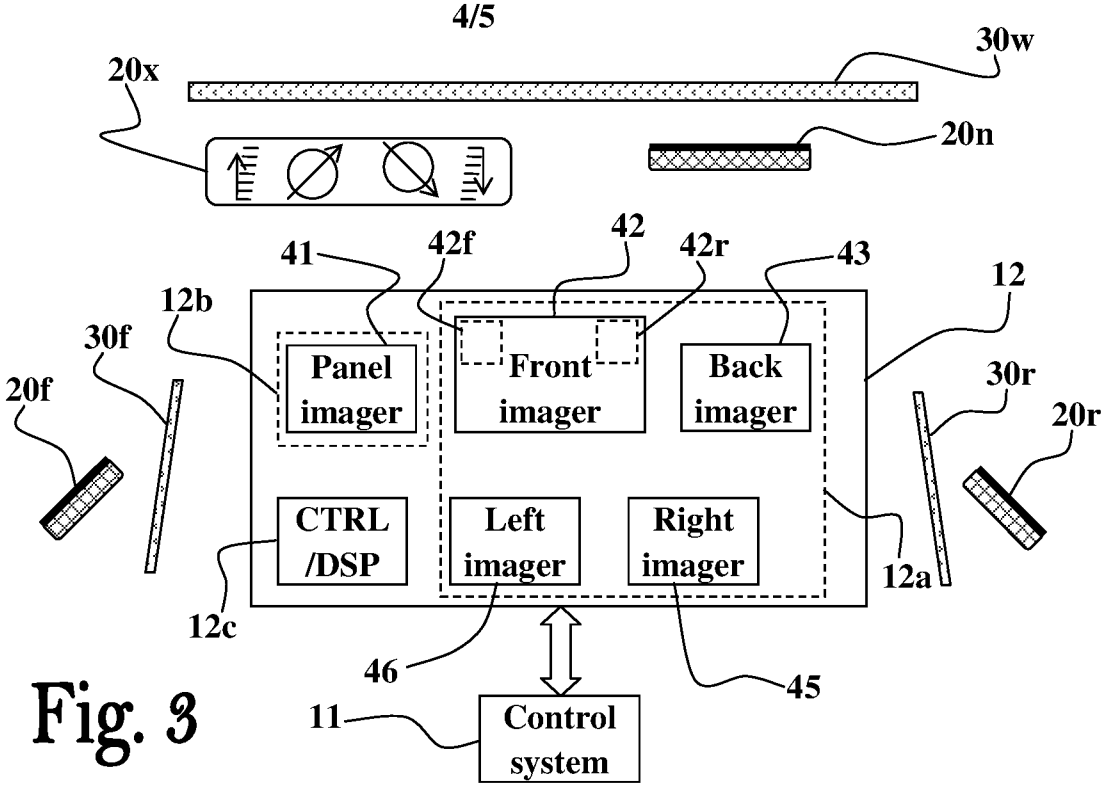

20x
30w
20n
41
42f
42
42r
43
12
12b
30f
Panel imager
Front imager
Back imager
30r
20f
20r
CTRL /DSP
Left imager
Right imager
12a
12c
46
45
11
Control system

Fig. 3

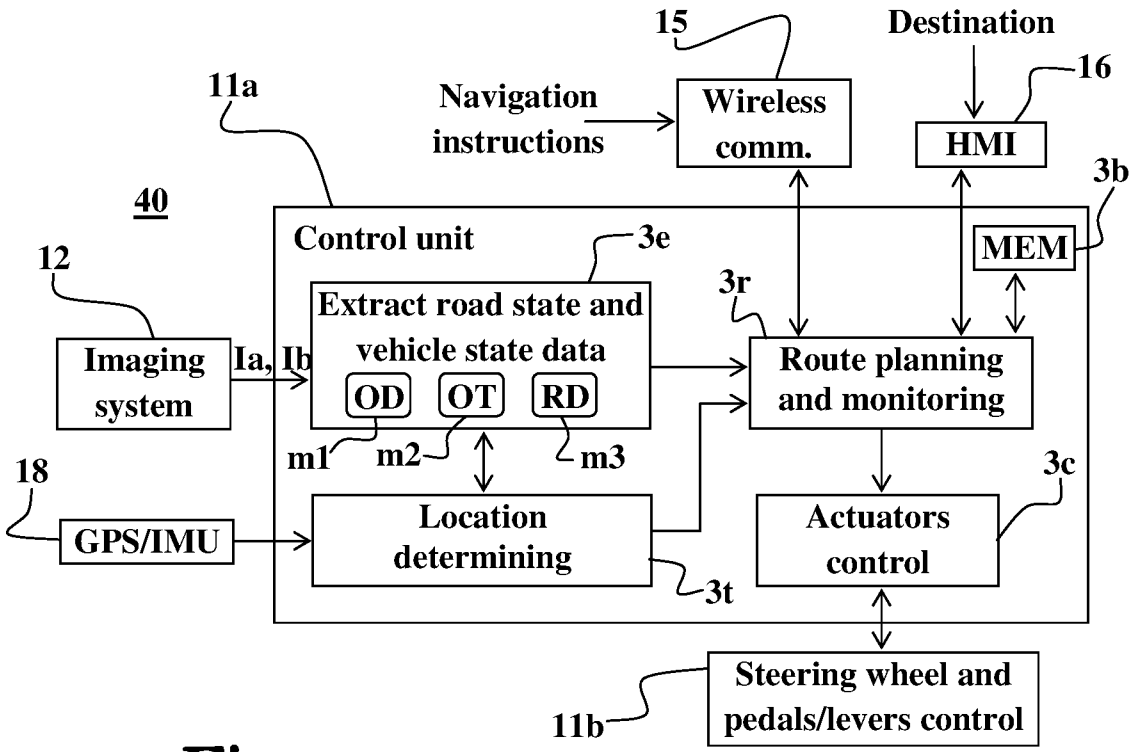

15
Destination
16
11a
Navigation instructions
Wireless comm.
HMI
3b
40
Control unit
3e
MEM
12
3r
Extract road state and vehicle state data
Imaging system
Ia, Ib
OD
OT
RD
Route planning and monitoring
m1
m2
m3
18
3c
GPS/IMU
Location determining
Actuators control
3t
Steering wheel and pedals/levers control
11b

Fig. 4

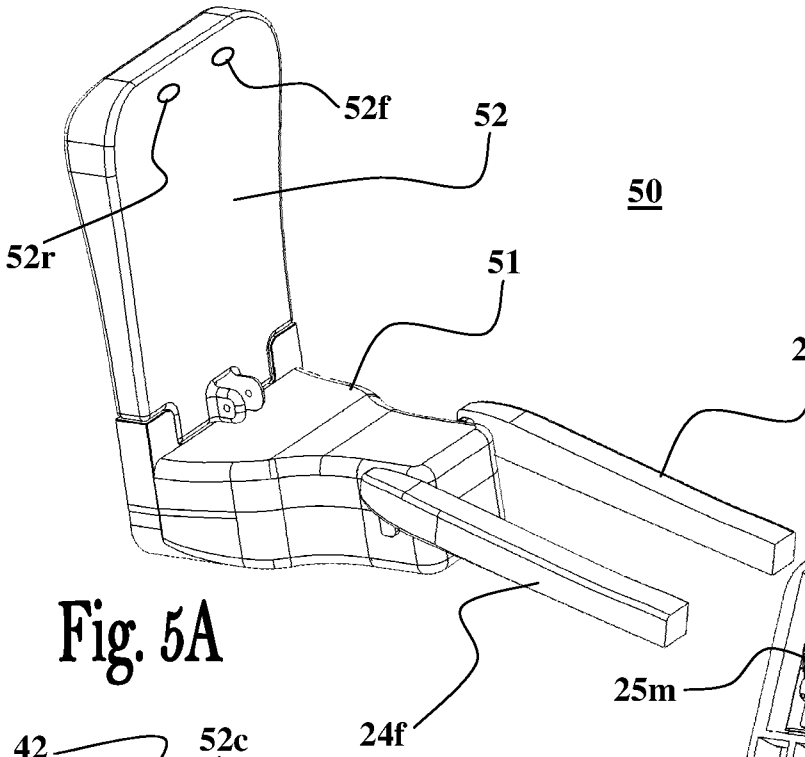


Fig. 5A

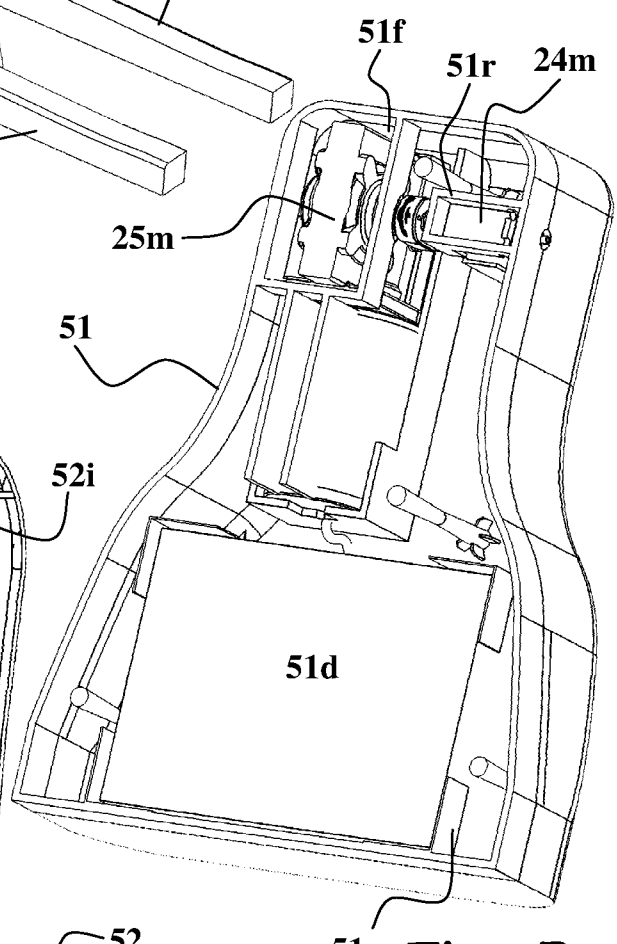


Fig. 5B

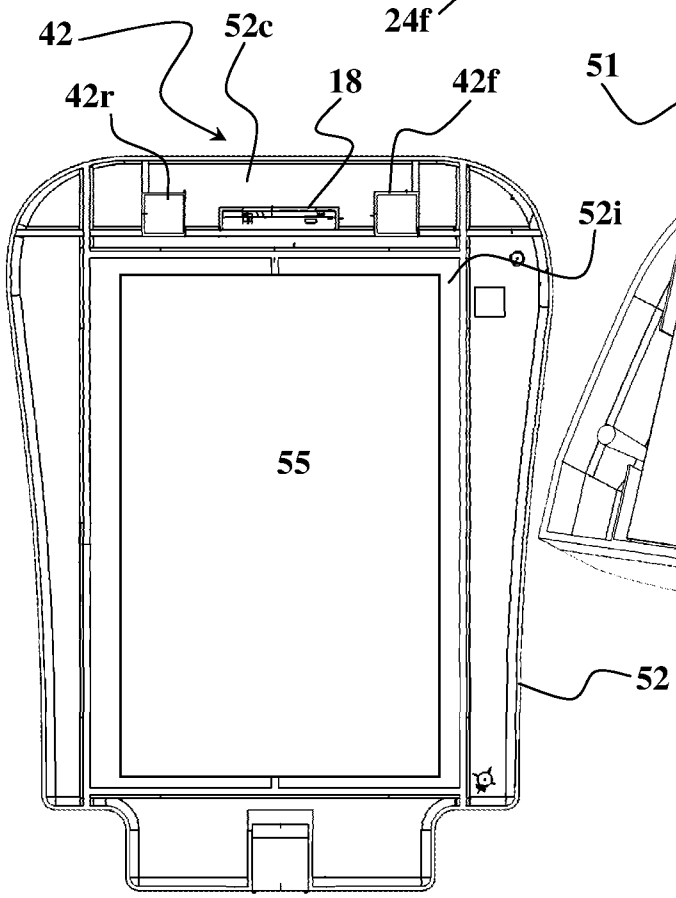


Fig. 5C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL2016/050453

A. CLASSIFICATION OF SUBJECT MATTER
IPC (2016.01) B60K 26/00, B62D 6/00, G05D 1/00

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 (2016.01) B60K 26/00, B62D 6/00, G05D 1/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Databases consulted: PATENTSCOPE, Esp@cenet, Google Patents, PatBase

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010057274 A LAYTON 04 Mar 2010 (2010/03/04) whole	1-22
Y	US 2011061963 A FARWELL 17 Mar 2011 (2011/03/17) whole	1-22
Y	CN 104002818 A XIE MING 27 Aug 2014 (2014/08/27) abstract,fig.1	8,9

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 Aug 2016	25 Aug 2016

Name and mailing address of the ISA:	Authorized officer
Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Facsimile No. 972-2-5651616	GUTKIN Solomon Telephone No. 972-2-5651763

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IL2016/050453

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
US 2010057274 A	04 Mar 2010	NONE	
US 2011061963 A	17 Mar 2011	NONE	
CN 104002818 A	27 Aug 2014	CN 104002818 A	27 Aug 2014