

A Comprehensive Platform for Localization and Navigation of a Mobile Vehicle

Field of the invention

- 5 The present invention relates to a knowledge based global localization and navigation platform to enable a mobile vehicle performing a serious scheduled or specified tasks at different sites in unmanned manner.

Background of the Invention

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Any unmanned mobile vehicles, such as unmanned aerial vehicle (UAV), unmanned land vehicle (ULV) and unmanned water vehicle (UWV), need a suitable localization and navigation system to enable them moving along the specified trajectories toward specified targets to perform specified tasks. During
15 the mobile vehicle moving in the field or outdoor, the global position system (GPS) based localization and navigation technology has been played a very important role till now. However, once the vehicle moving into an area in which the satellite signals are very weak or even lost, other localization and navigation technologies have to be used for the system in suitable way to guide the vehicle
20 to target. In additions, the accuracy or precision of localization of GPS alone may not higher enough to meet the requirement for the localization and navigation for a specified task inside a building.

Generally speaking, Map Based Localization (MBL) system is possible to
25 provide any trajectories to navigate the mobile vehicle to a specified target and so should be a very useful localization and navigation system, which has been widely used for the application of global localization, both outdoor by using such as Google Map and indoor such as a hospital map. However, there are still short of a commercial available platform with suitable hardware to integrate the
30 different maps into a whole map to enable any of mobile vehicles to any targets

globally, regardless in the field, in the city, and in the building such as a tower or a canal.

Summary of the invention

- 5 The present invention aims to provide a knowledge-based platform for the localization and navigation of a mobile vehicle, such as service robot, ship, car or plane to a serious of scheduled or specified targets.

10 In general, the present invention proposes a localization and navigation platform, which comprises an intelligent apparatus to be installed on the mobile vehicle and a number of active notes pre-installed or identified by the apparatus along the trajectories to the targets. The platform is built on a global coordinate system defined in the geographic and physical spaces. The apparatus and active notes are localized in geographic space on the global coordinate by
15 means of satellite base GPS in situation of the satellite signals are stronger enough, otherwise by the apparatus and pre-fixed active notes in physical space on global coordinate.

Any specified trajectories are identified by means of a proposed three
20 Dimensional Localization Map (3DLM) system. The 3DLM is a multi-map integrated with multi-layer map system. The basic map (M_0) is defined on the surface of the earth in geographic space on the global coordinate system. All of other maps, called as sub-maps, are defined in physical space and are to be embedded on the M_0 and then integrated into the global coordinate system.

25 The accuracy and precision of trajectories are decided by the sub-maps. If the sub-map is a city provided by such as Google map, the accuracy and precision could be in meter and should be enough for a car moving in the sub-map or city. If the sub-map shows the patient locations in a hospital, the sub-map may have
30 multi-layer to represent the variable floors and the accuracy and precision of the trajectories should be around cent meters.

The active notes in the platform are built by means of any commercial available technologies, such as the Radio Frequency Identification (RFID) based indoor position technology, active beacon location system (DLPS), laser beam
 5 localization system, magnetic fields guiding and so on for a schedule navigation plan. For special plan or trajectory, the notes along the trajectory will be identified by Kinect-based optical identification system validated by planner and then saved in the platform by the knowledge base system. The locations of all of the active notes are fixed in physical space on the sub-coordinate system to
 10 the sub-map and then integrated into the M_0 system in geographic space on global coordinate system.

The platform working together with the perspective apparatus installed on an UAV may be used for the following:

- 15
- (a) Providing parameter or information to control the UAV moving along the specified trajectory, such as along the power line for surveillance.
 - (b) Limit the UAV moving along a specified 3D channel.
 - (c) Providing parameter or information to localization the UAV globally.
 - 20 (d) Providing parameter or information to control the UAV by identifying and passing obstacles.

The platform working together with the perspective apparatus installed on an ULV to build a service robot may be used in hospitals for the following:

- 25
- (e) Providing parameter of information to control the robot to any targets in a hospital.
 - (f) Guiding the robot to perform robotic logistic solution for hospital.
 - (g) Guiding the robot to perform robotic telemedicine solution.
 - 30 (h) Guiding the robot to carry out the job for robotic device sharing solution.
 - (i) Guiding the robot for robotic clinical care solution.

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- (j) Guiding the robot to provide robotic ward service solution.
- (k) Guiding the robot for robotic environment service solution.

Brief Description of the Figures

An embodiment of the invention will now be illustrated for the sake of example only with reference to the following drawings, in which:

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Fig. 1 is a perspective view of the global coordinate system 100 on the platform according to an embodiment of the present invention. A Cartesian coordinate system with X-axis 101, Y-axis 102 and Z-axis 103 has been assigned on the system with X and Z coordinates on the center of Equator plane and Z-axis through 0° of Longitude. Y-axis is assigned through the North Pole, so it is right-hand coordinate system fixed on the geographic space.

Fig. 2 is a perspective view of proposed multi-layer map system. The basic map 200 (denoted as M_0) could be part or whole of the surface of the earth. The sub-maps 201, 202, 203 and 204 could be any shapes and will be integrated into the M_0 through a fixed point on M_0 detected by GPS. Each of sub-maps has a sub-coordinate system defined at the physical space. The sub-coordinates are also the right-hand Cartesian coordinate system with the original point at the fixed point on M_0 and X-axis toward to North direction detected by the digital compass on the fixed point.

Fig. 3 is a geographic map of Singapore. It forms a part of M_0 with a sub area 301 on the map.

Fig. 4 is an enlarged map of the area 301 with a building 401 number as Block 156 on it.

Fig. 5(a) is a map near area 301 with three nodes 501 on it. Three nodes are located outside the building block 159, so the position could be detected by GPS and saved in the apparatus 600 in Fig 6(a). These nodes 501 are also installed with active RFID tags so will enable the communication with apparatus 600 directly.

Figs. 5(b) and 5(c) are the schematic views of sub-map with planned trajectories inside the block 156. There are two layers for this sub-map shown by Fig. 5(b) and Fig. 5(c) to present the layout of two floors. A number of nodes

504 on the first layer Fig 5(b) and 507 on the second layer Fig 5(c) have been pre-installed on the building with active RFID tags on them. The positions of all of nodes are fixed and installed in the database of platform, which could be extracted by the apparatus 600. The trajectories 505 on Fig 5(b) and 508 on Fig 5(c) can be assigned by the platform and extracted by the apparatus 600, then guided the mobile vehicle along the trajectories.

Fig. 6(a) is a perspective view of the proposed apparatus 600, which comprises five functional components: nine axes Inertial Measurement Unit (IMU) together with GPS receiver and a digital compass 601; Web based camera 602; a number of ultrasound sensors 603; power supply and charging unit 604 and central process and control unit 605.

Fig 6(b) is a perspective view of central process and control unit 605. The unit composes four components: micro process and robotic controller 606; RFID reader 607; Modem 608 and battery 608.

Fig 6(c) is a perspective view of web camera 602. There are three cameras covered by 610, which can yaw 180° by a servo motor 611 controlled by the robotic controller inside the unit 605.

Fig 6(d) is a perspective view of power and battery charging unit 604. A spring loaded cover 612 to prevent the water splashing into the unit.

Fig 6(e) is a perspective view of IMU unit and GPS receiver. A digital compass is also integrated in the unit.

Fig. 7 is functional block diagram of the apparatus 600 in the proposed platform. It builds a basic system to collect the fundamental information from GPS, RFID and various sensors and then works with task manager through TCP/IP system. The apparatus 600 provides four servo control system to drive four independent mechanisms and can be easily expanded to 8, 16 or even more.

Fig. 8 is a perspective view of a mobile vehicle 800. The vehicle is driven by two servo motors 802 through four driving wheels. A turning mechanism 803 driven by another servo motor 804 is built on the vehicle to carry suitable tools for specified tasks. A magnetic sensors unit 805 with 1mm resolution on the vehicle is installed on the vehicle to increase the navigation accuracy. Two

bumpers 801 and 806 installed on front and back to provide ore safe measurements on the mobile vehicle.

Fig. 9 is a perspective view of the apparatus 600 integrated with the mobile vehicle 800. It builds a mobile localization and position system 900 to
5 perform specified task at the specified target.

Fig. 10 is completed functional block diagram of the system 900. The apparatus 600 serves as a basic platform and enables more features to be built, such as magnetic sensors 1001 to increase the navigation accuracy and safe bumpers 1002 for safety. Three driving mechanisms controlled by the robotic
10 controller to 1002, 1003 and 1004 have been integrated into this platform.

Detailed Description of the Embodiments

A localization and navigation platform which is an embodiment of the invention
5 will now be described with reference Figs. 1-10. The platform comprises three components:

- A multi map system (200) defined in geographic space, which comprises a basic map M_0 (201) defined at the surface of the earth by means of Cartesian coordinate system (101, 102 and 103) in the geographic space
10 and a number of embedded multi-layer sub-maps (202 to 205) defined inside the building by means of Cartesian coordinate system in physical space.
- A number of active and passive notes (501, 504 and 507) pre-installed and identified by the apparatus (600) at specified sites near the
15 trajectories.
- An apparatus (600), which comprises five functional modules (601 to 605) to receive the signals from task planner, GPS, RFID indoor position system, Kinect-based optical identification system, and a number of sensors including a nine axes IMU by means of a computer based
20 communication system and a robotic controller.

The platform invented includes a map infrastructure (200) defined at geographic and physical spaces. The basic map M_0 in Fig 2 (201) is defined on the surface of the earth at geographic space, so it will be detected by means of GPS. A
25 number of multi-layer sub-maps (202 to 205) are defined on the specified areas such as a building. The sub-maps could be any shapes and possible to overlapped as 204 and 205.

There are a number of coordinate systems defined at geographic and physical
30 spaces for the platform. Fig.1 is a perspective view of a main coordinate system defined at geographic space by means of a right-hand Cartesian coordinate

system. The original of the main coordinate is assigned at the geographic centre of the earth. The XZ-plane is set at the Equator Plane of the earth with Z-axis (103) through 0° of the Longitude. The Y-axis (102) is set to through the North Pole of the earth. All of points on the basic map M_0 will be denoted by means of this coordinate system at geographic space.

A number of sub-maps (202 to 205) will be embedded on the basic map M_0 (200) with a sub-coordinate system for each sub-map. All of the sub-coordinate systems are defined at physical space by means of right-hand Cartesian coordinate system. The original point of each sub-coordinate system could be set at any point of the sub-map and will be linked to the main coordinate system by means a number of notes around the sub-map with fixed coordinate value on the main coordinate system and the north direction detected by a digital compass in the apparatus (601) at geographic space.

Fig 3 is a perspective view of Singapore. It will serve as part of basic map M_0 in the platform. The smaller areas 301 and 401 on the map are also the parts of map M_0 . Inside the area 401, there is a building number as 159 with two maps shown in Fig 5(b) and Fig 5(c) as two layers of the building, which are assigned as one sub-map defined at physical space. There are two planned trajectories 505 and 508 shown on the sub-map.

The platform invented includes also a number of active or passive notes (501, 504 and 507). There are two groups of notes defined at geographic and physical spaces separately. Some notes are defined on the main map M_0 (501) which could be integrated into the basic coordinate system (100) by means of GPS system. These notes will be working as the based system to identify the location of a sub-map (503) and the apparatus (600). All of points inside the sub-map (503) with two layer shown in Fig 5(b) and Fig 5(c) with coordinate values specified at physical space will be transferred to the main coordinate

system at the geographic space such that the parameters detected by means GPS and the digital compass and IMU will be linked to the system directly.

5 A number of notes (504 and 507) inside the building 159 on map (503) will be assigned to specify the locations of targets and trajectories. The notes could be active ones identified by RFID reader of magnetic sensors on the apparatus (600) or passive ones identified by Kinect-based optical identification system (602) on the apparatus (600). These notes could be pre-installed on the sub-map shown in Fig 5(b) and Fig 5(c) or identified by the Kinect-based system
10 and then validated by the planner. After validation the new notes, the platform will treat it as a pre-installed note and will be saved into the platform by the knowledge-based system. All of notes inside the sub-maps will be defined at physical space by means of a sub-Cartesian coordinate system. The coordinates of these sub-coordinate systems will be integrated into the main
15 coordinate system to form a universal platform for localization and navigation a mobile vehicle globally.

The platform invented includes also an apparatus (600). The apparatus could be linked to any internet based server or computer through the internet protocol
20 suite TCP/IP and other mobile device and datacentre by means of Windows Azure infrastructure and cloud computing network.

The apparatus (600) is a self-driving system which could be installed on any UAV, ULV and UWV. It is also possible of carrying by a person or putting on or
25 inside a car, a ship or a plane.

The apparatus (600) comprises five functional modules (601 to 605). The module (601) comprises a nine axis IMU with a digital compass and a GPS receiver (613). The signals detected by the module will provide the basic
30 parameter to guide the mobile vehicle along the planned trajectory. A three

dimension geo-fencing system together with the robotic controller and suitable mechanisms will enable the vehicle moving inside the specified channel.

The module 602 comprises by three web cameras covered by 610. These web cameras will turn along the Yaw direction if the apparatus (600) fixed on horizontal position by a servo motor (601). Together with the identifying system by means of Robotic Development Suit (RDS) developed by Microsoft, the module 602 will identify the notes with some optical features and build the knowledge-based identification system.

The module 603 is an ultrasound sensor system to help identifying obstacles. The signals will be sent to robotic controller directly as shown in Fig 7.

The module 604 comprises a battery charging and power supplier system. Any commercial system could be built in if the commercial system meets the safety requirement. A spring loaded cover 612 on the front of the module 612 to prevent the water splashing in it.

The module 605 is a micro-process based central control and process unit. It further comprises by a micro-process circuit together with a robotic controller 606. A modem (3G, 4G or higher) 607 has be built in the module. RFID reader 609 will enable the apparatus to read the information from any RFID tags, both active and passive ones. The battery 608 will provide the power to the apparatus if no other power available.

Fig 7 provides an overview of electronic and electrical system 700 for the apparatus. The robotic controller 705 could receive varies information from commercial available sensors to control the servo motor for some specified tasks.

The platform invented are suitable for various mobile system. With the apparatus 600 installed on a mobile base 800, a mobile robot 900 will be built.

5 The mobile base 800 comprises by two servo motors 802 together with four driving wheels to enable a mobile vehicle, a turning beam 803 to carry the application instrument, a magnetic sensor unit 805 to identify the magnetic notes for increasing the accuracy and precision of navigation and two bumpers 801 and 806 for safety.

10 Fig 10 is a complete schematic view of the electronic and electrical system for the embodiment. The mobile robot 900 will work as a basic platform for service robot industry at any environment, such as hospitals, restaurants, hotels, and shop centres.

Claims

1. A comprehensive platform for localization and navigation of a mobile
5 vehicle to multi-targets, the platform comprising:
 - a basic map M_0 (201) on the surface of the earth with the points defined at the geographic space and described by a main Cartesian coordinate system (101 to 103).
 - a number of sub-maps (202 to 205) embedded in M_0 to describe the
10 details on some specified areas on M_0 .
 - a number of active or passive notes installed or set on the M_0 (501) which are defined at the geographic space so can be positioned by means of GPS.
 - a number of active or passive notes (504 and 507) installed or set on the
15 sub-maps which are defined at the physical space.
 - a computer based apparatus (600) work as a central process and control unit for the platform.
2. A platform according to claim 1, wherein the original point of the main
20 Cartesian coordinate is set at the geographic center of the earth with XZ-plane on the plane of Equator of the earth. The Y-axis is set to point to North Pole and Z-axis through 0° of Longitude of the earth.
3. A platform according to claim 1, wherein the north direction detected by
25 the digital compass in geographic space is specified as a Ground Direction after a probability correction on the north direction detected at static situation for device and any targets.
4. A platform according to claim 1, wherein the errors on Ground Direction
30 generated by the changing of latitude and altitude will be neglected.

5. A platform according to claim 1, wherein all of the sub-maps are defined at the physical space and positioned by the related sub-Cartesian coordinate systems.
- 5 6. A platform according to claim 1, wherein all of Validated Targets will be presented in the physical space on Cartesian coordinate.
7. A platform according to claim 1, wherein the notes specified at geographic space will be linked to the related sub-maps which are defined at the physical space. Any points on the sub-maps specified by the Cartesian coordinate systems could be converted to the main Cartesian coordinate system in geographic space.
- 10 8. A platform according to claim 1, wherein the notes at the physical space are specified directly by the sub-coordinate system assigned at related sub-map.
- 15 9. A platform according to claim 1, wherein the apparatus (600) is integrated with a nine axes IMU together with a digital compass (601).
- 10 10. A platform according to claim 1, wherein a GPS receiver (613) is installed in the apparatus (600) to receive the signal from satellite.
11. A platform according to claim 1, wherein a RFID reader (609) is installed in the apparatus (600) to receiver the signals from RFID tags on the notes.
- 25 12. A platform according to claim 1, wherein a modem (607) is installed in the apparatus (600) to enable the communication between the apparatus (600) and planner through an internet protocol suite TCP/IP. The modem could be a 3G, 4G or higher one.

13. A platform according to claim 1, wherein three web cameras (602) together with a servo turning mechanisms (611) is integrated into the apparatus (600). It enables a Kinect-based optical identification system working by means of RDS developed by Microsoft.

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14. A platform according to claim 1, wherein a battery (608) and a battery changing circuit and dock device (604) is integrated into the apparatus (600). A spring loaded cover on the front of the dock device to protect the charging circuit.

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15. A platform according to claim 1, wherein a robotic controller (606) is integrated in the apparatus (600).

16. A platform according to claims 1, 3 and 4, wherein the positioning systems changing from GPS to IPS or conversely is at the specified plane referring to Ground Direction.

17. A platform according to claims 1 and 5, wherein the sub-maps can be any shapes and may be overlapped each other.

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18. A platform according to claims 1, 5 and 17, wherein the sub-map can be comprised by a number of layers.

19. A platform according to claims 1 and 7, wherein the notes defined at the geographic space can be specified by means of GPS signals.

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20. A platform according to claims 1, 7 and 19, wherein the notes defined at the geographic space can be active or passive ones in relations with RFID reader, Kinect-based identification system and so on.

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21. A platform according to claims 1 and 8, wherein the notes defined at the physical space can be active or passive ones in relations with RFID reader, Kinect-based identification system and so on.
- 5 22. An apparatus according to claims 1, 9 to 15, wherein a self-power system enables the apparatus (600) possible of installing or carrying by any mobile vehicle or a person.
- 10 23. An apparatus according to claims 1, 9 to 15 and 22, wherein the any notes defined both at the geographic and physical spaces identified the apparatus by means of GPS will be stored in the platform invented and will be used as a knowledge based intelligent system.
- 15 24. A platform according to claims 1 to 23, wherein the platform together with related vehicle can be controlled or managed at any place through an internet protocol suit TCP/IP and the data will be accessible through Windows Azure infrastructure.
- 20 25. A platform according to claim 1 to 24, wherein the platform can be integrated with any mobile vehicle, such as car, ship, plane, and mobile robot.