# Offboard Navigation Apparatus Capable of being Coupled to a Movable Platform

## Field of the Invention

The present invention relates to an offboard navigation apparatus capable of being coupled to a movable platform used for the transportation and delivery of a load, and particularly, relates to an offboard navigation apparatus that provides locomotive power to the movable platform to make the movable platform capable of self-navigation when being attached to the offboard navigation apparatus.

## Background

With the technology of autonomous navigation, robotic devices are widely used in the consumer market and industry. These robotic devices move around a place relying on sensors and navigation systems without any human intervention whilst it is on the move. One example of such robotic devices is the Autonomous Guided Vehicles (AGVs) used to transport articles or objects around in a premises. However, the AGVs are inflexible to re-planning as extensive, expensive and inflexible modifications to the infrastructure are required for these vehicles to work. For example, one type of the AGVs has to follow markers or wires installed in the floor when navigating a place. The AGVs are usually huge platforms built for designated purposes. Thus, their size and fixed footprint prevent them from providing services in smaller or confined areas.

As a result, manpower is still largely employed to transport objects from one place to another in a number of industries, such as logistics, material-handling, medical, and manufacturing industries, when it is impossible or uneconomical to use the AGVs and other existing robotic devices. For example, in the hospitals, nurses or orderlies have to use trolleys to transport medical instruments and medicines to and from the wards.

Smaller AGVs or mobile robotic devices are devised to reduce manpower needed in these circumstances. However, the size of these devices still remains quite

significant as the navigation processing is performed onboard, i.e. on the moving devices themselves, and these devices must be equipped with powerful computing facilities to provide navigation commands in real time. In addition, these devices are mainly designed for carrying the load themselves, and they are not designed to work with existing general movable platforms used for transportation, such as push-carts, trolleys, wheelchairs and the like.

Therefore, it is desirable to have a navigation apparatus that is capable being attached to the existing general movable platforms used for transportation to provide locomotive power to make the movable platform capable of self-navigation.

**Summary**

In accordance with one aspect of the present invention, there is provided an offboard navigation apparatus capable of being coupled to a movable platform used for the transportation and delivery of a load, comprising: a base unit configured to be capable of being attached to the movable platform and providing locomotive power to the movable platform; and a navigation unit configured to drive the base unit to navigate the movable platform, the navigation unit comprising: sensors configured to obtain sensor data; and a communication unit configured to transmit sensor data to a server and receive navigation information of the offboard navigation apparatus from the server.

The base unit may comprise an attachment assembly configured to attach the offboard navigation apparatus to the moveable platform; the navigation unit may further comprise a processor to process the navigation information of the offboard navigation apparatus to provide a navigation instruction; the communication unit may be further configured to receive a navigation instruction from the server.

The navigation unit may be coupled directly to a driving system of the movable platform to navigate the movable platform when the movable platform itself is a self-powered platform.

The base unit may further comprise a power source; a moving mechanism configured to make the offboard navigation apparatus movable; and a driving unit driven by power supplied from the power source and configured to drive the moving mechanism.

The driving unit may be configured to receive a navigation instruction from the navigation unit and drives the moving mechanism according to the navigation instruction.

The moving mechanism may be a number of wheels; the moving mechanism may be continuous tracks.

The power source may be a battery; the power source may be a combustion engine.

The navigation unit may further comprise a processor configured to calculate a latency of a network through which the offboard navigation apparatus and the server communicate, the latency of the network being a difference between sending sensor data from the offboard navigation apparatus to the server and receiving processed data corresponding to the sent sensor data by the offboard navigation apparatus from the server, and determine the speed of the offboard navigation apparatus based on a threshold value of a positional accuracy of the offboard navigation apparatus and the latency of the network.

The offboard navigation apparatus may further comprise an interface configured to receive the threshold value of the positional accuracy of the offboard navigation apparatus from a user.

The offboard navigation apparatus may further comprise an odometer configured to estimate the position of the offboard navigation apparatus.

The speed of the offboard navigation apparatus may be determined to be inversely proportional to the latency of the network.

## Brief Description of the Drawings

Embodiments of the offboard navigation apparatus will now be described with reference to the accompanying figures in which:

Fig. 1 shows a schematic diagram of an offboard navigation apparatus according to an embodiment of the present invention, a server with which the offboard navigation apparatus communicates, and a movable platform to which the offbard navigation apparatus is attached.

Fig. 2 is a perspective view of an example of the offboard navigation apparatus.

Fig. 3 is a perspective view of the offboard navigation apparatus of Fig. 2 and an example of the movable platform when the offboard navigation apparatus is not attached to the movable platform.

Fig. 4 is a perspective view of the offboard navigation apparatus and the movable platform of Fig. 3 when the offboard navigation apparatus is attached to the movable platform.

Fig. 5 illustrates how the offboard navigation apparatus of Fig. 3 is attached to the movable platform of Fig. 3.

## Detailed Description

Fig. 1 illustrates a schematic diagram of an exemplary offboard navigation apparatus 100 working with a server 200 to navigate a movable platform 400 mainly used for the transportation and delivery of a load. The offboard navigation apparatus 100 is capable of being coupled to the movable platform 400 to drive the movable platform. The offboard navigation apparatus 100 also communicates with the remote server 200 via a communication link such as a wireless network 300 (for example, WiFi, 3G, 4G, etc.) to harness the processing power of the server 200 to perform navigation processing.

The server 200 may be any type of device capable of receiving and sending data, and may comprise powerful processors suitable for navigation processing. The server 200 may be a cloud-computing platform so that the processing load is distributed among the cloud. Navigation applications having a user interface may also be installed at the server 200 so that a user is able to configure parameters related to offboard navigation at the server 200 and monitor the entire navigation process.

The movable platforms 400 may be push-carts, trolleys and wheelchairs which are being pushed or pulled by human. However, they are not limited to wheeled vehicles including vehicles on spherical wheels (i.e. ball-based vehicles), and they may be any platform that can be pushed or pulled from one place to another, such as platforms having sliders on the bottom surface. The movable platforms may be powered platforms, i.e. movable platforms equipped with a power source, such as electric wheelchairs.

A navigation unit 2 and a base unit 4 which are electrically connected with each other by wiring 28 are included in the offboard navigation apparatus 100.

The navigation unit 2 configured to drive the base unit 4 comprises a plurality of sensors 10, a processor 12 and a communication module 14.

The plurality of sensors 10 may be any type of sensor capable of obtaining data surrounding the offboard navigation apparatus 100 or data of the environment in which the offboard navigation apparatus 100 operates. Cameras, LIDARS or inertial measurement units or a combination of aforementioned devices may be used as the plurality of sensors 10. The sensor data obtained are then transmitted to the server 200 through the communication module 14 for navigation processing in order to derive the actual position of the offboard navigation apparatus 100.

The processor 12 is used to perform processing required at the navigation unit 2. As the majority of the navigation computation is allocated to the server 200 equipped with powerful processors, minimum processing, such as interacting with the other components of the navigation unit 2 and performing routine functions, is

performed by the processor 12. For example, it monitors the gathering of the sensor data obtained by the plurality of sensors 10, pre-processes the sensor data before transmitting it to the server 200, gives instruction to send sensor data to the server 200 at appropriate timings through the wireless network 300, monitors the positional information or navigation information of the offboard navigation apparatus 100 received through the communication module 14 from the server 200 and provides a navigation instruction signal to the base unit 4 based on the positional information received. It may be possible for the server 200 to send the navigation instruction instead of the positional information of the offboard navigation apparatus 100 to the navigation unit 2. In such cases, the processing of the positional information to provide the navigation instruction is not performed by the processor 12.

Various existing offboard navigation methodologies can be used in the offboard navigation apparatus 100. The method described in the Singapore Patent Application No. 201304289-0 which provides adaptive offboard navigation that responds to changes in network conditions may be employed in the offboard navigation apparatus 100. In such cases, the processor 12 also determines the speed of the offboard navigation apparatus 100 with respect to a latency of the wireless network 300 to achieve a satisfactory positional accuracy of the offboard navigation apparatus 100. To maintain a specific level of positional accuracy, the speed of the offboard navigation apparatus 100 is determined to be inversely proportional to the latency of the network 300.

The communication module 14 transmits the sensor data from the navigation unit 2 to the server 200 and receives the processed data for navigation from the server 200.

The base unit 4 is capable of being attached to the movable platform 400 and provides locomotive power to the movable platform 400 by either pushing or pulling the movable platform 400. It comprises a driving unit 16, a moving mechanism 18, a locomotive power source 20 and an attachment assembly 22.

The base unit 4 is removably mounted to the movable platform 400 via the attachment assembly 22. A variety of mechanical means such as clamps or inserts can be used as the attachment assembly 22. The offboard navigation apparatus 100 becomes a bolt-on component of the movable platform 400 when it is rigidly attached to the movable platform 400 via the attachment assembly 22, and thus makes the movable platform 400 capable of self-navigation.

The driving unit 16 of the base unit 4 receives the navigation instruction signal from the processor 12 of the navigation unit 2 through the wiring 28 and drives the moving mechanism 18 according to the navigation instruction signal to move the base unit 4 (i.e. the offboard navigation apparatus 100) in a specific direction with a specific speed. The driving unit 16 is powered by the locomotive power source 20.

Any kind of portable power source may be used as the locomotive power source 20 to supply driving forces to the driving unit 16. For example, a battery or a relatively small combustion engine may be used. If a battery is used as the locomotive power source 20, the battery also provides power to the various electrical and/or electronic components of the offboard navigation apparatus 100. If another kind of power source is used as the locomotive power source 20, a separate battery has to be provided to supply power to the various components of the offboard navigation apparatus 100.

The moving mechanism 18 may be a number of wheels. Continuous tracks, a belt capable of providing motive traction, may also be used to replace the wheels as the moving mechanism 18 so that the offboard navigation apparatus 100 is suitable to move on uneven surfaces. In such cases, if the movable platform 400 to which the offboard navigation apparatus 100 is attached is also equipped with continuous tracks, the movable platform 400 is able to navigate smoothly on the uneven surfaces as the tracks glide over bumps, small obstacles and trenches on the surfaces.

When the method of the Singapore Patent Application No. 201304289-0 is employed in the offboard navigation apparatus 100, an interface 24 configured to

accept a positional accuracy of the offboard navigation apparatus 100 that is input by the user and an odometer 26 used to estimate the distance or displacement travelled the offboard navigation apparatus 100 are provided. As illustrated in Fig. 1, these two components are provided in the base unit 4. It is also possible to provide these two components in the navigation unit 2. Other than the conventional odometry methods for wheeled and tracked vehicles, the visual odometry method in which the distance travelled is estimated by using sequential camera images can also be used in the offboard navigation apparatus 100. At least one camera is provided in the offboard navigation apparatus 100 when visual odometry method is desired.

The base unit 4 may also be provided with additional sensors as anti-collision measures to enhance safety. When the offboard navigation apparatus 100 attached to the movable platform 400 is in operation, i.e. moving according to the navigation information, if an obstacle such as a person or a large object is detected by these sensors within a predefined safety distance from the base unit 4, the offboard navigation apparatus 100 may be brought to a stop for a certain period. The movement of the offboard navigation apparatus 100 is then resumed when the obstacle is no longer present within the safety distance.

The offboard navigation apparatus 100 as shown in Fig. 1 makes the movable platform 400 capable of self-navigation when it is attached to the movable platform 400 via the attachment assembly 22. During self-navigation of the movable platform 400 in which the offboard navigation apparatus 100 become the bolt-on component, the plurality of the sensors 10 of the navigation unit 2 obtains sensor data concerning the environs of the movable platform 400. The processor 12 then pre-processes the sensor data obtained and send it to the server 200 through the communication module 14. Based on the sensor data received, the server 200 performs navigation processing to calculate the positional information of the offboard navigation apparatus 100 (which would be the same as the positional information of the movable platform 400) and send it back to the navigation unit 2. After receiving the positional information of the movable platform 400, the processor 12 derives the navigation instruction based on the positional information and sends a signal to the driving unit 16 of the base unit 4. The driving unit 16

powered by the locomotive power source 20 drives the moving mechanism 18 to move the offboard navigation apparatus 100 according to the navigation instruction so that the movable platform 400 is pushed or pulled to and from designated locations without any human direction and manpower.

If the offboard navigation apparatus 100 is powered by a battery, that is, the locomotive power source 20 is a battery, the offboard navigation apparatus 100 may be configured to work with a docking station. When the battery is running low, the offboard navigation apparatus 100 may be automatically navigated to the docking station by the navigation unit 2 to charge the battery. It may also be configured to leave the docking station when the battery is fully charged so that the docking station is available to other similar offboard navigation apparatuses in the premises.

When the movable platform 400 is a self-powered platform, the navigation unit 2 may be coupled directly to the drive system of the movable platform 400 by sending the navigation instruction to the drive system to navigate the movable platform 400.

An example of the offboard navigation apparatus 100 is shown in Fig. 2, and Fig. 3 and Fig. 4 illustrate the exemplary offboard navigation apparatus 100 before and after being attached to an example of the movable platform 400 respectively. For simplicity, a trolley is presented as the example of the movable platform 400.

The exemplary offboard navigation apparatus 100 comprises the navigation unit 2 (a mast unit) and the base unit 4 connected by a post 3 which covers the wiring 28 between the navigation unit 2 and the base unit 4. The base unit 4 is in contact with the ground and the navigation unit 2 is arranged on top of the post 3. In such arrangement, the plurality of sensors 10 of the navigation unit 2 is not blocked by the movable platform 400 when the offboard navigation apparatus 100 is attached to the movable platform 400. Thus, the sensor data obtained is not affected by the different movable platforms 400 used. The navigation unit 2 may be disposed at other positions so long as consistent sensor data can be obtained. The processor 12 is covered in the casing of the navigation unit 2.

The driving unit 16 and the locomotive power source 20 are enclosed in the casing of the base unit 4. Two wheels are shown as the moving mechanism 18 driven by the driving unit 16.

The attachment assembly 22 is provided on the front surface of the base unit 4 facing the movable platform 400. It is attached to the movable platform 400 through an adapter 410. The adapter 410 may not be part of the offboard navigation apparatus 100. As illustrated in Fig. 5, the attachment assembly 22 has a plate-like structure to be fastened to a corresponding connecting part of the adapter 410 with bolts and nuts. The adapter 410 grips the metal columns of the trolley 400 with bolts and nuts as well. The adapter 410 may be designed with a different mechanism for attachment to another kind of movable platform 400, providing flexibility in mounting the offboard navigation apparatus 100 to various kinds of movable platform 400 without any modification of the attachment assembly 22.

The offboard navigation apparatus 100 shown in Figs. 2 to 5 and described above is only a workable example, and various modifications can be made. For example, the adapter 410 may not be necessary and the attachment assembly 22 is attached directly to the movable platform 400. Further, a variety of mechanical means such as clamps or inserts can be used as the attachment assembly 22.

As described above, offboard navigation is employed in the offboard navigation apparatus 100 such that the majority of the processing is performed by the server 200. Therefore, the navigation unit 2 and base unit 4 can be kept relatively small and inexpensive without the requirement of powerful computational facilities in the offboard navigation apparatus 100. Further, no infrastructure modifications are required as the navigation unit 2 uses the plurality of sensors 10 to locate the offboard navigation apparatus 100 using existing features of a place.

In addition, the offboard navigation apparatus 100 is capable of being attached to any movable platforms, even small ones like ordinary trolleys, and thus provides a degree of flexibility hardly achieved by the AGVs or other existing mobile robotic

devices. It is a modular add-on autonomous kit that can be attached to any ordinary movable platform to transform it into an intelligent self-navigating platform, and the user is offered with the flexibility to decide which movable platform he or she would like to automate by simply attaching the offboard navigation apparatus 100 to the selected movable platform. The user is also offered with the flexibility to revert back to manual push/pull by simply removing the offboard navigation apparatus 100 from the selected movable platform.

Whilst there has been described in the foregoing description embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations or modifications in details of design or construction may be made without departing from the present invention.

**Claims**

1. An offboard navigation apparatus capable of being coupled to a movable platform used for the transportation and delivery of a load, comprising:

a base unit configured to be capable of being attached to the movable platform and providing locomotive power to the movable platform; and

a navigation unit configured to drive the base unit to navigate the movable platform,

the navigation unit comprising:

sensors configured to obtain sensor data; and

a communication unit configured to transmit sensor data to a server and receive navigation information of the offboard navigation apparatus from the server.

2. The offboard navigation apparatus according to claim 1, wherein the base unit comprises an attachment assembly configured to attach the offboard navigation apparatus to the moveable platform.

3. The offboard navigation apparatus according to claim 1 or 2, wherein the navigation unit further comprises a processor to process the navigation information of the offboard navigation apparatus to provide a navigation instruction.

4. The offboard navigation apparatus according to claim 1 or 2, wherein the communication unit is further configured to receive a navigation instruction from the server.

5. The offboard navigation apparatus according to any one of claims 1 to 4, wherein the navigation unit is coupled directly to a drive system of the movable platform to navigate the movable platform when the movable platform is a self-powered platform.

6. The offboard navigation apparatus according to any one of claims 1 to 4, wherein the base unit further comprises

a power source;

a moving mechanism configured to make the offboard navigation apparatus movable; and

a driving unit driven by power supplied from the power source and configured to drive the moving mechanism.

7. The offboard navigation apparatus according to claim 6, wherein the driving unit is configured to receive a navigation instruction from the navigation unit and drives the moving mechanism according to the navigation instruction.

8. The offboard navigation apparatus according to claim 6 or 7, wherein the moving mechanism is a number of wheels.

9. The offboard navigation apparatus according to claim 6 or 7, wherein the moving mechanism is continuous tracks.

10. The offboard navigation apparatus according to any one of claims 6 to 9, wherein the power source is a battery.

11. The offboard navigation apparatus according to any one of claims 6 to 9, wherein the power source is a combustion engine.

12. The offboard navigation apparatus according to any of claims 1 to 11, wherein the navigation unit further comprises a processor configured to

calculate a latency of a network through which the offboard navigation apparatus and the server communicate, the latency of the network being a difference between sending sensor data from the offboard navigation apparatus to the server and receiving processed data corresponding to the sent sensor data by the offboard navigation apparatus from the server, and

determine the speed of the offboard navigation apparatus based on a threshold value of a positional accuracy of the offboard navigation apparatus and the latency of the network.

13. The offboard navigation apparatus according to claim 12, further comprises an interface configured to receive the threshold value of the positional accuracy of the offboard navigation apparatus from a user.

14. The offboard navigation apparatus according to claim 12 or 13, further comprises an odometer configured to estimate the position of the offboard navigation apparatus.

15. The offboard navigation apparatus according to any one of claims 12 to 14, wherein the speed of the offboard navigation apparatus is determined to be inversely proportional to the latency of the network.