Autonomous Navigation Method Using a DGPS

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ABSTRACT **-** So far, many researches have been done on developing navigation methods for mobile robots. Most of those methods use laser range scanner sensors, cameras, and magnetic sensors, which require prebuilding a map on a desired route to be able to autonomously navigate. Prebuilding the map is to manually move the mobile robot on the desired route from a start position to a goal position with a joystick. Therefore, it is troublesome, takes a lot of time depending on the distance. However, we can now easily inspect the location indicated by latitude and longitude on the website. Accordingly, we consider that it is possible to make the mobile robot perform autonomous navigation without prebuilding a map by using these latitude and longitude. Therefore we aimed at an autonomous navigation system using a DGPS (Differential Global Positioning System). The mobile robot with the proposed navigation method basically navigates based on the encoders and it uses the position data from the DGPS to correct the cumulative error in travel distance caused by wheel slippage and uneven terrain. As an experimental environment, we chose a track and sidewalks in campus and built a database by using "Google Map". As an experimental result, the mobile robot accomplished an autonomous navigation on the full course of the database with the proposed method even the DGPS could not temporally get position data. The error between the database and the trajectory of the autonomous navigation was less than 1.5 meters.

Keywords**:** autonomous navigation, mobile robot, DGPS

1. Introduction

Recently, autonomous mobile robots have been introduced at several situations such as rescue site (rescue robots), golf course (autonomous mowing robots), and amazon's delivery service (drones). Thanks to the autonomous navigation methods, which so far have been done by many researchers around the world. For instance, J. Eguchi et al. present a method using a combination of DGPS and scan matching for the making of occupancy grid maps for localization [1]. The physical landmarks scanned by the laser range scanner sensors are stored in the grid map, where the mobile robot positions are calculated based on encoders. The DGPS plays an important role in correcting the cumulative error in travel distance caused by wheel slippage and uneven terrain. In other researches, J. Guivant et al. presents an autonomous navigation and map building using laser range sensors in outdoor applications [2] and Y. Moracles presents an autonomous robot navigation in outdoor cluttered pedestrian walkways [3]. In [1], [2], and [3], building high accuracy maps are required in order to achieve autonomous navigations, and the processes in prebuilding maps takes a lot of time. It is therefore navigation method using GPS is becoming popular [4][5][6]. In this study, we propose an autonomous navigation method that uses longitudes and latitudes obtained from a website such as the Google map [7]. With the proposed method, the mobile robot can autonomously travel on any routes, where it has never been before. Using a DGPS in the mobile robot navigation is not a new idea. However, success of using position data obtained from the website for mobile robot navigation has never been reported [8].

2. Proposed navigation method

We have two objectives. One is to convert the longitudes and latitudes obtained from the website into the mobile robot's database. Another is to navigate the mobile robot on the desired route using this database. To perform the autonomous navigation, we use a mobile robot mounted with two encoders, which directly connect to right and left wheels to calculate the robot's position, and a DGPS. The mobile used in this study is shown in Fig.1 and the specification of the DGPS is shown in Table1. The mobile robot navigates by calculating its position and distance to a target with encoders. The DGPS is used to compensate the cumulative position error caused by wheel-slippage.

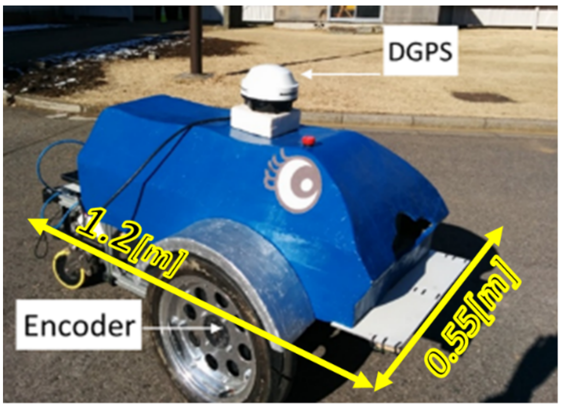


Fig.1 The mobile robot and the DGPS

Table1 Specification of the DGPS

Model number	Hemisphere A101
Satellite re-acquisition time	1.0[s]
Voltage	7-36[v]
Accuracy	Less than 0.6[m]

Fig.2 indicates system architecture of the mobile robot. The DGPS acquires its own position data from the satellites. Then, this position data is sent to a shared memory and the shared memory keeps a record of the last readings in a ring buffer to make it possible to be used in multi navigation programs called navigators in this study. Next, position data is sent to navigators. In this study, we use two navigators: one uses encoders and another uses a DGPS. From these navigators, commands such as ID, priority and speed instruction are sent to actuator control module (ACT). Finally, Speed instruction with the highest priority is sent to motor driver to rotate the motors. Similarly, pulse number of the encoders is sent to the ACT to calculate the mobile robot's travel distance.

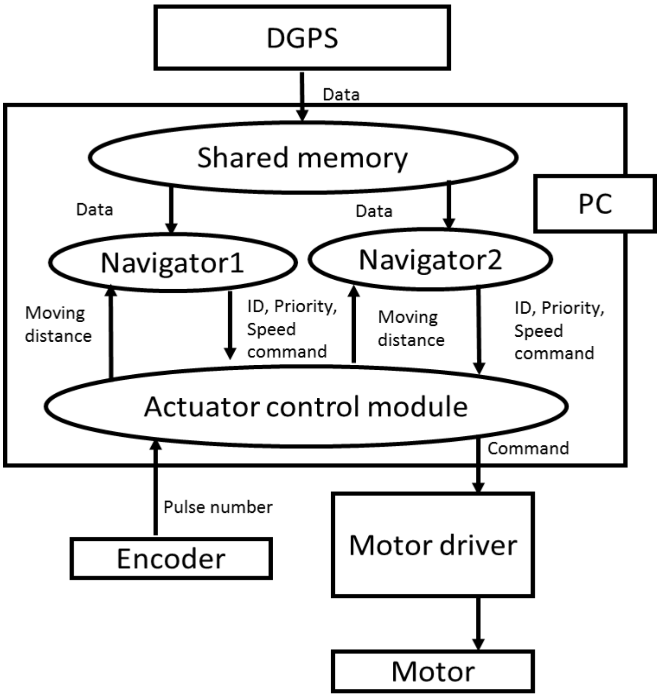


Fig.2 System architecture of the mobile robot

2.1) Position calculation using the DGPS

The DGPS can acquire position data indicated by latitude and longitude from the satellites every second. However, it is impossible for the mobile robot to use this position data in its original form. Therefore, it is necessary to convert the DPGS data from longitude and latitude into the mobile robot's coordinate (orthogonal coordinate system). In this study, we use the WGS84 (World Geodetic System 1984) coordinate system as a standard coordinate of the DGPS. The WGS84 coordinate system is indicated in Fig.3 and the DGPS data can be converted into the mobile robot's coordinate system by using equation (1) to (4).

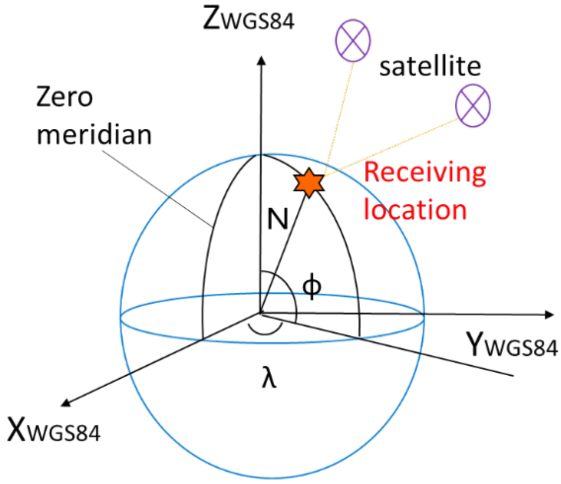


Fig.3 WGS84 coordinate system

$$e^2 = 2f - f^2 \tag{1}$$
$$N = a/\sqrt{1 - e^2 sin^2\varphi} \tag{2}$$
$$x = Ncos\varphi cos\lambda \tag{3}$$
$$y = Ncos\varphi sin\lambda \tag{4}$$

Where a = 6378137 [m] is the average radius of equatorial plane; f = 1/298.257223563 is the oblateness; e is eccentricity; φ is latitude [rad]; λ is longitude [rad]; and (x, y) is the mobile robot's coordinate (orthogonal coordinate system) [m].

2.2) Position calculation using encoders

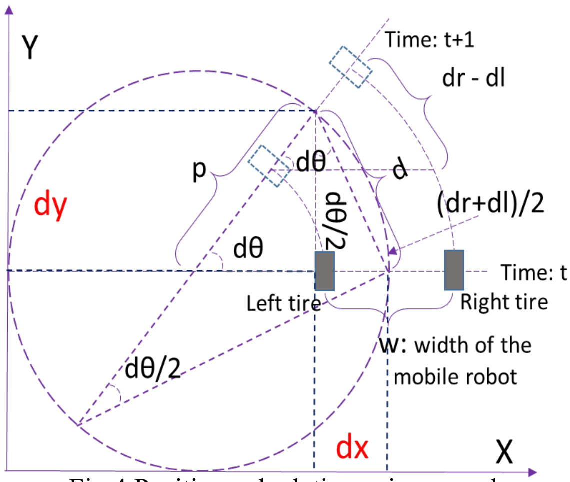


Fig.4 Position calculation using encoders

The DGPS can acquire position data from the satellites with the maximum error of 0.6m. However, it is impossible to use DGPS's position data under the trees and near the high buildings. It is because of the ionosphere and the troposphere, which may cause the error of time delay of signal from satellites, and the multi-path phenomenon that occurs when the GPS signal is reflected off objects such as tall buildings or large surfaces before it reaches the receiver [7]. In this study, we use navigation method using encoders to cover the areas, where the DGPS cannot receive data from the satellites. Fig.4 illustrates the calculation of robot's position using encoders. The mobile robot position can be calculated by using equation (5) to (9).

$$d\theta = (dr - dl)/w \tag{5}$$
$$p = (dr + dl)/2d\theta \tag{6}$$
$$d = 2psin(d\theta/2) \tag{7}$$
$$dx = dcos(d\theta/2) \tag{8}$$
$$dy = dsin(d\theta/2) \tag{9}$$

Where *dr* and *dl* are rotation velocities of left and right wheels [m/s]; *w* is *the* distance between the wheels of the mobile robot [m]; $d\theta$ is the angle rate of the mobile robot per second [rad/s]; and (dx, dy) is derivation of the mobile robot's position (orthogonal coordinate system) [m].

2.3) Algorithm of the proposed navigation method

If the mobile robot uses only encoders to perform its autonomous navigation, the cumulative error in travel distance and heading direction caused by wheel slippage and uneven terrain will occur. This cumulative error may cause the mobile robot deviate from its desired route. In this study, we use the position data received from the DGPS to modify this cumulative error. The flowchart of proposed navigation method is shown in Fig.5. The self-position modification is performed, when the position error calculated from encoders and the one received from the DGPS is larger than 1m, by replacing the self-position calculated from an encoder with the self-position calculated from the DGPS. By doing this, the mobile robot can keep staying on the desired route or without deviating from the route of the database.

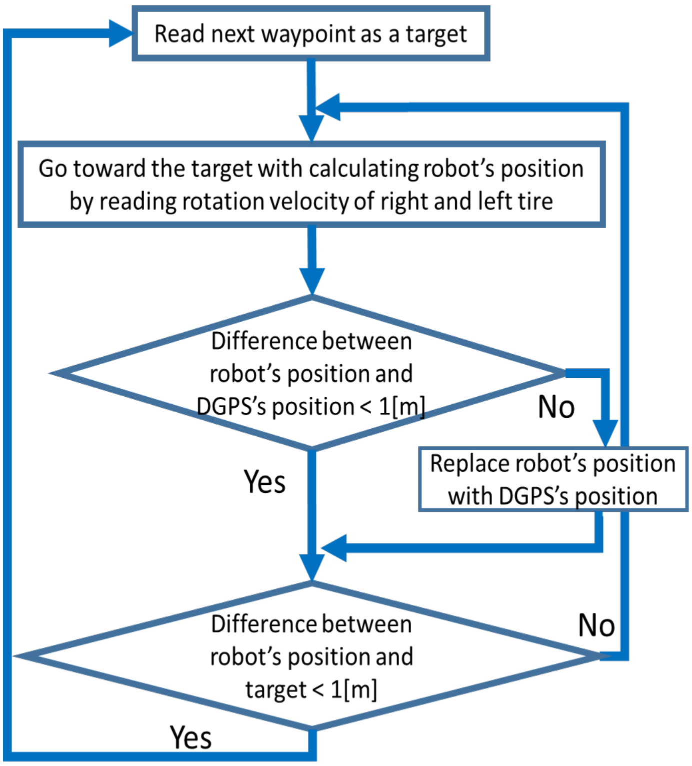


Fig.5 Flowchart of the self-position modification

3. Experiment

3.1) Experimental environment

We built a database using latitudes and longitudes obtained from the Google Map. As shown in Fig.6, we chose a position in soccer ground of our campus as the start point and a position at the back of Techno-building as a goal point. The soccer ground is best location for starting since the DGPS can obtain the position data from multi satellites and it means that the mobile robot can get a very accurate position data. At the back of Techno-building is not an ideal location because the DGPS cannot get its positon data temporally and it means that the mobile robot cannot depend on the DGPS's position data. There are two checkpoints from the start position to the goal position. In the checkpoint 1, the DGPS cannot get accurate position data temporally because it is under trees. Moreover, it is uneven terrain and width of the path is less than 2.5 meters. Therefore, wheel slippage can be occurred easily and it is hard for the mobile robot to navigate autonomously without implementing self-position modification. In the checkpoint 2, width of path is approximately 5 meters with even terrain, which is a good condition for the mobile robot to navigate autonomously based on the encoders. However, the DGPS cannot get position data because it is between the tall buildings and there is a transfer bridge above it. Therefore, the mobile robot cannot depend on DGPS's position data.

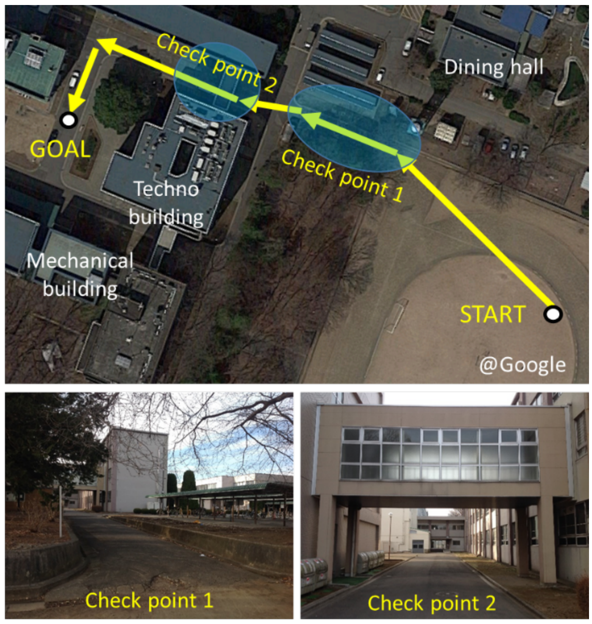
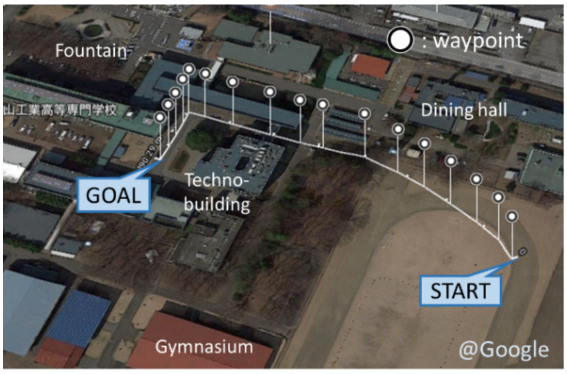


Fig.6 Experimental environment

3.2) Database building

First, open Google Map and put waypoints on the desired route with approximately 5 meters interval from the start position to the goal position manually. Because it is difficult to set the waypoints shorter than 5 meters length with the Google Map. Moreover, as shown in Fig.5 the distance between waypoints have to be longer than 1 meter. Next, save these position data consisting of latitude and longitude in a text file. Finally, convert these position data into the mobile robot's coordinate (x, y). Fig.7 shows a process of the database building.



(a) Putting waypoints from start to goal

(b) Saving waypoint's position data in a text file

Fig.7 Database building

4. Result and Future work

As a result, the mobile robot successfully accomplished the autonomous navigation on the full course using the database obtained from the Google Map by modifying its own positions with the DGPS. Speed of the mobile robot is 0.3 meters per second and it took about 10 minutes. The mobile robot was moving autonomously smoothly in almost times but temporally deviated from database when it was in the checkpoint 2. It is because of the DGPS couldn't get position data under the transfer bridge. Therefore, position of the mobile robot was modified largely by the DGPS after passing the checkpoint 2 as shown in Fig.8. And positioning error of the mobile robot is less than 1.5 meters. From that result, we assure that the mobile robot can move autonomously on the desired route to some extent as long as width of the path is larger than 3 meter even the mobile robot cannot get the DGPS's position data temporally.

As our future work, in order to apply to practical situations, we consider combining with a laser range scanner sensor to avoid an obstacle like pedestrian, and cameras to detect a traffic light. Studies using these sensors have been done in our laboratory and we confirmed that these studies have already succeeded. Therefore, it can be combined with my work. Another work is to build the database from the Google Map automatically instead of manually building it as of today to make it more quickly and simply.

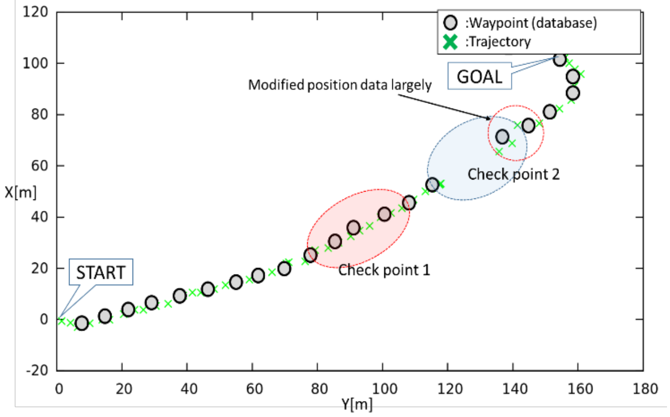


Fig.8 Experimental result

5. Summary

①In this paper, a navigation system using a DGPS was described. The navigation system consists of a navigation method using encoders and a navigation using the DGPS.

②In order to navigate the mobile robot along the database, we made a position modification method that can return the mobile robot back to the database when it deviates from the database more than one meter.

③During experiment, the mobile robot successfully completed the full course of 200 meters using database obtained from a website even the mobile robot is under the trees, bridge and surrounded by buildings.

④As our future works, in order to build the database quickly and simply, build it from the website by putting waypoint and saving its position data automatically. In addition to do that, we propose combining with another sensors to detect a traffic light and avoid an obstacle.

References

[1] J. Eguchi and K. Ozaki: Journal of Robotics and Mechatronics, Vol.26 No.2 (2013), pp. 506-514

[2] J. Guivant, E. Nebot, and S. Baiker: Journal of Robotic Systems, Vol.17, No.10(2000),pp.565-583

[3] Y. Moracles, A. Carballo, E. Takeuchi, A. Aburadani, and T. Tsubouchi: Journal of Field Robotics, Vol.26, No.8(2009), pp.609-635

[4] Hwan-Seok, Ok-Deuk Park,Han-sil Kim: ICCA International Conference,Vol2(2005),pp.858-862

[5] K. Seung-hun, R. Chi-won, K. Sung-chul, P.Min-yong: IEEE Robotics and Automation, (2007), pp.3414-3419

[6] Y. Erikawa, Y. Ando, M. Mizukawa: Proceedings of the JSME Conference on robotics and Mechatronics(2008), p2P2-D21(1)-(2)

[7] K. Shuto, R. Sam Ann and T. Akio:5th International symposium on technology for sustainability, paper ID 40

[8] K. Ohno, T. Tsubouchi, B. Shigematsu, S. Yuta: Advanced Robotics, Vol.18, no.6(2004), pp.611-635