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Construction of an Environmental Map including Road Surface Classification Based on a Coaxial Two-Wheeled Robot

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Abstract**—**This research details the construction of an environmental map as well as road surface identification based on a coaxial two-wheel robot. The proposed system utilizes ROS and SLAM algorithm for indoor/outdoor environment mapping from sensor data and road-surface discriminator based on attitude estimation and image processing. From the research, environmental maps of various road surfaces were constructed and road types successfully identified with 80% accuracy using Deep Learning.

Keywords**—**Coaxial Two-Wheeled Robots, Environment Maps, SLAM, Deep Learning.

I. INTRODUCTION

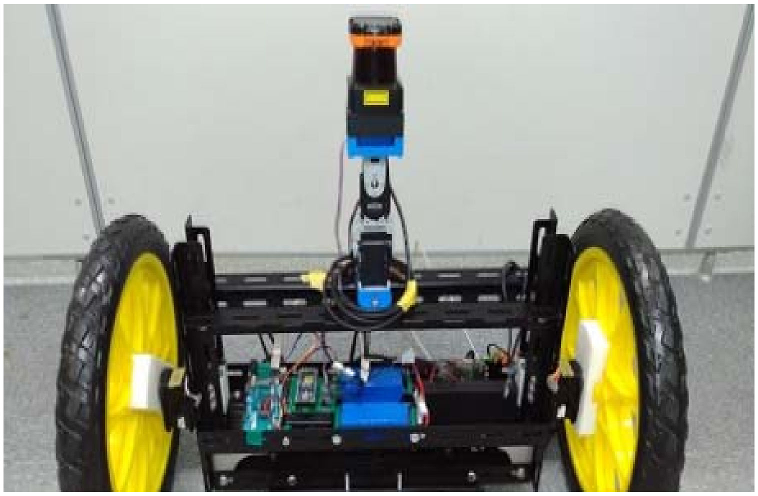
IN recent years, robots have been increasingly utilized in service industries such as cleaning, security, and others. They are mainly manufactured with a uniform design and are custom-made to an environment with plenty of movement space. In this conventional setup, it is easy to detect objects like walls and paths for smooth motions. In order to develop further integration of service robots, it is necessary to realize motion in diverse road surfaces / wall surface conditions as well as stabilize movement in narrower space. This research focuses on a small size robot that can function in a dynamic environment without prior preprograming and optimization of the operation spaces.

This study is based on a coaxial two-wheeled robot, a mechanism with two large wheels rather than a conventional mobile robot with four wheels, to create environmental maps and detect road surface. The research employ the use of Simultaneous Localization and Mapping (SLAM) algorithm to build the maps with the objective of robotic self-position estimation. The coaxial two-wheel mechanism is suitable for movement in a narrow space because of its small turning effect since it is capable of swinging the super pendulum. The challenge with it is that it is difficult to obtain a stable sensor value owing to its forward and backward oscillation. For this reason, we introduced a horizontal maintenance controller for the geodetic sensor base based on 6 axis motion sensors (3 acceleration axis, 3 gyro axis) to feed the SLAM algorithm and an image acquisition system for road surface classifications map.

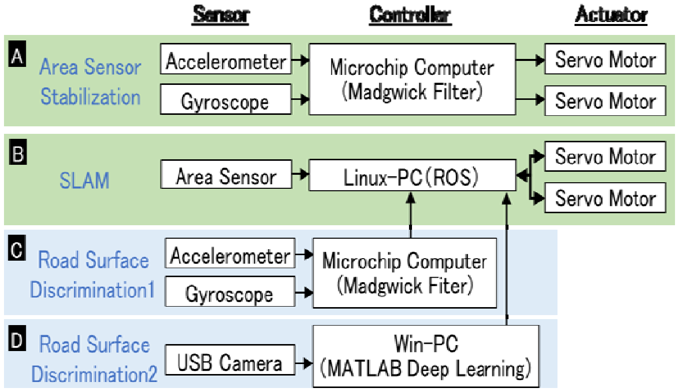
II. PROPOSED SYSTEM

The proposed coaxial two-wheeled robot (Fig.1a) consists of two wheel servo motors, two horizontal angle control servo motors, one movement control and image analysis computer, two 6-axis motion sensor microprocessors, one geodetic sensor and two 6-axis motion sensors. As shown in Fig.1b, the movement control is based on the Robot Operation System (ROS) running on a Linux-equipped PC. SLAM adopts the ROS wrapper of GMapping which inputs the sensor and the wheel rotation data. When combined with Rao-Blackellized Particle Filtering (RBPF), the system is able to estimate its own position at high speed. In order to make the sensor always horizontal, sensor fusion using Madgwick filter is applied to the acceleration and angular velocity value obtained from the motion sensors attached to the base. From the algorithm, the attitude (roll angle, pitch angle) and angle control for maintaining the base horizontal is fed to the two servo motors.

In road surface identification, the surface angle of the road is determined using Madgwick filter attitude values. The road type is classified based on image analysis performed on Matlab using SegNet algorithm which is one of Deep Learning package. Image analysis results are fed to ROS for accurate construction of the environmental map.



(a)A 2 Wheel Coaxial Robot



(b) System Architecture

Fig.1 Proposed coaxial two-wheeled robot.

III. VERIFICATION OF BASIC PERFORMANCE

A. Horizontal control of horizontal pedestal

We first verified the horizontal control function by measuring the posture of the upper part of the sensor base during translational motion. The posture measurement is realized by applying Madgwick filter to the measured values of acceleration / angular velocity from the 6-axis motion sensor. The results shown in Fig.2 outlines the effects of applying horizontal controller. The right figure in Fig. 2 shows the measurements when no controller is applied and when the controller is applied on the left. When the horizontal control is not applied, the amplitude of the pitch angle indicating the forward / backward oscillation is 10 to 40 degrees around the center of 20 degrees, while it is 5 to 10 degrees around the center of 0 degree when applied. From this, when using the horizontal controller, we proved the suppressing of the forward and backward swinging.

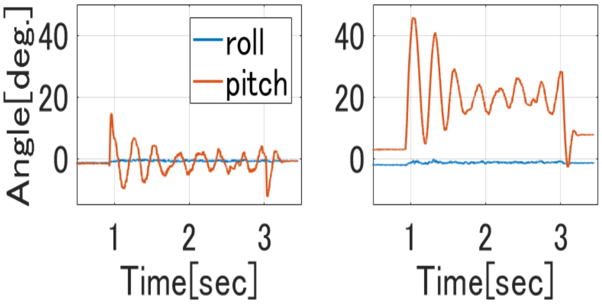


Fig.2 Performance of the horizontal controller.

B. Construction of environment map using attitude control

Next, we verified the map construction in multiple environments using the mobile robot equipped with horizontal controllers. For the environment, we selected indoor space and varying multiple outdoor spaces. The outdoor environment comprises of asphalt pavement, concrete pavement and interlocking pavement for representative sample of road surfaces. Further, two types of sloping roads, paved with non-flat surface and unpaved surface, were also evaluated. The map construction results for all the evaluated environments are shown below.

Fig. 3 shows an indoor environment (office setup). The black dots on the map indicate that an object has been detected, and the red dot shows the travel position of the robot. Fig. 4 -8 shows varying outdoor environments and corresponding construct of the map.

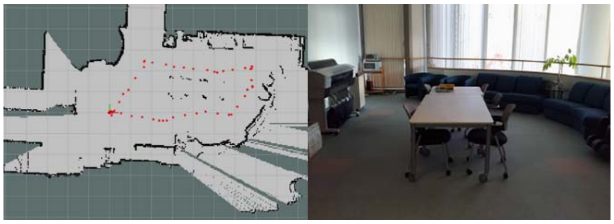


Fig.3Experiment indoor environment: office.

Fig.4Experiment outdoor environment: Asphalt.

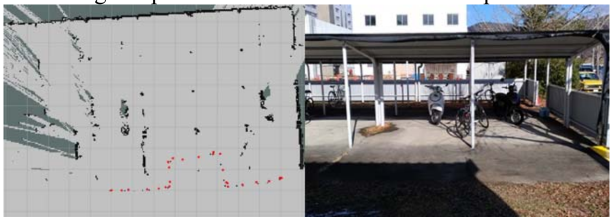


Fig.5Experiment outdoor environment:Concrete.

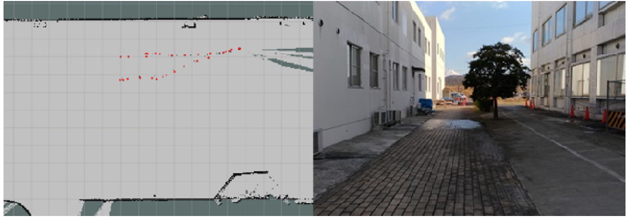


Fig.6Outdoor environment: Interlocking pavement.

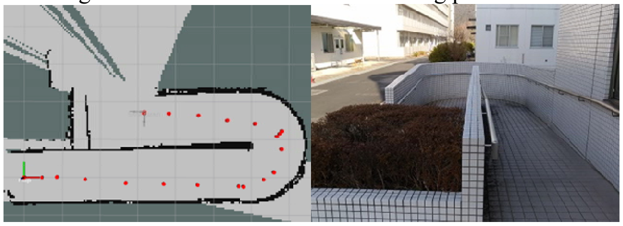


Fig.7Outdoor environment: Paved slope.

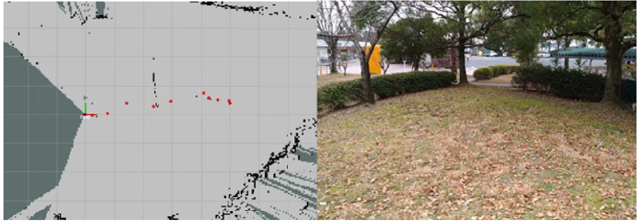


Fig.8Outdoor environment:Unpaved slope.