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Steps Climbing by Sub-Tracks Angle Control for a Rough Terrain Mobile Robot with Multistage Tracks

Toyomi Fujita and Takahiro Suzuki

***Abstract*—The authors have presented a tracked mobile robot which consists of multistage sub-tracks to increase mobility on rough terrain. In order to reduce loads to an operator who has to perform a remote control of the robot manually, this study considers an autonomous step climbing by this type of robot. A sub-tracks grounding detection unit has been devised to sense the status of grounding of a sub-track. Using this device, the robot is able to climb steps autonomously by detecting its status of grounding without manual control of the angle of sub-tracks. The presented system has an advantage that it is very simple because only microswitches are used and we can therefore control the robot more easily.**

***Index Terms*—Tracked mobile robot, Multistage sub-tracks, Angle control of sub-track, Sub-track grounding detection unit, Steps climbing.**

I. Introduction

In recent years, tracked mobile robots which can move on rough terrain are expected for a rescue purpose in disaster area. In order to increase mobility in that area, many kinds of tracked vehicle which has multiple tracks have been developed. These types of robot generally have several sub-tracks, or flippers, at the front and rear side of the main body with two main-tracks such as the robot with two sub-tracks [1][2][3] and with four sub-tracks [4][5][6]. These mechanisms are however difficult to climb more complex terrain, for example the steps which have different heights, due to a few contact points.

In order to solve this problem, our earlier study have presented a rough terrain mobile robot consisting of not only main tracks but also multistage sub-tracks [7]. This robot is able to have 6 or more sub-tracks to increase mobility on rough terrain. However, it has a problem that an operator has to perform a remote control of the robot manually by operating a remote-controller and there are a lot of loads to the operator.

This study considers an autonomous step climbing by this type of robot which has sub-tracks in order to reduce the load to the operator. The authors have devised *sub-tracks grounding detection unit* which can sense the status of grounding of a sub-track. The robot is able to climb steps using this unit without manual control of the angle of sub-tracks.

This paper presents this unit newly developed in this study in Section II as well as the robot system which has been developed by the authors. Section III describes how the robot climbs steps using this unit.

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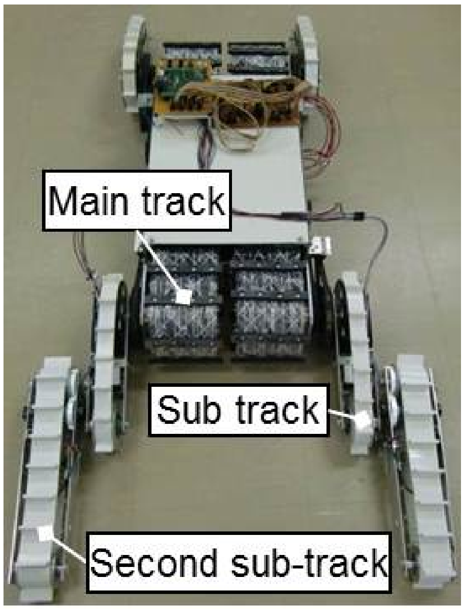

Fig. 1. Prototype of the robot with eight tracks

II. Robot System

A. Overview of Robot

The authors have devised the tracked mobile robot that consists of multistage sub-tracks. Figure 1 shows the overview of the robot with eight tracks: two main-tracks, four sub-tracks, and two multistage sub-tracks. The length of the robot is 1380 [mm], when all tracks are stretched to be straight, the width is 730 [mm], and the height is 230 [mm]. The total weight is 38 [kg].

The main-track consists of two sprockets, two chains, and some rubber blocks. It is covered with plastic sheet in order for dust and water proofing. The driving for the main-track transmits from the drive motor to the main shaft through the pulley. To control the angle of the sub-track, the drive of the angle control motor is transmitted to the pulley of the sub-track through gears, pulley, and timing belt as shown in Fig. 3.

Figure 2 shows the overview of the robot with ten tracks. This is extended one by adding two more multistage sub-tracks to the robot with eight tracks shown in Fig. 1. The length of the robot is 1570 [mm], when all tracks are stretched to be straight; the length from the main-track to the end of the multistage sub-track is 640 [mm]. The total weight is 42 [kg].

Figure 4 shows developed unit of the multistage sub-track.

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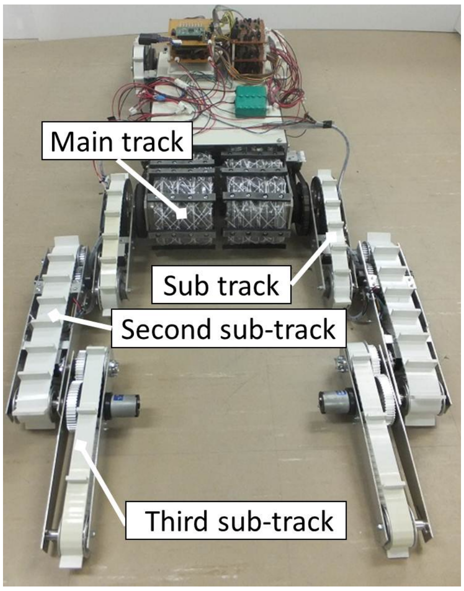

Fig. 2. Prototype of the robot with ten tracks

The height is 360 [mm], the width is 110 [mm], and the height is 54 [mm]. The weight of the unit is 2 [kg]. We are able to expand to the ten tracks from eight tracks easily because of this unit structure of the multistage sub-tracks.

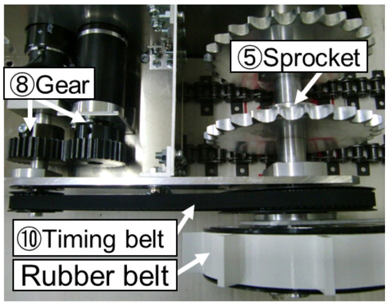

Fig. 3. Mechanism of sub-track angle control

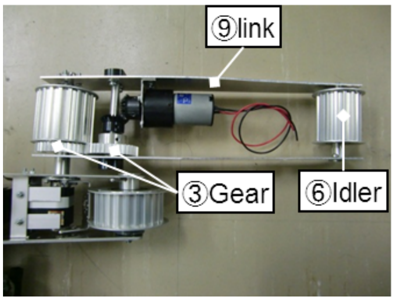

Fig. 4. Unit of sub-track

B. Sub-Track Grounding Detection Unit

Six micro switches, Omron SS-5GL2, were used for the angle control of a sub-track. Each of them was attached to each of six sub-tracks. The authors have devised a unit which consists of a small pipe with axis and the switch so that it turns on appropriately when the sub-track is grounding.

The schematic diagram of the unit is shown in Fig. 5. The axis is fixed to frame of the sub-track and the pipe is suspended by the axis when the sub-track is not grounding; then the pipe rotates with contacting to the upper part of the axis. The micro switch is attached so that it is placed on the lateral side of the pipe and the switch is *OFF* when the sub-track is not grounding as shown in Fig. 5 (a). When the sub-track is grounding, the pipe is pushed up then the switch turns *ON* as shown in Fig. 5 (b). Even if only a part of surface of the sub-track is touched to the ground, the switch can be *ON* as long as a pressure is given in the detectable area shown in Fig. 5 (a).

This unit enables the robot to automatically control the angle of the sub-track for grounding; it can keep moving the sub-track down while the switch is *OFF* until it turns *ON* to touch the ground. Thus, the load of an operator can be decreased and the operation is expected to be easier.

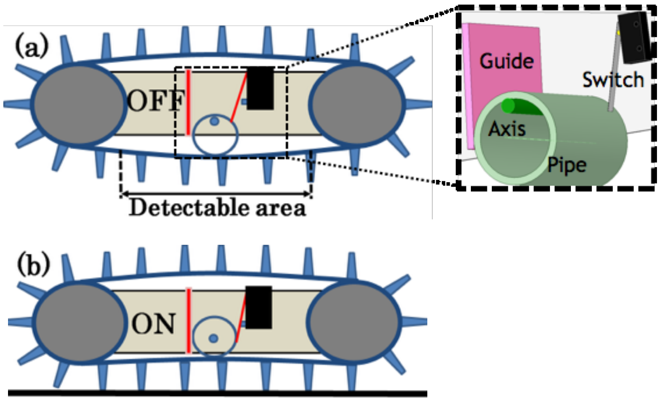

Fig. 5. Schematic diagram of *sub-tracks grounding detection unit*: (a) when not grounding (b) when grounding

C. Control System

Figure 6 shows control system for the robot. An operator control the motion of the robot remotely using a controller (PS PAD) with wireless communication. A SH2-7045F board was embedded in the robot for both drive and angle controls of the main-tracks and the sub-tracks. A H8-3052F board was also embedded for the interface with the control board and PS PAD; the H8-3052F receives control signals from the PS PAD and send the corresponding commands to the SH2-7045F. The program for those controls is developed in a host PC. The SH2-7045F board performs PWM control for the drive motors and angle control motors in the main-tracks and the sub-tracks according to motion commands received from the controller (PS PAD) or the host PC.

III. Steps Climbing

We consider a motion in which the robot climbs steps autonomously using the *sub-track grounding detection unit* described in Section II-B. As a basic motion, we suppose the robot which has six sub-tracks. The robot has 1350 mm in length including sub-tracks; the lengths of main body and sub-track are 840 mm and 330 mm respectively. Let

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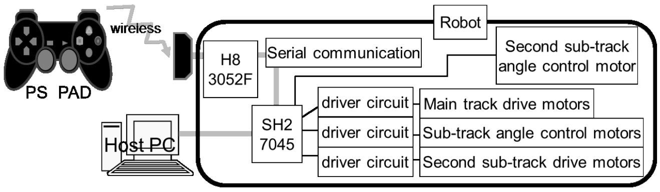

Fig. 6. Control system

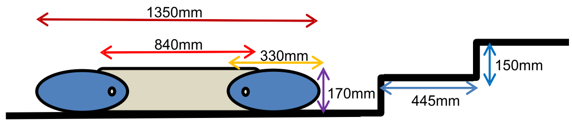

Fig. 7. An environment for step climbing

us suppose that each step has 150 mm in height and 445 mm in length as an environment for the motion as shown in Fig. 7.

The sequential motion of the step climbing is shown in Fig. 8. In each panel, the state of grounding of the sub-track is indicated as *ON* or *OFF* corresponding to the state of the switch in the *sub-tracks grounding detection unit*; the state is used in the following description as well.

The panel (A) of Fig. 8 shows initial state. In this state, the robot moves forward by keeping the angle of front sub-tracks so that the tip of the sub-tracks is over the height of the step. When the front sub-track touches the step, the state turns *ON*. After sensed the state of *ON*, the sub-track is moved down to lift the main body of the robot up. The main body then touches the corner of the step and the front sub-track will becomes *OFF* as shown in (C). Then, the robot is able to drive forward by moving the rear sub-track down and the front sub-track up as shown in (D). After that, the front sub-track turns *ON* by touching it on the corner of the next step as shown in (E). The body then touches the corner and drives forward by moving the both of front and rear sub-tracks up as shown in (F). When the rear sub-track touches the corner of the first step as (G) shows, it is moved down and the front sub-track is then touched on the corner of the next (third) step because of falling down of the body as shown in (H). Then, all tracks can be touched on the corners of steps by moving the rear sub-track up and the front sub-track down with keeping both of the state *ON*. The body and sub-tracks become straight to be the sate of (F) again. Thus, the robot can continue the motion of (F), (G), and (H). At the final step, the state of (G) becomes the state of (I) and the front sub-track does not turn *ON* even if the rear sub-track is moved up as shown in (J). This state can be detected by checking the time of *OFF* of the front sub-track. The rear sub-track may also become *OFF* but it soon becomes *ON* again because of touching the corner of the final step as shown in (K). In this sate, the robot can move the front sub-track down to touch the upper ground and the rear sub-track up as shown in (L). The robot then keeps moving forward and finishes climbing the steps.

IV. Conclusions

This study devised the *sub-track grounding detection unit* so that a mobile robot with multistage sub-tracks controls the angle of each sub-track autonomously by detecting its status of grounding. The robot is able to climb steps easily by this system with reduced loads of operator. The presented system has an advantage that it is very simple because only microswitches are used and we can therefore control the robot more easily.

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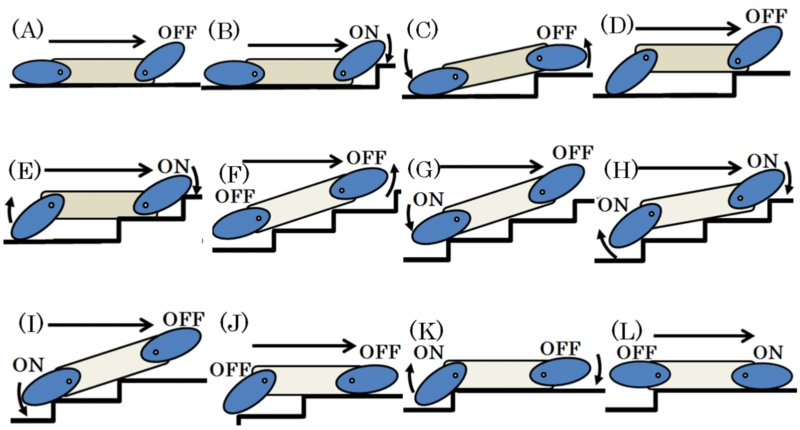

Fig. 8. Step climbing motion using the *sub-track grounding detection unit*