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## Development of Rough Terrain Mobile Robot Control Strategy Capable of Position and Direction Estimation by a Single Marker

To cite this article: Yuki Kurahashi and Hideki Toda 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **472** 012019

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# Development of Rough Terrain Mobile Robot Control Strategy Capable of Position and Direction Estimation by a Single Marker

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**Abstract.** In the present study, a mobile robot control strategy of rough terrain capable of position and direction estimation by a single marker was proposed, and the effect was performed. To realize wheel / caterpillar mobile robot movement on the rough terrain such as house farm, two major problems (1) the precise position estimation and (2) the direction estimation are important before the development of the control theory. Generally, the position / direction have been estimated by the wheel rotation (odometry) and gyro or acceleration sensor's output integration, but there are many problems such as many impacts from the ground and the wheel slipping on the rough ground to the precise estimation. The aim of this study is to develop a method (algorithm) to estimate the mobile robot direction using a single marker placed at the top of the robot by changing the front movement and the target direction movement periodically. The reason using a single marker is that it is difficult process to find and analyze positions of the many markers attached on the robot in the camera image from a long distance, and the positions of many markers have been unstable by the tilting of the robot, agricultural product's shadow, getting dirty of the body and so on.

Our proposed method would be effective in the difficult situation to find or analyze the marker position of the robot surfaces by the reason of camera position and the environment, and it could realize wheels / caterpillar type mobile robot movement on the muddy situation.

## 1. Introduction

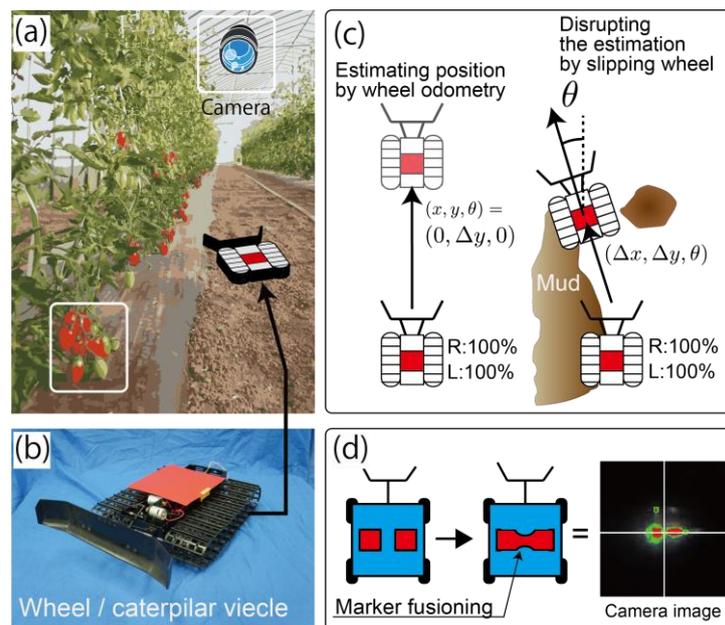
In this paper, a mobile robot control strategy of rough terrain capable of position and direction estimation by a single marker was proposed, and the effect was performed. Current agriculture in Japan has a problem of aging of agricultural workers, and the substitution of agricultural work by robots is becoming increasingly important socially [1]. To realize wheel / caterpillar mobile robot movement on the rough terrain such as house farm, two major problems (1) the precise position estimation and (2) the direction estimation are important before the development of the control theory.

Figure 1a shows the major situation of the mobile robot movement environment for application in the house farm. Previously proposed robot application in house farm used multi aluminum / stainless rails on the ground to realize correct position / direction movement of the robot, however many cost is necessary for the equipment and the rails becomes a factor hindering effective use of agricultural ground. Even if the rail is set up on the farm, the problem of measurement and movement of the mobile robot's current position is caused by dirt or slippage on the rail. The need for long-term maintenance has not yet been discussed. As another solution of the mobile robot localization and control, colored markers attached on the mobile robot (ex. Fig. 1b) could be used, and the position would be measured by camera attached on the ceil. But the extracting position of the markers are generally difficult by the reason of



mixing with environment colors, marker shape (area) instability, the distance from the camera to the markers, and multi markers geometric position combination problem. To estimate the position and the direction of the robot, two markers are necessary at least in 2D map. But it is not always possible to detect the two markers in the rough terrain field in the house farm by above some reasons; especially a marker fusion is a serious problem (Fig.1d) in this situation. These causes disable robot direction detection. In addition, since the wheel / caterpillar rotations affected by the slip on the dirt (Fig.1c), the position estimation by the wheel / caterpillar rotations (odometry) was failed generally.

Our proposed method uses one marker on the mobile robot to increase the detection performance of the robot by the camera on the ceil, and the direction of the robot is estimating by a novel two phase movement control algorithm. In this paper, basic examination of the position estimation / movement control of a caterpillar mobile robot in rough terrain situation were performed.



**Figure 1.** Difficulty of the position estimation of the wheel / caterpillar type mobile robot platform in the rough terrain house farm

## 2. Previous study

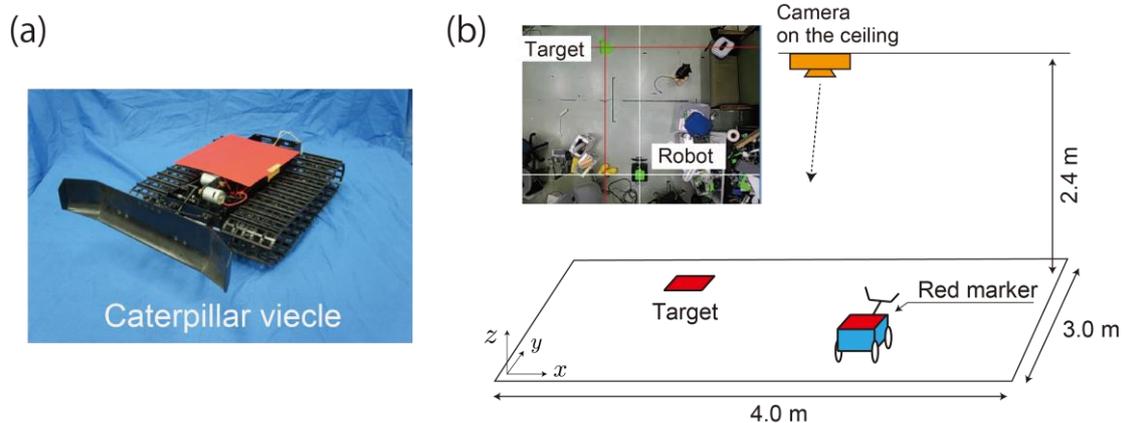
Auto-runner[2] is a previously proposed unmanned pesticide spreader in house farm environment. It could realize the pesticide spread by moving the all area on the house railed with metal rail. Since the robot does not estimate its own position, it cannot manage with slippage on the rail, and it is expensive setup. In University of Shimane[3], it represents omnidirectional mobile robot to convey objects in a complicated and narrow environment by using a special wheel called a omni-wheel, it can move in all directions. It have constructed an algorithm that estimate the position and orientation of the mobile robot with high accuracy acceleration and gyro sensors mounted on the robot, and the rotation angle of the driving wheel. Since the wheel usually slipped on the farm, the acceleration and gyro sensor values could not correspond to the real wheel rotation angle information and it is impossible to estimate the correct position and direction.

## 3. Method

### 3.1. Experimental Devices and the Setup

Figure 2 shows the experimental setup devices, (a) Caterpillar mobile robot (BLIZZARD SR, Kyosyo Corp., 35×30×8cm) attached red marker (0.18×0.18m), (b) Setup of the experiment. Camera (640×480 pixels, view angle 130 deg, 30 fps) was attached on the ceiling, and two markers were used as the robot

and target position respectively. The mobile robot was controlled by two channel motor driver, Arduino microcomputer and middle spec PC (AMD A10-7860K, 8GB ram).



(a) Caterpillar mobile robot (BLIZZARD SR, Kyosyo Corp., 35×30×8 cm) attached red marker (0.18×0.18m). (b) Setup of the experiment. Camera (640×480 pixels, 30 fps) was attached on the ceiling and two markers (the robot and target) were found by red color image analysis.

**Figure 2.** Experimental setup devices.

### 3.2. Control Algorithm

The mobile robot was controlled by two different control strategy in this study. When the center of the gravity of the red markers were measured as  $\vec{x}_1$  (robot) and  $\vec{x}_2$  (target), the direction of the target was defined  $\vec{b} = \vec{x}_2 - \vec{x}_1$  (Fig. 3a). Normal vector  $\vec{a}$  was defined as estimated robot direction, and it was calculated from Method (1) the robot caterpillar rotations and (2) a 300 msec period "forward" movement of the robot denoted by A in Fig. 3b. Method (1) was previously proposed general direction estimation algorithm and the caterpillar rotations only were used to estimate the direction in this study. On the other hand, Method (2) was a proposed strategy, and there is two control phases in the strategy - (A) Forward movement phase to estimate which is the head direction of the robot, and (B) Approach phase to control the robot to the target position. In the Forward phase, the R and L channel power balances of the caterpillar robot were set same values eg.100% while 300 msec period, and the red marker position movement was measured and set as  $\vec{a}$  in the 300 msec phase. Next Approach phase use  $f_R$  and  $f_L$  as R and L channel powers of the robot defined below in the period of 300 msec,

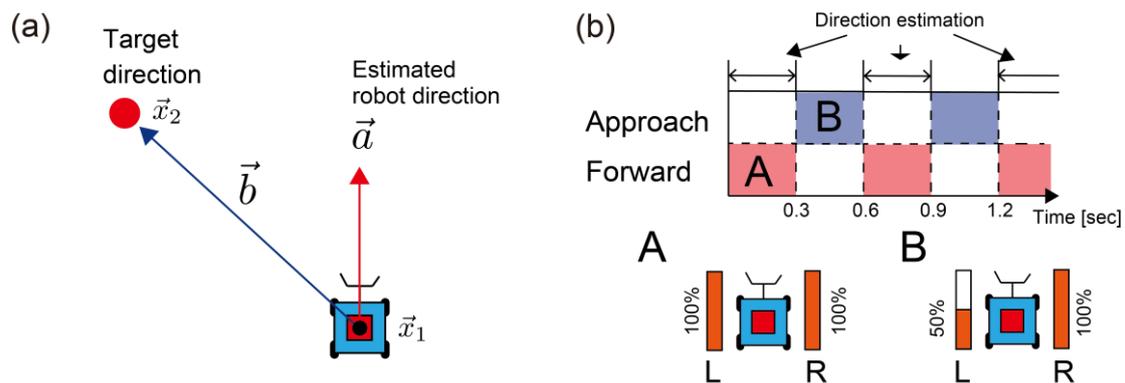
$$Cross_z = \vec{a} \times \vec{b} \quad (1)$$

$$f_R = \alpha Cross_z + \beta_R \quad (2)$$

$$f_L = \alpha Cross_z + \beta_L \quad (3)$$

where  $\alpha$  is constant,  $\beta_R$  and  $\beta_L$  are power bias parameters depended on the machine.

The parameters were set to move the robot forward direction if the cross product value  $Cross_z$  is zero. In the Method (1) control, the Eq.1 to Eq.3 are used.



**Figure 3.** (a) Definition of the vector  $\vec{a}$  and  $\vec{b}$ . (b) Proposed control strategy two phase method.

#### 4. Experiment

Experiment 1 performs basic forward movement test when the right caterpillar power changed 40 to 100% and the left power was fixed 100% (power supply was 12 V DC, the power was changed by 1 kHz PWM and the ON time ratio). Experimental time was 500 msec. From this experiment, the power bias parameters  $\beta_R$  and  $\beta_L$  were determined. The ground condition of the room was flat (polished concrete), but slippery surface for the plastic caterpillar.

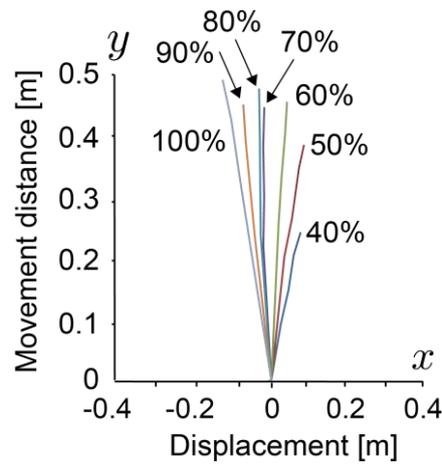
Experiment 2 performs movement control to the target position on the slippery surface of the polished concrete when Method (1) and (2) control strategy. The area of the experiment was  $4 \times 3$  m field, and the target position was set  $(-0.4, 2.3)$  m from the start position.

#### 5. Result

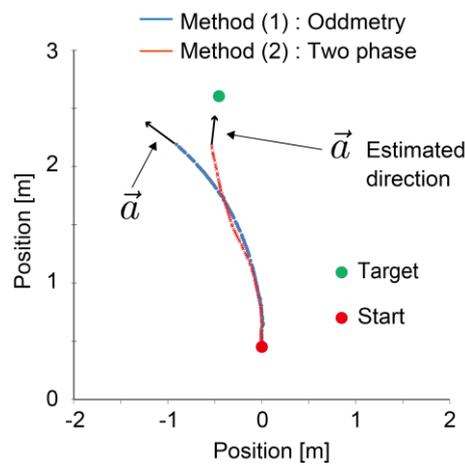
Figure 4 represents the trajectory plotting result of experiment 1. The robot was started from  $(0,0)$  position. Since 100% plot is tilting to the left side  $(x,y)=(-0.13,0.45)$ , the movement power of the right motor is large comparing with the left. Even if the power input to the motors were completely same, the real robot movement would be affected by another factor such as caterpillar surface friction, gear friction loss and so on. From this result, the robot was moved to almost straight ahead when the power of R:L = 70%:100%. As a result, we set  $\beta_R=35\%$  and  $\beta_L=50\%$  respectively in later experiment.

Figure 5 represents the trajectory plotting result of experiment 2. Red and green circle were start and target position respectively. Blue colored plot was the result of Method (1): odometry. The trajectory largely deviated to the left side, and the front direction of the robot was different from the target direction (black arrow). Red colored plot was the result of our proposed Method (2). 300 msec periodical "forward" and "approach" switching control could realize the movement control to the target direction even though in the slippery surface of the polished concrete, and the estimated direction  $\vec{a}$  was estimating correctly in all the situation. The mechanism of the Method (2) was summarized in Fig. 6 especially in the slipper situation. If the left caterpillar was slipped in a situation (Fig. 6A), even though the power balance was 50:50, the robot position was moved left top side and the direction also changed at the same time.

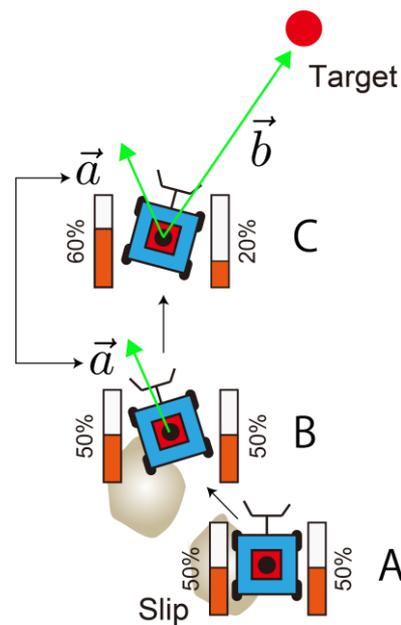
In the situation B of Fig. 6, the robot performs "Forward" phase (Fig. 3), and the vector  $\vec{a}$  would be obtained. In a small area of the slippery environment, the direction of the  $\vec{a}$  would be a kind of pseudo "straight" direction of the robot. Next in the approach phase, the robot would calculate the wheel power on the condition that the vector  $\vec{a}$  is regarded as "straight" direction in the small slippery area. This periodical control process was assumed in the proposed algorithm, and it could realize the performance of rough terrain movement.



**Figure 4.** Result of experiment 1 basic forward movement test dependency of the right caterpillar power.



**Figure 5.** Result of experiment 2: Difference of the trajectory of Method (1) and Method (2) control strategy.



**Figure 6.** Mechanism of the proposed control Method (2).

## 6. Conclusion

In this paper, a mobile robot control strategy of rough terrain capable of position and direction estimation by a single marker was proposed, and the effect was performed.

To realize wheel / caterpillar mobile robot movement on the rough terrain such as house farm, it is necessary to solve the precise position estimation and the direction estimation are important before the development of the control theory. This study developed a method to estimate the mobile robot direction using a single marker placed at the top of the robot by changing the front movement and the target direction movement periodically. Experimental result shows that even if there is slip while the forward phase, obtained vector  $\vec{a}$  could treat as a kind of pseudo "straight" direction of the robot, and cross product between  $\vec{a}$  and  $\vec{b}$  would be useful for R and L channel power control. Our proposed method would be effective in the difficult situation to find or analyze the marker position of the robot surfaces by the reason of camera position and the environment, and it could realize wheels / caterpillar type mobile robot movement on the muddy situation.

## 7. References

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