Lecture Notes in Electrical Engineering 365

Felix Pasila
Yusak Tanoto
Resmana Lim
Murtiyanto Santoso
Nemuel Daniel Pah
Editors

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Introduction

This book includes the original, peer-reviewed research papers from the 2nd International Conference on Electrical Systems, Technology and Information (ICESTI 2015), held during 9–12 September 2015, at Patra Jasa Resort & Villas Bali, Indonesia.

The primary objective of this book is to provide references for dissemination and discussion of the topics that have been presented in the conference. This volume is unique in that it includes work related to Electrical Engineering, Technology and Information towards their sustainable development. Engineers, researchers as well as lecturers from universities and professionals in industry and government will gain valuable insights into interdisciplinary solutions in the field of Electrical Systems, Technology and Information, and its applications.

The topics of ICESTI 2015 provide a forum for accessing the most up-to-date and authoritative knowledge and the best practices in the field of Electrical Engineering, Technology and Information towards their sustainable development. The editors selected high quality papers from the conference that passed through a minimum of three reviewers, with an acceptance rate of 50.6 %.

In the conference there were three invited papers from keynote speakers, whose papers are also included in this book, entitled: "Computational Intelligence based Regulation of the DC bus in the On-Grid Photovoltaic System", "Virtual Prototyping of a Compliant Spindle for Robotic Deburring" and "A Concept of Multi Rough Sets Defined on Multi-Contextual Information Systems".

The conference also classified the technology innovation topics into five parts: "Technology Innovation in Robotics, Image Recognition and Computational Intelligence Applications", "Technology Innovation in Electrical Engineering, Electric Vehicle and Energy Management", "Technology Innovation in Electronic, Manufacturing, Instrumentation and Material Engineering", "Technology Innovation in Internet of Things and Its Applications" and "Technology Innovation in Information, Modeling and Mobile Applications".

In addition, we are really thankful for the contributions and for the valuable time spent in the review process by our Advisory Boards, Committee Members and Reviewers. Also, we appreciate our collaboration partners (Petra Christian

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On behalf of the editors Felix Pasila

Chapter 17
Odometry Algorithm with Obstacle Avoidance on Mobile Robot Navigation

Handry Khoswanto, Petrus Santoso and Resmana Lim

Abstract Many algorithms have been devised on mobile robot navigation system. Some of them use algorithm based on newer concept like fuzzy logic or genetic algorithm. Some are stick on older algorithm like odometry. A simple, less intensive calculation algorithm for a lightweight telepresence robot is required. To accommodate the requirement, odometry algorithm is chosen specifically. Obstacle avoidance feature is proposed to enhance the algorithm. A mobile robot prototype is implemented using Arduino UNO, two DC geared motors, single caster wheel, and an ultrasonic sensor. Two kind of experiments are performed. The first experiment is to verify that odometry algorithm is working. The second one is used to verify obstacle avoidance mechanism. The results are satisfying. Mobile robot can avoid the obstacle and reach the destination correctly. Further experiment is needed to decide about ultrasonic sensor placement in a real telepresence robot.

Keywords Odometry algorithm · Mobile robot · Telepresence robot · Arduino

17.1 Introduction

An autonomous robot is required to have navigation capability. Given a certain destination point in its environment, the robot is expected to reach the destination autonomously. Many algorithms with different degrees of complexities have been devised in the recent years. Some of them use fuzzy logic [1–3], genetic algorithms [4–6]. Some also stick on older algorithm like odometry. Odometry is a basic method of navigation, used by virtually all robots [7]. Odometry also proven successfully used on project like Mars Exploration Rovers [8].

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There is a need to have a simple, less intensive calculation to support an ongoing project of telepresence robot with an open protocol framework [9]. In this case, a design decision has been made to do an exploration on the potential of odometry algorithm. An obstacle avoidance feature also proposed to enhance the algorithm when facing unexpected obstacle on the robot's navigation route.

The paper describes how the odometry algorithm can be used by a mobile robot to reach a certain goal location using single ultrasonic sensor and servo motor. Using knowledge of wheel's motion, an estimation of robot's motion can be derived. The mobile robot prototype uses Arduino controller, L298 DC Motor driver, and disk encoder using optocoupler sensor. The mobile robot is differentially driven, it has a motor on the left and right side and equipped with single caster wheel on the back side. To add the capability of obstacle avoidance, a single ultrasonic sensor and Tower Pro micro servo motor are added to the prototype.

17.2 Hardware and Mechanic Design

This paper designed mobile robot with the aim of reaching the destination point even though there are particular obstacles on its route. The system block diagram is given on Fig. 17.1.

The robot uses ultrasonic sensors to detect the distance of objects in front of it. Ultrasonic sensors placed on servo motors so that it can rotate 180°. The rotation of the servo starting from −90° to 90° in increments of 45°. Using servo motors, the ultrasonic sensor is capable of facing on five different directions (left, oblique left, front, oblique right, and right). To calculate the rotation of the motor, a mobile robot uses an acrylic disc encoder with 12 holes that can be read by optocoupler. Installation of disc encoder is parallel with the wheels. The actuator uses two geared DC motor with two shafts. The first shaft installed on encoder disk and the other shaft is mounted on wheel. Figure 17.2 represent the mechanical design of mobile robot prototype.

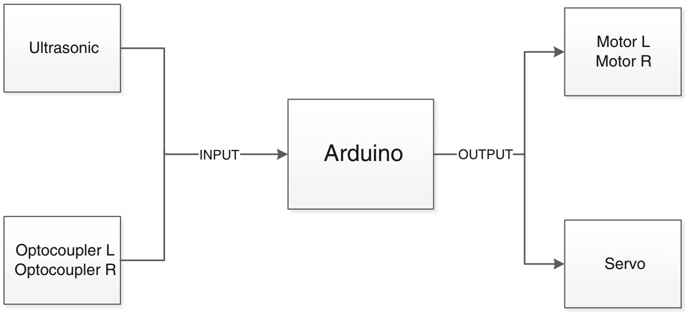


Fig. 17.1 System block diagram

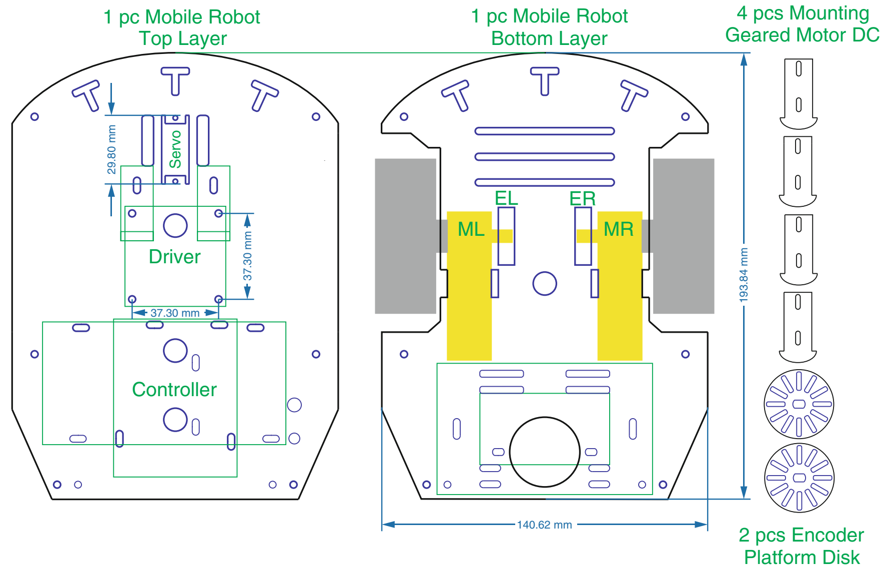
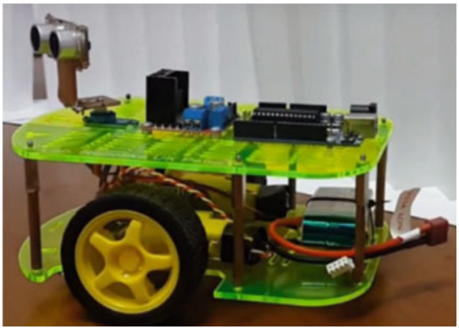


Fig. 17.2 Acrylic mobile robot platforms and mounting parts

Figure 17.2 shown the top and bottom platform layer, and the mounting accessories for DC Geared Motor and disc encoder. On the top layer there is a square hole which is used to place a micro servo motors. Micro servo motor is used to enable the movement of ultrasonic sensor. The second devices on top layer are L298 DC motor driver and Arduino UNO controller. On bottom layer, there are two geared DC motors, namely motor left (ML) and motor right (MR). Two DC motors are installed using 4 mounting pieces in the right places. Each disc encoder has 12 holes for one rotation. So, one tick represents 30 degrees of rotation of the wheel. Each of these holes will generate a pulse that will be read by optocoupler sensor. An optocoupler, also known as an optoisolator or photocoupler, is an electronic component that interconnects two separate electrical circuits by means of a light sensitive optical interface. Figure 17.3 represents the implemented mobile robot prototype.

Fig. 17.3 Mobile robot prototype



17.3 Odometry and Robot Model

Odometry is measurement method from motion sensor or rotation sensor to estimate change in position over time. Odometry is used by some robots, whether they be legged or wheeled, to estimate (not determine) their position relative to a starting location. This method is sensitive to errors due to the integration of velocity measurements over time to give position estimates. Rapid and accurate data collection, equipment calibration, and processing are required in most cases for odometry to be used effectively.

Figure 17.4 explain about detailed odometry geometry for our mobile robot. The vehicle starts from (x, y, θ) and destination position at (x′, y′, θ′). The center between two wheels of the robot travels along an arc trajectory. Remembering that arc length is equal to the radius times the inner angle, the length of this arc is:

$$d_{center} = \frac{d_{left} + d_{right}}{2} \tag{17.1}$$

On basic geometry, the equation is:

$$\varphi r_{left} = d_{left} \tag{17.2}$$

$$\varphi r_{right} = d_{right} \tag{17.3}$$

If $d_{baseline}$ is distance between the left and right wheels:

$$r_{left} + d_{baseline} = r_{right} \tag{17.4}$$

Subtracting from Eqs. (17.2) and (17.3) above:

$$\varphi = \frac{d_{right} - d_{left}}{d_{baseline}} \tag{17.5}$$

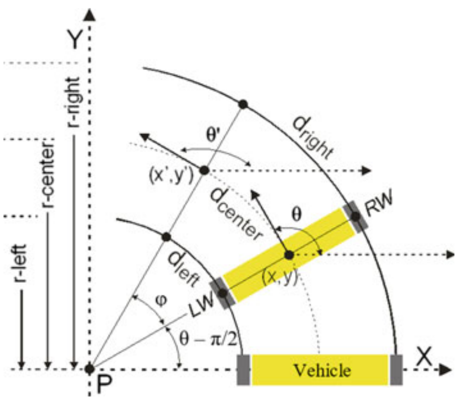


Fig. 17.4 Odometry geometry for mobile robot

Wheel encoders give the distance moved by each wheel, left and right wheel. Assume the wheels are following an arc trajectory for short time scale.

$$x' = x + d_{center} \cos \emptyset \tag{17.6}$$

$$y' = y + d_{center} \sin \emptyset \tag{17.7}$$

$$\emptyset' = \emptyset + \frac{d_{right} - d_{left}}{d_{baseline}} \tag{17.8}$$

Calculation of wheel circumference is needed to know how far motion of the robot. Mobile robot uses two wheels with 65 mm diameter. Each wheel is equipped with 12 holes disc encoder for one rotation. The equation is as follows.

$$\Delta tick = tick' - tick \tag{17.9}$$

$$d_{left} = 2.\pi.r.\frac{\Delta tick\_left}{N} \tag{17.10}$$

$$d_{right} = 2.\pi.r.\frac{\Delta tick\_right}{N} \tag{17.11}$$

17.4 Software Design

The flowchart of the system is depicted on Fig. 17.5. Position estimation is used to predict robot position by counting the pulse sent by optocoupler. The direction of the robot can be known from the result of pulse count from the left and right optocoupler. Robot reads the destination coordinate and always check the odometry pulses (dtick1 and dtick2). Controller updates the newest position of mobile robot (x_new, y_new, teta_new). After the robot gets the newest coordinate, controller calculates the difference between destination coordinate and current coordinate.

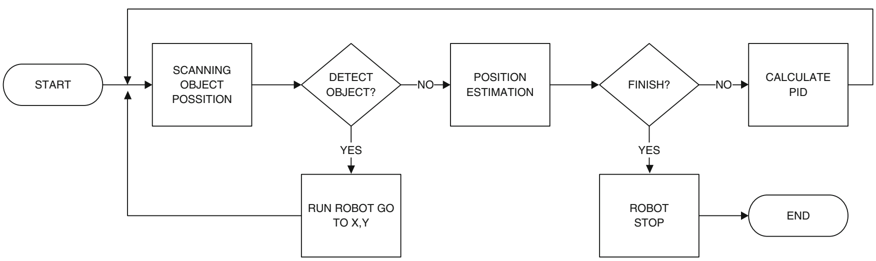


Fig. 17.5 System flowchart

Error is used to calculate PID parameters and determine the speed of left motor and right motor. This algorithm is repeated until destination point is reached.

Obstacle avoidance mechanism begins with the reading of obstacle position. Servo will rotate the ultrasonic sensor and get the data of distance between robot and obstacles from several different angles (0, 45°, 90°, 135°, and 180°). Each distance is saved and transformed using rotation and 2D translation depicted in Eqs. 17.12 and 17.13. Equation 17.12 is derivation of Eq. 17.13 where $R(x, y, \theta)$ is a 3 × 3 matrix. The transformation result gives the coordinate of world view depicted at Eq. 17.13.

$$R(x', y', \theta') = \begin{bmatrix} \cos(\theta') & -\sin(\theta') & x' \\ \sin(\theta') & \cos(\theta') & y' \\ 0 & 0 & 1 \end{bmatrix} \tag{17.12}$$

$$\begin{bmatrix} x_{di} \\ y_{di} \\ 1 \end{bmatrix} = R(x, y, \theta)R(x_{si}, y_{si}, \theta_{si}) \begin{bmatrix} d_i \\ 0 \\ 1 \end{bmatrix} \tag{17.13}$$

17.5 Result and Discussion

Mobile robot starts at the origin, pointed down the xy axis. Its starting state is (x, y, θ) on (0, 0, 0) and the mobile robot will going to (x′, y′, θ′). The experiment result will prove the usability of the navigation method.

The first experiment of mobile robot goes to goal without any obstacles with destinations coordinate (180, 50 cm). The second one goes to goal with obstacles with the same coordinate. Figure 17.6 shows how the mobile robot reach the destination on coordinates (180, 50 cm). The research experiment is completed with four obstacles. The obstacles are paper board sound damper with the height 25 cm and paper fold 1 cm. The obstacles are used to disturb ultrasonic wave transmission.

From 10 experiments with 4 obstacles and random position a success rate of 90 % is achieved. Without obstacles, 100 % success rate can be achieved.

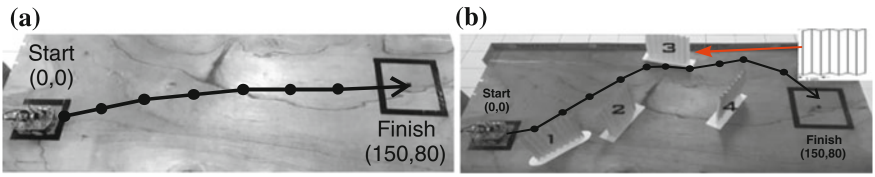


Fig. 17.6 Experiment: **a** without obstacles, **b** with obstacles

17.6 Conclusion

Odometry method is able to carry the mobile robot to reach its destination. One of the weaknesses of the system is drifting of the wheels. In the second experiment paper board sound damper as obstacles is added. In this schema, the mobile robot still can reach its goal. Considering the result of the experiment, there is still a need of further experiment to decide on ultrasonic sensor placement on a real telepresence robot.

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