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Mobile Robot Position Determining Using Odometry Method

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Abstract

In this article, the authors propose an analysis of the cumulative error of robot movement. We are considering a two-wheeled robot based on an Arduino board with three ultrasonic rangefinders. The position of the mobile robot is calculated using the odometry method. Experiments were carried out on various coatings. And the calculated position of the robot was compared with the real one. When writing a mobile robot control program, it is proposed to take these results into account.

Key words: Mobile robot, Robot control, Odometry, Error accumulation

Introduction

At the current stage of technological development, robotic devices are finding more and more areas of application in human activity. This is due, first of all, to the fact that robotic devices are able to work better, longer and more reliably than a person, completely excluding such systematic errors as the "human factor"[1]-[6].

Planning the workspace with a robotic device will allow us to receive accurate, high-quality and easy-to-understand information without physical effort. For successful navigation in the surrounding space, the robotic system must build a route, correctly set the angles of rotation of the wheels and their speed of rotation, correctly interpret the information about the environment that comes from the sensor and constantly monitor its own coordinates. For efficient navigation, mobile robots need to adopt effective localization strategy [7]-[14].

But it is necessary to understand that even the most accurate engines cannot guarantee movement without error. In addition, sensors, in our case ultrasonic rangefinders, also have their own error, which largely depends on the distance to the object/obstacle. Moreover, when writing a control program for a mobile robot, developers must take into account the fact that there is an error, which will tend to accumulate over time, that is, to increase. Thus, research related to the estimation of the accumulated error is extremely relevant and timely

Related works

Plenty of authors consider a problem, connected with a motion error. Different scientists use different approaches to solve the problem of accumulated robot motion error Among them some researchers try to solve this problem by improving accuracy another ones propose to estimate such an error in order to correct control program.

In [15] authors propose a new calibration method to improve the circular plane kinematic accuracy of industrial robot by using dynamic measurement of double ball bar (DBB). Researchers in [16] also are solving a problem of calibration. They propose to use a camera attached to the mounting plate of the robot is used to capture a fixed reference sphere as a point constraint and to record robot joint angles and gauge block lengths that are used as a distance constraint. This study is interesting by its significant results. After calibration, the average distance error of robot motion is decreased from 2.05 mm to 0.24 mm. Nguyen, H. N. and others proposes a new method for enhancing robot position accuracy[17]. They use an artificial neural network in order to compensate the robot position errors, which are caused by these non-geometric error sources. Scientists in [18] also decided to use an artificial neural network as well as conventional identification procedures to reduce the absolute position error of robots. They reached a high level of accuracy using only measurements data and deep learning methods.

We see that a lot of authors use artificial neuron networks of different types to solve the problem of movement error compensation. Thus, in [19] authors note that pose error prediction of robots is possible by the neural network.

Cao, C. T. and his co-authors [20] have studied a method to reduce the absolute position error of robots using machine vision and neural network. Their application of the proposed algorithm in the actual robot experiment reduced the error to 50.3%. But there is another approach to solve the problem mentioned above. And this approach consists of using various sensors, including ultrasonic rangefinders, laser tackers and so on, which allow real-time assessment of the robot's position relative to other objects. And [21] is an example of such approach. This paper explores the use of a real-time robot kinematic error compensation technique where an external high-precision feedback sensor (in this case a laser tracker) directly measures the robot kinematic error and corrections are implemented during processing.

Among the many ways to improve robot positioning, we can highlight one more – odometry. A disadvantage of using it alone is unbounded error accumulation. So, odometry calibration is critical in reducing error propagation [22]. This paper presents an analysis of the developments and advances of systematic methods for odometry calibration.

Authors [23] in view of kinematic parameters errors, propose an odometry calibration method for three-wheeled omnidirectional mobile robots.

Odometry is a simple and practical method [24]-[28]. This method provides a periodic real-time estimation of the relative displacement of a mobile robot based on the measurement of the angular rotational speed of its wheels. But it has some disadvantages. The main disadvantage is unbounded accumulation of errors. In [24] researchers propose their own procedure to evaluate and correct the systematic odometry errors of a human-sized three-wheeled omnidirectional mobile robot. Thus, we see many ways to improve the accuracy of a robot's movement. One of the relatively simple ones is the odometry method. Although it has its drawback – an accumulative error, we propose to calculate it and take it into account when controlling robots. This is exactly what is discussed below.

The mobile robot hardware development

To implement the task, it is necessary to develop a system that includes a mobile robotic device and a program for processing data received from the device, the architecture of which is shown in Figure 1.

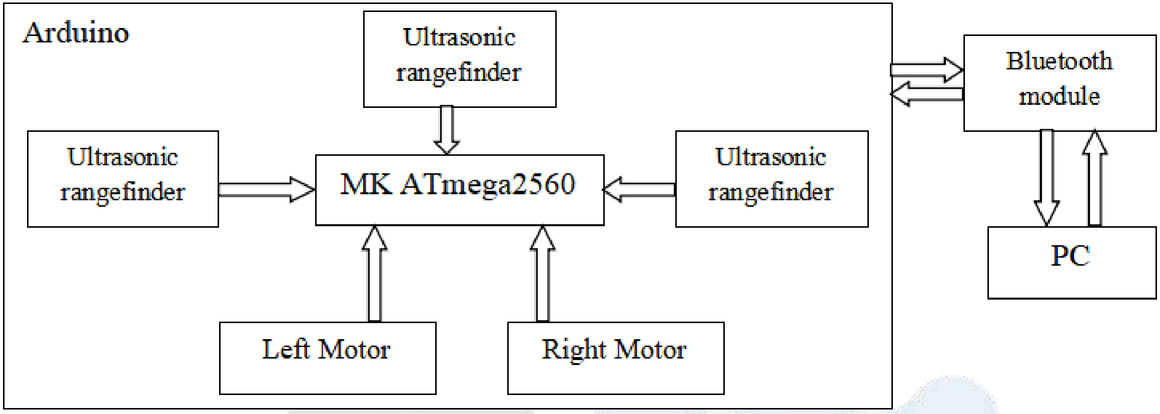


Figure 1: Developed system architecture

According to the assembled scheme, we will describe the hardware part in more detail. So, one of the main parts of the developed system is the Arduino control board based on the ATmega 2560 microcontroller, which controls the sensors and motors, and also receives and sends pointers from the rangefinders to the PC via the Bluetooth wireless information transmission module.

Due to the fact that the implementation of the main function of controlling a mobile robotic device is iterative, at the beginning, a check is made to see if the mobile robot has achieved the goal.

We must say that we are consedering a simple room with no interior corners. During the environment analysis, i.e. mapping, the conclusion that the analysis is over is made by counting the number of turns. If the device makes a turn counterclockwise, then the value of the global variable count of turns is decremented, if clockwise - it is incremented, when the number of turns reaches four – mobile robot concludes that he went around the entire perimeter of the simulated room. Therefore, after start, the first step in the iteration is to check whether the mobile robotic device has achieved its goal.

If the goal is achieved, then robot should go to label A2, which will transfer the mobile robot to the state of waiting for control commands from the control computer. If the goal is not achieved, then you should measure the analysis of the distance to the obstacle ahead and go to the "while" loop of the forward movement, which leads before the mobile robot moves forward, it measures the left turn conditions and sends the received data regarding the movement and the distance to the obstacle on the left to the computer and is executed as long as the distance to the obstacle is more than twenty-five centimeters.

If the data from the mobile robot is displayed without processing, it can be seen that the sensor sends data with some error. And the data about obstacles in the places where they combine (corners) cannot be obtained due to the design features of the mobile robot, namely, because the mobile robot is equipped with only three rangefinders, which are located in the front part of the structure, due to which a "blind zone" is formed at the turns of the MR.

This means that in order to obtain a reliable map of the model of the surrounding space, it is necessary to process the received data.

Analysis of the measurement error accumulation for the traveled path

Since the measurement of distance traveled by a mobile robotic device is carried out by means of a odometry software implementation, when the mobile robot moves in a straight line, the measurement data may be affected by wheel slippage during movement. In order to determine the effect of slippage while driving in a straight line, we will conduct an experiment where the mobile robot will move along an obstacle 250 centimeters long and send data to a personal computer.

Figure 2 shows the data received from MR in graphic form and saved to a file for further processing.

Figure 2: Received data in graphic form

While traveling a distance of 250 centimeters, mobile robot sent 181 data packages to a personal computer. The wheel diameter of the mobile robot is 6.5 centimeters. It is known that the length of the wheel circumference is determined by the formula:

$$C = 2\pi R = \pi D = 3.14 \cdot 6.5 = 20.41, \qquad (1)$$

where p – a mathematical constant equal to the ratio of the length of a circle to its diameter;

D – wheel diameter.

Due to the fact that the mobile robot is not equipped with stepper motors, but with direct current motors, software implementation of odometry is more difficult. Empirically, it was determined that a full rotation of the wheel is made in 560 milliseconds, and it is assumed that in 40 milliseconds one cycle of the encoder associated with the wheel takes place, i.e., 14 encoder counts are made for one full rotation of the wheel. Then, taking into account formula 1, the formula for the traveled distance will take next form (2):

$$L = \frac{n}{N} \pi D, \tag{2}$$

where L – the final distance traveled (for a given period of time);

n – the total number of encoder counts;

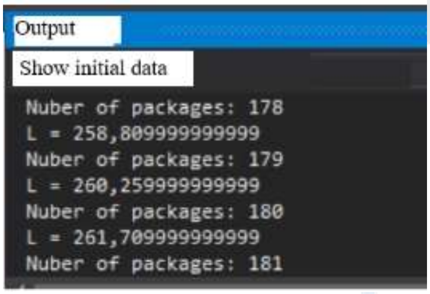
N – the number of encoder readings per wheel rotation;

D – wheel diameter;

p – a mathematical constant equal to the ratio of the length of a circle to its diameter.

Based on the data obtained from mobile robot, we calculate the path traveled by it (3):

$$L = \frac{181}{14} \cdot 3.14 \cdot 6.5 \approx 262 \tag{3}$$

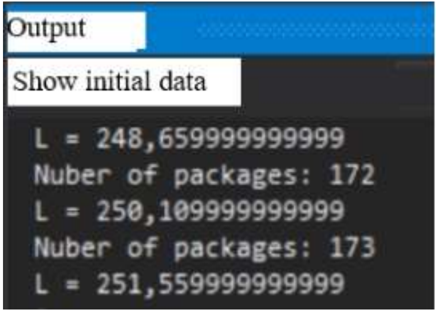


```
Nuber of packages: 178
L = 258,809999999999
Nuber of packages: 179
L = 260,259999999999
Nuber of packages: 180
L = 261,709999999999
Nuber of packages: 181
```

Figure 3: Results of traveled path software calculation

That is, the path calculated using the software implementation of the odometry principle, the path traveled by the mobile robot is 263 centimeters, which is 7 percent more than the real distance traveled.

When testing the calculation of the distance traveled by a mobile robotic device on a carpet surface, where the adhesion of the mobile robot wheels to the surface was significantly greater, 173 data packages were received, and the distance traveled was 251.6 centimeters, the measurement result is shown in Figure 4.



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L = 248,659999999999
Nuber of packages: 172
L = 250,109999999999
Nuber of packages: 173
L = 251,559999999999
```

Figure 4: Results of traveled path software calculation

That is, with minimal wheel slippage, the error in calculations is 0.4 percent. However, it is necessary to take into account that as the distance traveled increases, the error will accumulate. This means that when controlling a mobile robot, this error must be taken into account.

Conclusion

The article discusses a mobile robot built on the basis of an Arduino board. It contains 2 motors (for left and right wheels), as well as 3 ultrasonic rangefinders. This study used a Bluetooth connection.

By conducting an experiment, it was established that the distance calculated by the program differs from that actually traveled by the robot.

An interesting result was that when moving on carpet the error was only 0.4 percent, while on a smooth surface it was 7 percent.

Therefore, further studies are planned to determine the adjustment ranges at different travel distances for different floor coverings.

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