DEVELOPMENT OF RESTAURANT SERVING ROBOT USING LINE FOLLOWING APPROACH

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Abstract - As the era of industrial revolution 4.0 is coming, most of robots are developed to replace the human works and services. However, in Vietnam, putting robots in service industry such as waiter robot serving in restaurants is still very limited. This study presents the initial development of restaurant serving robot using line following approach. The robot is designed by referring to the survey on the size and appearance requirements at a restaurant. Robot is programmed to come to a specific table by mapping data. Based on the line reading algorithm implemented on microcontroller PIC18F4550, the robot follows the line marked on the floor to move to the desired table position and returns to the service counter after completing the task. There are ultrasonic sensors on the robot that can detect the obstacle to help the robot stop and output warning signal. The robot also can output some simple voices to customers in English, Korean and Vietnamese such as "Welcome", "Please enjoy your food", ...

Key words - Serving robot; Line following; PWM; PIC18F4550

1. Introduction

In recent years, robotic technology has been focused to develop on wide range of applications from military to civil and industrial. Among them, wheeled mobile robot is the most common type of robot that is developed for consumer purpose. The mobile robot is maximized its efficiency by integrating smart sensors, image processing technology, GPS, and so on. However, when the mobile robot operates in a flat and narrow space, the robot moving by following the marked line on the floor has been the best solution so far. These robots can perform a variety of tasks, including: transport and sorting robots, medical robots, navigation robots for the visually impaired.

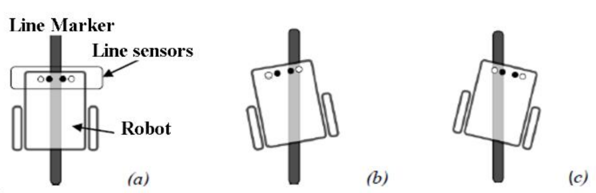

Figure 1. *The movement of the robot (a) straight, (b)left offset, (c) right offset*

Robots have appeared in a number of restaurants in Japan, China or advanced countries around the world as chefs or waitresses. In Vietnam, the first robot which is made by composite structure and put on a wheeled base structure was developed with a purpose of serving as a waiter in a coffee shop in 2017. This robot named Mortar is developed by a young engineer team including Do Trung Thanh, Nguyen Quoc Phi and Pham Quang Viet with an idea starting from their experience in a Japanese sushi restaurant that is completely served by a robot. Thus, three young men have the idea of opening a fantasy style coffee shop using the robots as the serving staffs [1]. For consumer application, wheeled mobile robot is often chosen for its advantages such as simple structure, availability of robot's parts, cost in manufacturing, easy to operate and so on. Thus, the author comes up with an idea of using wheeled mobile robot as waiter serving robot in a restaurant. The controller to drive the robot speed is very important because if it is accelerated or decelerated too fast, the food or drink putting on it may have spilled out.

Traditional line following robot uses the ON / OFF method which means the robot switches off one of the motor if it moves off the path. This is a very simple robot control method that helps the robot return to the target path. However, the limitation of this method is the robot always vibrates to the right or to the left of the path. This affects the movement speed of the robot, the stability is not very high, and much energy is lost. Another method that applies the pulse with modulation technique to control the rotational speed of the motor based on the average value of the pulse output signal of the controller [2]. This method overcomes the oscillation of the robotic movement, but the limitation of this method is the identification of PWM values to control the speed of the two motors while keeping it following the target line. The drawbacks are the difficulties to find optimal values and poor adaptability to different types of pathways. PID controllers are widely used in automated wheeled mobile robots. This algorithm attempts to correct the errors between the actual measured values and the desired values by calculating and exporting the correction values from which the operating system is calibrated [3-5]. Beside the controller algorithm for driving the movement of the robot, a set of sensors and circuit modules are very important to expand the working capability and improve the work efficiency of the robot. In this study, the robot is employed with 3 ultrasonic sensors SRF04 for obstacles avoidance, sound module JQ8900 for output greeting command to customers, a custom made 6-LED line sensor for target path tracking, and a custom made LCD panel for displaying robot status and interfacing.

Within this paper, the author introduces the initial design of the restaurant serving robot for a specific requirement at a local restaurant in Danang through restaurant owner's survey and discussion. Then, the manuscript focuses on the controller configuration of the controller system and the implementation of the line following technique for the movement of the restaurant serving robot. The conclusion sums up whatever the author has achieved so far and proposes the direction for improvement of the system in the near future.

2. Structural design of the robot

Through surveys and inquiries at restaurants in the city, the team has launched a human-shaped robot model with two separate food trays to meet the amount of food needed on the table. Based on that, after many designs and discussions, the author has chosen the suitable design as shown in Figure 2. As the requirement from the owner of a local restaurant where the robot will be tested in reality, the robot would look not too big and has friendly and unique appearance, thus, it has two trays to increase the amount of foods and drinks that can be delivered at a time. The proposed design is the two-wheel drive robot that consists of two-actuated wheels and two passive caster wheel. The lower tray must be put on the robot at a height equal to the height of restaurant table of 750 mm. The robot has three separated parts which are the base for moving the whole robot, the body with two trays for carrying the food, and the controller panels for inputting the command for robot's operation. The base takes up the majority of the robot mass, thus, when the robot moving with low speed and acceleration, the foods and drinks would stay in their container.

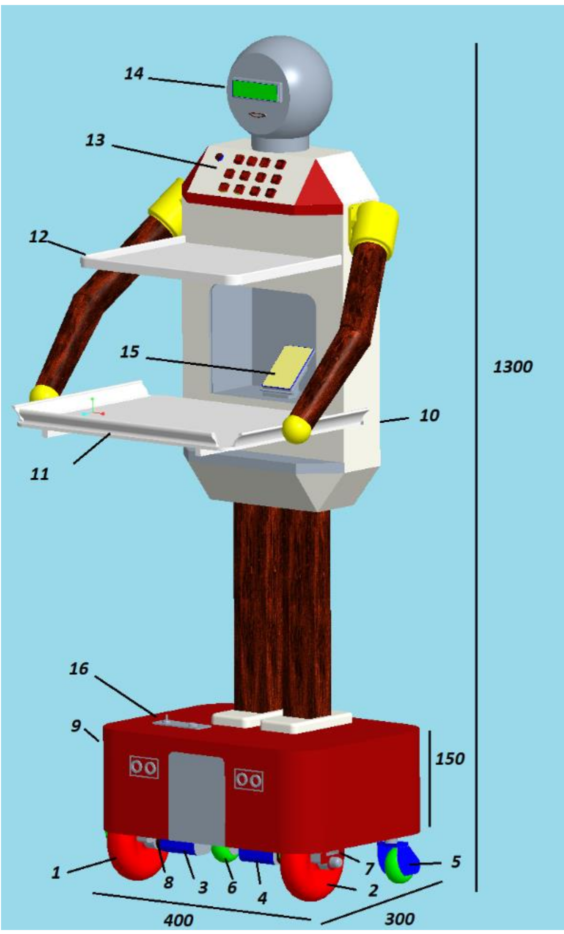

Figure 2. *3D design of the serving robot with two tray*

The numberings in Figure 2 are described below:

- 1, 2 are the wheels driving robot.
- 3, 4 are the robot motors.
- 5, 6 are the Robot direction wheel.
- 7 is the bearing.
- 8 is the couplings.
- 9, 10 are the base and body of the robot.
- 11, 12 are the food trays.
- 13 is the control panel.
- 14 is the LCD display.
- 15 is for mounting smart tablet.

Table 1. *Robot Specifications*

Number	Description	Specification
1	Weight of robot	20 [Kg]
2	Motor power	35 [W]
3	Diameter of drive wheel	120 [mm]
4	Maximum speed	0.15 [m/s]
5	Maximum weight (with food)	30 [Kg]
6	Maximum operation time	12 [hours]
7	Height of the robot	1.3 [m]

Choosing motor

Assuming the total mass of the robot and the foods are loaded on the four wheels of the robot.

• The power produced by the torque caused by the rolling resistance force is calculated as follows:

$$P_{ms} = F_c \times v \times k = m \times g \times f_{ms} \times v \times k$$
$$= 20 \times 9.8 \times 0.4 \times 0.15 \times 2 = 23.52 \text{ (W)} \quad (1)$$

Where:

- P_{ms}: power caused by resistance force;
- F_c: resistance;
- v: robot speed;
- m: robot mass;
- g: gravity coefficient;
- f_{ms}: coefficient of rolling resistance (selected 0.4);
- k: safety factor (selected as 2).

Therefore, the actual power needed is.

$$P_{tt} = \frac{P_{ms}}{\eta_1} = \frac{23.52}{0.99} = 23.57(\text{W}) \quad (2)$$

• From calculation above, the motor is selected as shown in Figure 3 with the following specifications:

- Power consumption: 12VDC;
- Motor power: 30W;
- Speed of rotation: 120 v / p;
- Weight: 550g.

Figure 3. *Main motor of the robot*

3. Controller design and programming

The overall configuration of the robot controller is shown in Figure 4. The author uses two microcontrollers

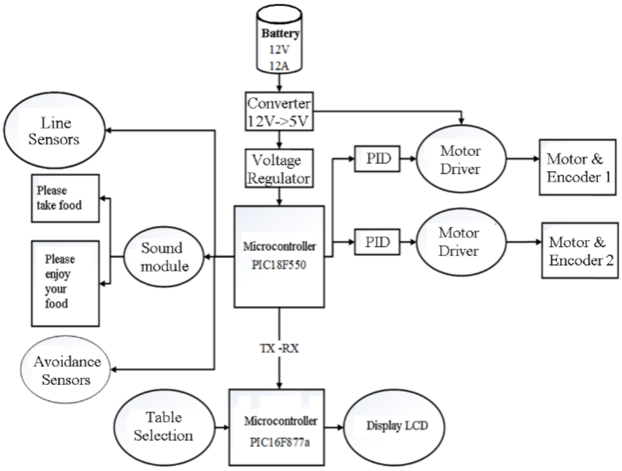

Figure 4. Configuration of the robot controller

for controlling the robots. The PIC18F550 is for controlling the motors and operations of the robot while the PIC 16F877A is for selecting table and LCD display control. The power source is the battery 12V-12A which is regulated into 12V-5A using LM2596 chip and 5V-2A using LM2576 chip. The 12V-5A is for driving the motors via two motor drivers while the 5V is for operating the two microcontrollers. The line follower sensor and avoidance sensor are connected to the PIC18F550. The sound module with speaker is also connected to PIC18F550 for outputting greeting sound. The PIC16F877A is for controlling the mapping data of the tables in the restaurant and navigating the robot to the designed table. The LCD display module is also controlled by PIC16F877A microcontroller. The list of modules of the robot is shown below:

• **Central processing unit**: The robot employes aPic18F4550 microcontroller. It performs the function of receiving and processing data from sensor blocks, RF receiver blocks, signal processing blocks for PID control of the robot.

• **Table selection block and display**: Select the working mode of taking order or delivering food to table. Select the speaking language of English/ Korean/ Vietnamese. Show operation status.

• **Sensors**: Read and send data to the center microcontroller to process and follow the line.

• **Motor Driver Block**: The team designed and created a driver to control a large 30A motor. The driver receives signals from the central processor block for opening and closing as well as sending PWM signal to run the motors.

• **Power Unit**: A 12V-12Ah battery power supply is used for the whole system.

• **Battery Charger**: A 12V-20A rechargeable battery circuit allows the battery to be fully charged within 5 hours.

•**Audio block**: Used to communicate with customers by voice in three different languages.

The program of the main microcontroller PIC18F550 is represented by a block diagram as shown in Figure 5.

The main microcontroller PIC18F550 is responsible for receiving signals from the PIC16F877A microcontroller via the UART port to receive data on the table, client, service or order. After receiving the data from the line sensor and detecting obstacles sensor, the main microcontroller processes and helps the robot stick to the line to move to the designed table and avoid collisions. PID controller is applied to smoothly move the robot so the food would not slip out the plate. For the convenience of restaurant service, the team also install a set of RF transceiver modules to remotely control the returning to the original position after the robot completes its task. The program of the microcontroller PIC16F877A is shown in a block diagram as shown in Figure 6.

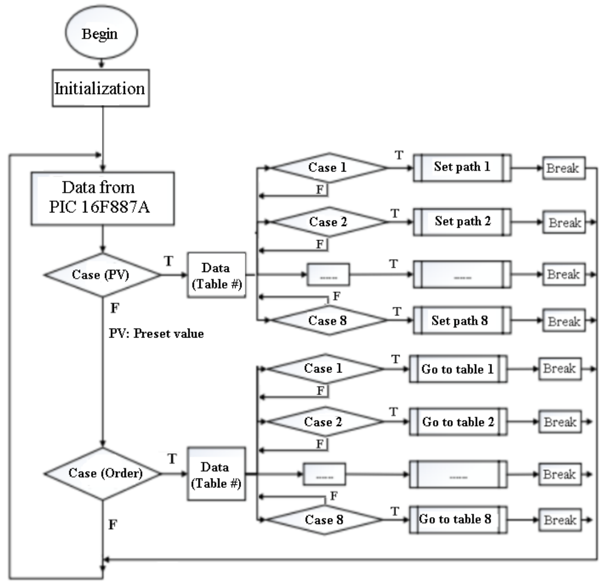

Figure 5. Block diagram of main microcontroller PIC18F550

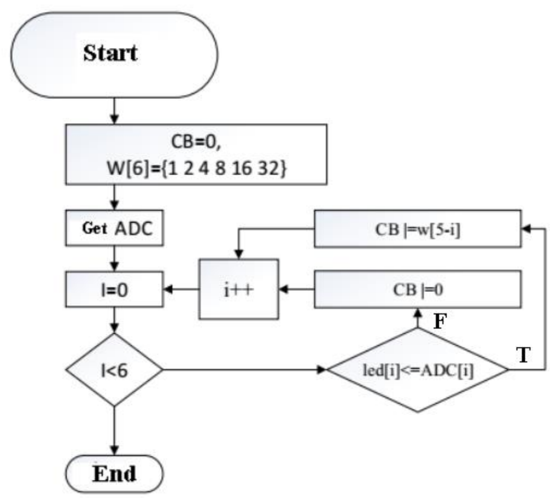

Figure 6. Block diagram of main microcontroller PIC18F550

At the beginning of the program, the CB variable is fed back to 0, then the program proceeds to read all inputs from the sensor. After reading, these values are taken in turn and compared to the sample ADC. If the ADC value of this sensor is less than the sample ADC value then the program will decide it is the white line and the corresponding bit in the CB variable will be raised to 1 for the bit operation (CB | = w [5-i]).

The array w [6] will consist of the elements: {1, 2, 4, 8, 16, 32}.

For example: The outermost LED on the left (i = 0) touches the line corresponding to position R7 when:

Comparison L [0] <ADC [0] should perform the operation:

CB = = in [7-i]. CB = CB | 32

CB = 0 | 100000 = 100,000

CB = 100000 = 32. (R7)

Thus, the bit corresponding to the leftmost LED has been raised to level 1. This whole process takes only 276µs. Figure 7 shows an example of line following method that is described above.

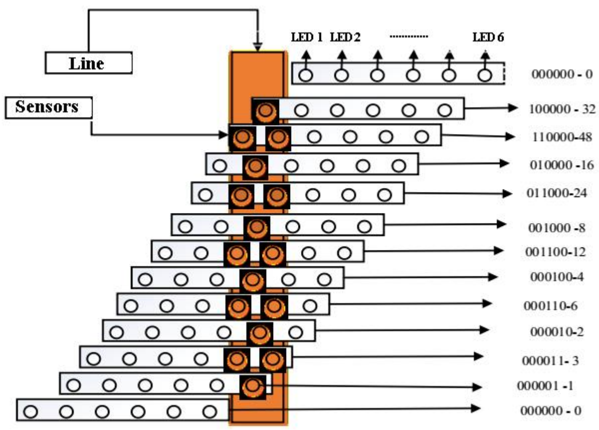

Figure 7. *Block diagram of main microcontroller PIC18F550*

4. Conclusion and discussion

We have successfully built the robot as shown in Figure 8. The results of the research, design and manufacture of robots are as follows:

• We have designed and manufactured the actual robot model to bring food to customers. However, the appearance of the robot is not completed because it will be painted and decorated according to the customer requirement. For this study, we only show the basic model of the robot.

• The robot can move stably and accurately to the table without having food or drink spilled out.

• Mechanical structure is robust, easy to assemble and transport.

• The robot has a solid structure, stable travel speed.

The future research orientations are as follows:

• Adding audio processing functions to communicate with and is able to answer question from customers.

• Adding cameras to identify regular customer for menu recommendation, and count the amount of food served per day.

• Providing robotic arm that can be manipulated to give verbal communication with customer such as waiving or shaking hand.

Figure 8. *Actual robot in operation*

Although the robot has been successfully built and tested, there are some limits for this system. First of all, the wheel of the robot is small so when moving to a bumper on the floor it may cause food spilling. Secondly, the movement of the robot when turning is not very smooth due to lack of algorithm controller for tuning action; therefore, the robot movement algorithm needs some extra implementation. However, this is serious work that has big potential application in reality especially at restaurants of a tourist city like Da Nang.

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REFERENCES

[1] Information on https://news.zing.vn/robot-200-trieu-dong-thay-nhan-vien-phuc-vu-o-quan-ca-phe-ha-noi-post804012.html (assessed on Oct, 2018)

[2] Tran Quoc Cuong, Tran Thanh Phong, Speed Control of Dc Motor By PWM Method Using Microcontroller. *Journal of Science, Tien Giang University*, May, 2012.

[3] John A. Shaw, The PID Control Algorithm: How it works, how to tune it, and how to use it, 2nd Edition, *Process Control Solutions*, Dec 2003.

[4] Pakdaman, M., Design and Implementation of Line Follower Robot, *Tabari Inst. of Babol, Iran*, page(s): 585, Conference Location: Dubai, Dec, 2009.

[5] WAN ROBAAH BINTI W AHMAD, A DC Motor Controller Using PID Algorithm Implementation on PIC, *Faculty of Electrical & Electronics Engineering, University Malaysia Pahang*, Nov, 2008.

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