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Low-Cost Autonomous MicroRobot for Quick Navigation

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ABSTRACT

The paper presents the design and development of an autonomous micro-robot that has the capability to avoid obstacle and to navigate from source point to destination point. The prototype is built with micro controller, reflective sensors, motor driver and specific components. PIC programmer has been used to load the micro controller. The navigation platform is a maze composed of 3 x 3 blocks with 5 control points. The movement's directions include forward, turn left and turn right. The robot will provide light indicator once it reaches the final destination or after passing the last control point. The development cost of the micro robot is approximately One Thousand Pesos.

KEYWORDS: Robotics; Mechatronics; Navigation; Reflective sensors

1 INTRODUCTION

Autonomous robots place special demands on their mobility system because of the unstructured and highly varied environment it might drive through [1]. The fact that even the best sensors are poor in comparison to human's ability to see, feel and balance it is a great challenge to develop one that can function equivalent to what it must perform. In addition to the ability of the android or machine is the size that is oftentimes is directly proportional to the cost of production. Thus, having a smaller size means having less production expenses. Developing a small robot that can navigate will start a new evolution in automation.

Autonomous agents are mobile versatile machines capable of interacting with the environment and executing variety of tasks in unpredictable conditions. Autonomy is the capability of navigating the environment. Navigation relies on the topological and metric description of the environment [3]. One of the major components for the creation of autonomous robot is the ability of the robot to *"plan its path"* and in general the ability to *"plan its motion"*. In a limited or carefully engineered environment, it is possible to program the robot for all possible combinations of motions in order to accomplish specific task. The problem of path planning is not confined to the field of robotics, but its applications exist in various genres [3].

A micro robot contains several essences in various technical fields such as MEMS, Micro Assembling, Actuators, Sensors and Micro Computer. The International Micro Robot Maze Contest (MAZE) has been held for 13 years in Nagoya, which is in parallel with the International Symposium on Micro Mechatronics and Human Science (MHS) [2]. It was established in order to promote the related technique

of micro robotics in 1991. Since then, various robots have exhibited their performance and unique mechanisms in MAZE [4].
The proponents present the design and development of a robot for 23rd International Micro Robot Maze Contest 2014. The micro robot is fully autonomous while navigating and solving the maze.

2 CONTROL STRATEGY

Maze Solving Robot, which is also called "Micro-Mouse Robot", is one of the most popular autonomous robots. It is a small self-reliant robot that can solve a maze from a known starting position to the centre area of the maze in the shortest possible time. This robot attracted people from all phases of life. Micro-Mouse Competitions have been taken a place for about three (3) decades. There are many algorithms and techniques that have been discovered and used to solve the maze [7]. A common example is shown in *Figure 1*.

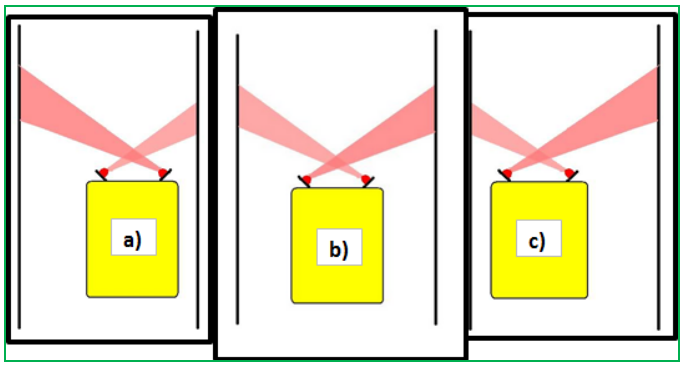

Figure 1: One-stage local feedback control strategy

2.1 Contest Rules

The International Micro Robot Maze Contest (MAZE) has been held for 13 years in Nagoya, which is in parallel with the International Symposium on Micro Mechatronics and Human Science (MHS). Through the robot contest, exchange of thoughts and ideas with regard to technological innovation in micro machines and micromechanics is expected. The MAZE spearheads five (5) types of competitions [5]:
1. Category 0: Micro Robot Racer by 1 cm cube robot
2. Category 1: Tele operated Micro Robot Maze by 1 cm cube robot
3. Category 2: Autonomous Micro Robot Maze by 1 inch cube robot
4. Category 3: Legged Micro Robot
5. Category 4: Free Performance by Micro Robot

In this study, the micro robot was designed and developed for Category 2a competition. Robot was made at the less than 25.4mm x 25.4mm x 25.4mm in dimension. Antennas or other interface device are not included in this restriction. The robot is categorized into Fully Autonomous Controlled Robots.
Category 2a: Fully Autonomous Micro Robot Maze
All robots must contain all devices including the battery and control units inside its body. During trial, you cannot touch the robot and cannot operate your robot by any ways.
Competition - Compete in the time from Start point to Goal point through five points settled in the maze on the flat ground.
Contest Ground - The material of this ground is an aluminum alloy to avoid electrostatic charge and its surface is finished with fine aventurine so that machine should not slip.

Trial - Trial must be finished within 3 minutes. The trial can be challenged again if the trial time is remained.
Foul Play - The following actions are authorized the Foul Play: (1) Touching robot in the trial, (2) Energy supply cable etc. move the robot in the trial, (3) Movement or vibration done by the contestant in the contest ground or desk by body etc. or (4) Special cases authorized by judges.
Penalty - 5 second penalty per a foul play mentioned above will be added to trial time.
The micro robot will automatically change its direction at an intersection of the maze; the global feedback from the human operator is then eliminated.

2.2 The Maze

As part of the contest rule, the robots will have to compete in the time from Start to Goal point through five points settled in the maze on the flat ground. The material of the contest ground is an aluminum alloy to avoid electrostatic discharge and its surface is finished with fine aventurine, so that the machine will not slip.
A test maze is essential to fine tune all various algorithms and control routines when making a micro mouse. In this study, the proponents used a 5x5 maze as shown in figure 2-3 as patterns indicated in the contest rule.

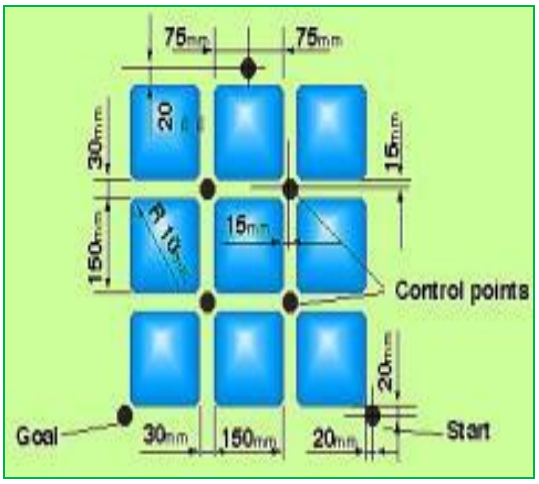

Figure 2: 5x5 Test maze design


Figure 3: Test maze prototype

2.3 Maze Solving Algorithms

Solving mazes has been studied for years and years in mathematics, which means there are too many algorithms to study with. An algorithm is a set of instructions that, when carried out, produce a certain result. The result in our case is a route to the target destination of the maze (from start point to goal point as shown in *Figure 2*).
The robot is required to pass all five control points in the maze. The designed path of the robot is shown in Figure 2 indicated by the direction of the arrows. From the start point, the robot must be in the position such that it is facing the goal point. The following is the pseudo code of the algorithm to traverse the desired path.

1. initialize counter =0 // counter counts the
   // number of junction
2. Follow the right wall
   While (counter != 8){
   {
   when it senses a junction
   increment counter
   switch (counter)
   {
   case 0: turn right; break;
   case 1: go straight ; break;
   case 2: go straight ; break;
   case 3 : go straight; break;
   case 4: turn left and follow left wall; break;
   case 5: turn left and go straight; break;
   case 6: go straight; break;
   case 7: go straight; break;
   case 8: turn right and follow the right wall;
   }
}

The path direction is clearly illustrated in Figure 4.

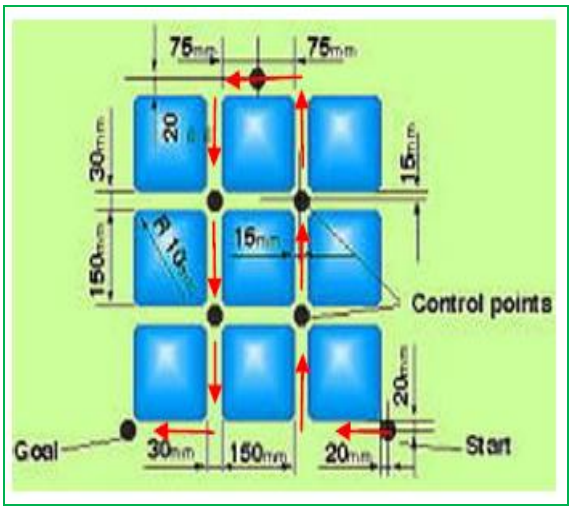

Figure 4: Algorithm Path Direction

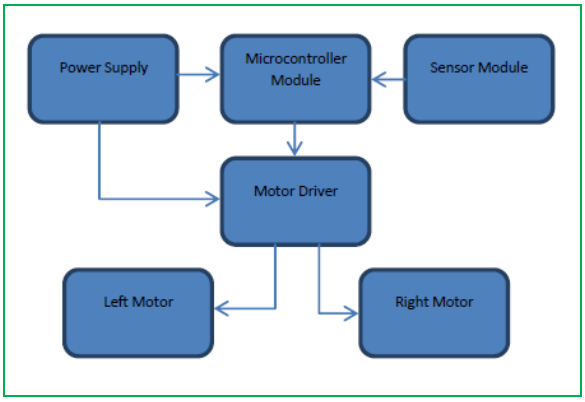

Figure 5: Hardware system block diagram

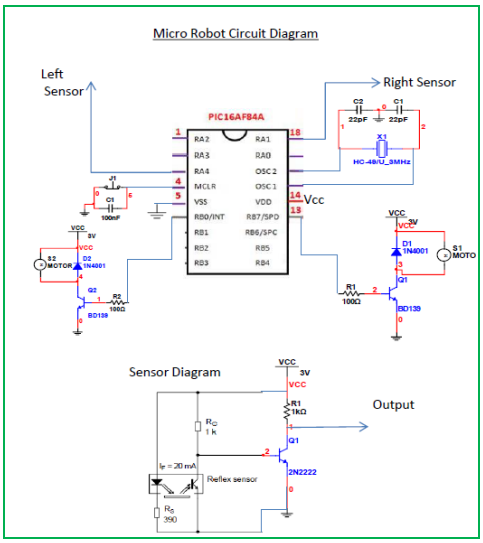

Figure 6: Hardware system schematic diagram

3. HARDWARE DESIGN & DEVELOPMENT

The design was made simple to minimize the cost but achieving the intended function. The overall design is illustrated in *Figure 4. Hardware system block diagram and Figure 5. Hardware system Schematic diagram.*

The power supply will come from the 3-V CR2032 battery as shown in *Figure 6*. The microcontroller module provides the control system of the robot. This contained PIC16F84A microcontroller (*Figure 7*), 4MHz crystal oscillator (*Figure 9*) and 22pF capacitor (*Figure 10*). The sensor module tells the robot when to stop, move forward, left or right. It was formed by CNY70 reflective sensor (*Figure 11*), CN2222 transistor and 1K-Ohm resistor. The motor driver with left and right motor are composed of

2N2222 transistor, 1N4001 diode, 100-Ohm Resistor and DC motor. This provides the moving mechanism for the robot to maneuver.

Figure 7: 3v CR2032 Battery

Figure 8: PIC16F84A Microcontroller

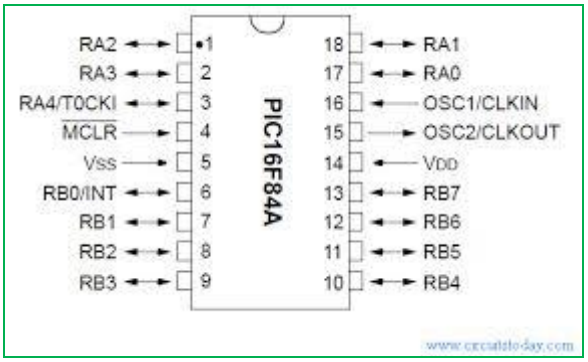

Figure 9: PIC16F84A Microcontroller PIN configuration

Figure 10: 4MHz Crystal Oscillator

Figure 11: Capacitor: 22pF ceramic capacitor

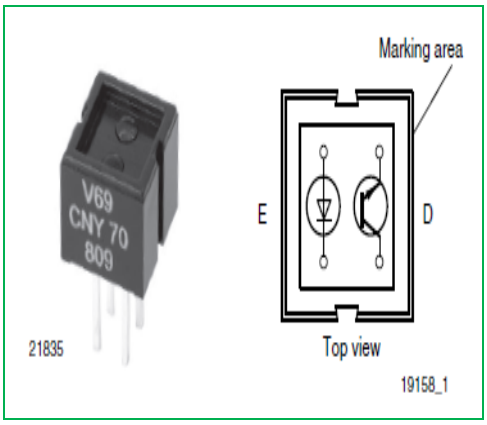

Figure 12: CNY70 Reflective Sensor

3.1 Chassis

The robot is a 1X1 structure with plastic metal and 2-small toy car wheel. The prototype is shown in Figure 13.

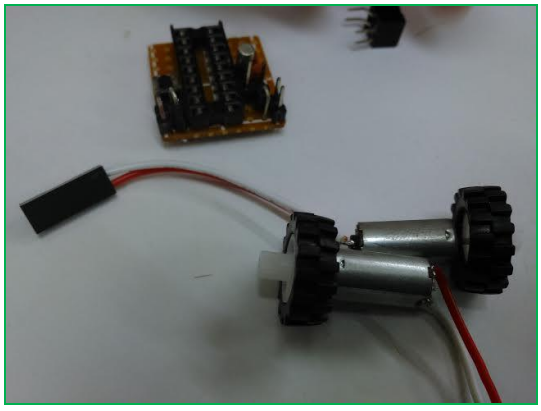

Figure 13: Robot Prototype

Table 2 Parts/Components Cost Listing

	Item	Description	Cost(PhP)
	PIC16F84A	Microcontroller	159.00
	CR2032	Battery/Power supply	113.00
	Other Parts & Electronic (Capacitor, Transistor, Resistor, diode)	Chassis parts & other electronics	212.00

The cost excludes transportation and other related or miscellaneous expenses.

4. CONCLUSIONS

The proponents were able to design and develop a micro mobile robot that falls within the given constraints: small, has on-board energy source and can fulfill the given tasks. Furthermore, it was found out that it does not require spending more in developing an autonomous robot that navigates and solve a maze. As shown in *Table 2*, the proponents spent less than 1000PhP for parts and components.

5. ACKNOWLEDGEMENTS

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