International Journal of Computer Applications (0975 – 8887)
Volume 184– No.26, August 2022

An Optimized Path-Planning Concept for a Micro-Mouse Robot for Autonomous Applications in Terrained Environments

Sindhusree M.
Research Scholar (VTU Campus), Muddenahalli & Assistant Prof., Dept. of ECE, DSCE, Bangalore

Aishwarya N.
Assistant Professor, Dept. of E & CE, DSCE, Bangalore, Karnataka

Aditya T.B.
Undergraduate Student of Second Semester, Dept. of Computer Science & Engg., PES University, Bangalore

Pavithra G., PhD
Associate Prof., Dept. of Electronics & Communication Engg., Dayananda Sagar College of Engg., Bangalore

T.C. Manjunath, PhD
Ph.D. (IIT Bombay), Fellow IETE, Fellow IE, Chartered Engineer, Sr. Member IEEE
Professor & Head of the Dept. of Electronics & Communication Engg., Dayananda Sagar College of Engg., Shavigemalleshwara Hills, Kumaraswamy Layout, Bangalore, Karnataka, India

ABSTRACT
The design, manufacture, and implementation of a micro-mouse robot controlled by a microcontroller are discussed in this study. Micro mice is a mobile robot that has been developed & is being done programmed to go thro' a maze like structure by learning the way. The goal of the research was designing & building a small path following mechanism to help with the construction of a moving object tracking system. The design and construction of the micro-mouse was the first stage of the project. To give a load torque, electric motors have been incorporated. The electronics were tackled next, and were controlled by the Micro-mouse microcontroller in order to transmit and receive positioning information in order to enable tracking. The communication is carried out via the RF Transmitter and Receiver module. The majority of the torque-related development work has been accomplished. The project was a success in general, and all of the design concepts were proven. Further changes / tweaks are suggested to perfect the tracking of the process & a realistic future expansion to the work that could be for developing it to become a perfect model from the practical implementation standpoint.

General Terms
Algorithms, Micro mouse Robot, Paths, Plan, Micro controller

Keywords
Drivers, Stepper Motor, Simulation, Application, Environment, terrains.

1. INTRODUCTION
This research looks at the design, construction, and implementation of a micro-mouse robot that is controlled by a microcontroller. Micro-mouse is a mobile robot that has been designed and programmed to learn how to navigate around a maze. The project's purpose was to design and construct a modest path following mechanism to aid in for developing of a mobile object tracking system. The micro-design mouse's and construction was the first stage of the project. Electrical devices (motor) has been used for providing very good load torque to the system for movement in all the 8 possible directions. The next step was to tackle the electronics, which were controlled by the Micro-mouse microcontroller in order to transmit and receive positional data and enable tracking. The RF Transmitter and Receiver module is used for communication. The majority of torque-related research and development has been completed. In general, the research work done was a tremendous success & all of the conceptual designs were tested. More improvements and tweaks are suggested to improve the tracking, and a future expansion of the work can be to perfect it from a practicality point of view from the implementation aspects in the RT environment [1].

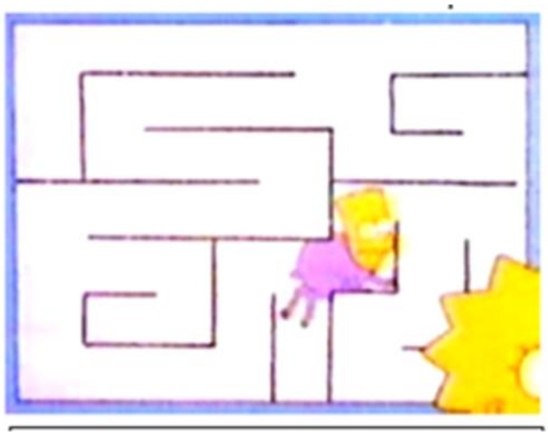

Fig. 1. Route taken by the micromouse to move from s to d

2. TYPICAL EXAMPLE OF
Micro mice was a little moving robot that can be navigated thro' a maze. Two micro-mices was designed in this project. The 1st mouse was quickly exploring the maze scenario & understand the way before departing from a defined maze area. The 2nd working mice was fastly learning the mice's courses quickly and then move from a specific maze corner to capture the first micro mouse as quickly as possible. A motor driven module,

which comprises of two motors driven wheels, an micro-controller board, which consists of a microprocessor, external RAM (required) & the devices to drive the motors & lastly a motor controlling board, use to drive the motors, make up the standard Micro mouse. A control method to do the steering of the Micro mouse and allow the Micro mouse for sensing the position & is designed once the Micro mouse has been manufactured. After that, a second control algorithm is to be created so that the maze problem could be solved systematically by the mice. Certain Micro mouse parameters must be measured or retrieved from the Micro mouse hardware as part of the creation of these algorithms. These are calculated by capturing measurements from the Micro mouse while it is run through the maze area. Mechanical, & Electronics & Software design and development are required for the project. The design and fabrication of a mechanical structure for the Micro mouse is the first step toward the completion of the project. The electronics, as well as an interface with the mechanical components, are then built to provide control and communication. The software design is the project's final component. To interpret and control the electronics, a programme is built [2].

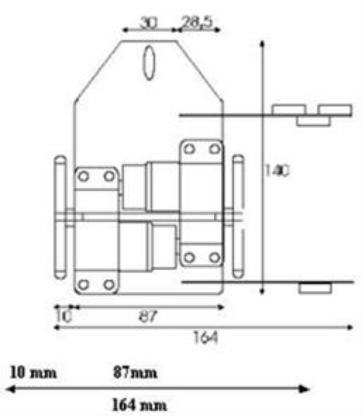

Fig. 2. Top view of the micro-mouse (plan view)

3. OBJECTIVE

The project's goal was to create a automated module that could track a mobile object & follow it, and eventually or catching up with the predecessor mice (1st one). Two micromouse are used to make the prototype in this case. The first micromouse is an item that moves freely. The first micromouse sends information about where it is right now. This information is recorded by the second micromouse, which then follows the first on the most appropriate path. The trail, which is traced by the two micromouses, is built in the shape of a maze. The following is a diagram of the proto type of the maze schematic area of the layout as shown in the Fig. No. 1 [3].

4. PHYSICAL DIMENSIONS

In this section, the physical dimensions of the designed & fabricated micro mouse is presented in a nut shell. The maze measures 72 × 72 cm in size and is DIVIDED into 16 cell area, each measuring 18 by 18 cms. Then, the maze route is 16.2 cm width in area with extra wall of thickness differing by 1.8 cm, making it 18 cm width with wall like structure, according to typical maze construction. The overall length of the Micromice is 18 x 22 cm, while the sensor is 18 x 18 cm. Over the micro mice, the sensor circuitry [26] is embedded or fixed onto it so that to make it more compact. The wheels are made of lightweight metals such as aluminium. The diameter of the wheel is 4.2 cm since the circumference is 13 cm [4].

5. IDEAS FOR THE CONSTRUCTION

Here, the ideas for the construction process of the micro mouse is presented in brief. It is feasible to design the micromouse in two completely distinct methods. The traditional analogue technique, which uses comparators and analogue motor control, is one option. The second method, the digital method, can be implemented using either digital logic devices or a microprocessor. The advantage of utilising a microprocessor is that it is simple and convenient to adapt the software for different works & to boost overall speeds w/o changing the h/w or s/w or using a trial & error methodology with a lot of resistive devices which could vary its resistance (Potmeters) [5].

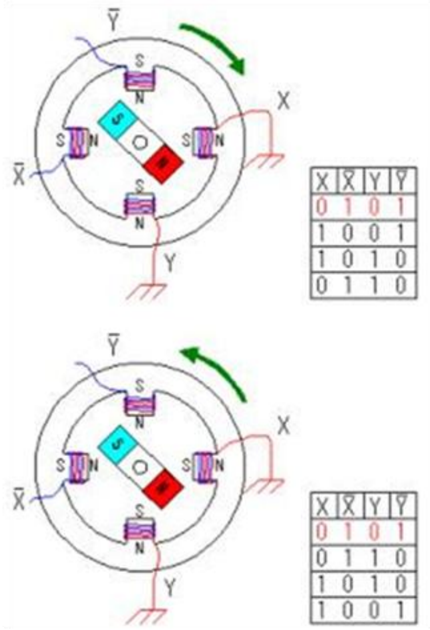

Fig. 3.A stepper motor (CW/CCW) that we employed in our research.

As a result, we utilised a microcontroller, which is extremely fast in operation and simple to programme due to its limited instruction set. Because the data and address buses are totally segregated in the hardware architecture, one instruction can be executed in only one processor cycle. The microcontroller's I/P and O/P are also relatively simple to utilise as they could be accessed direct by the application problem. The motors will be controlled by 2-1/2 bridges, each of which has two logic levels MOSFETs, one to run the motor & the other one for applying the brakes to the motor to stop the mice for colliding with the obstacles [6].

The Transistor devices are capable of high voltages and currents and can be directly operated by CMOS-Logic devices. During the design phase, it was decided that driving backwards was unnecessary. Pulsed infrared sensors will be employed for wall detection. The pulse application of the sensor [26] greatly improves their sensing distance & eliminates the need for variable resistors. It has been put a lot of hard work to make the micro mouse as small & very much light, so that it could spin and run between the maze's walls. Weight loss allows you to move around more freely. The top view of the developed and fabricated micro mouse is displayed in the Figure 2 [7].

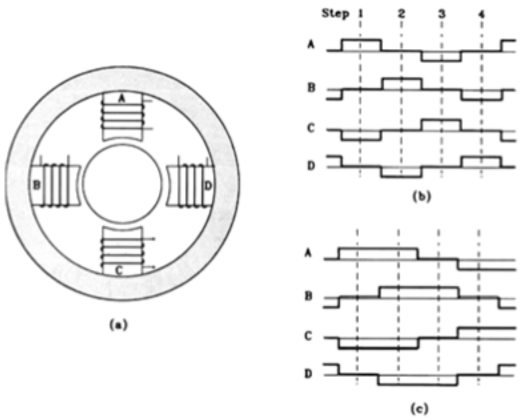

Fig. 4.(a) Permanent Mag stepper motor drive, (b) 90-step, and (c) 45-step.

6. CONSTUCTION OF MECHANICAL SYSTEM OF THE MICRO-MOUSE

The construction of the mechanical part of the mouse is presented in this section. The gearboxes are put as close together as possible in order for reducing the chassis size area, as seen in the diagram below. Everything on the chassis was positioned in such that the mice could go as near as to the maze walls w.r.t. the ground scenario avoiding the obstacles as possible in order to lower the centre of gravity. The sensor arms are made of epoxy materials (the same components as used for the chassis) & is being done soldered with the plate ground so that it will not move and be stable in order to keep the overall weight down. A fabric hanger was utilised in place of the ball bearing we had previously used. Because the micro mouse's front weight was lowered, the micro mouse was able to steer more easily [8].

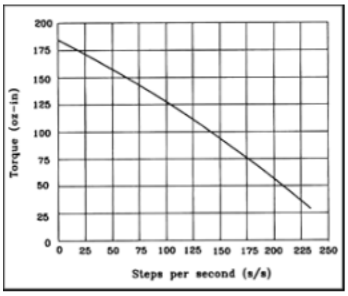

Fig. 5. Torque characteristics of the stepper motor

7. STEPPER MOTOR USAGE IN WORK

A stepper, often known as a stepping motor, is a device that convert electrical pulse into proportional mechanical movements. The shaft of the stepper is developed with a number of discrete unique steps for each revolution. A step is the angular rotation performed by the output shaft each time the motor receives a step pulse. These motors are particularly helpful in digital control circuits, including such as robotics, because they are well-suited to accepting digital pulses for step control. The shaft rotates by a specific number of degrees with each step or rotation [9].

The rotation of the output shaft that is caused by each step is represented by a step angle, which is measured in degree. A simple use for a stepper motor is shown in the diagram below. The paper is driven a specified amount of distance every time the controller gets an input signal. Stepper motors are widely used in m/c tool, process controlled system, tapes & disc drive systems, and programmable controllers, in addition to the paper driven mechanism in printers. Permanent magnet (PM) and variable reluctance stepper motors are the most common types (VR) [10].

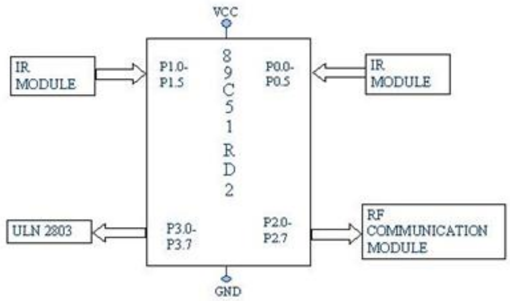

Fig. 6. Electronic circuit block diagram

The diagram above depicts a permanent magnet stepper motor with 4 stator winding. By pulsing the stator coils in a specific order, the motor's speed and direction can be controlled. Figure 1 shows the timing diagram for the pulses required to rotate the PM stepper motor (b). The motor shaft rotates counterclockwise in 90° increments as a result of this sequential direction of +Ve& -ve pulses. The waveforms in Figure below shows that the pulses could be done in a overlapping manner & the motor could be rotated at 45° intervals counterclockwise. By supplying pulses to either the clockwise or counterclockwise driving circuits, the direction of rotation can be determined. With each subsequent pulse, the rotor displacement can be precisely replicated. Stepping motors are often run without feedback, which greatly simplifies the control circuit. One of the most common stepper motor drive circuits is the unipolar drive, as shown in Figure. This circuit, which uses bifilar windings and four Darlington transistors, controls the motor's rotational direction and stepping rate.The Fig. 5 shows the torque characteristic of the motors that was employed in our work [11].

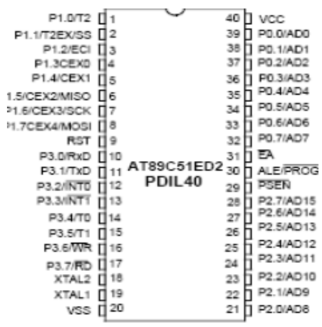

Fig. 7.Pin diagram of microcontroller

8. BLOCK DIAGARM

The Fig. No. 6 shows the electronical circuitry with the block diagrammatic representation of the system developed in this project work [12].

- Port 0 can be connected to the IR sensing unit module via the Schmitt triggering circuit 74HCT14, which can be utilised for TTL mode of compatibility, as indicated in the block diagram.
- The IR sensor module is also connected to Port 1 via the Schmitt trigger.
- The RF communication module is attached to Port 2.

- The Stepper Motor is connected to Port 3 via the ULN2803, which serves as a current booster.
- Components List
- 74HCT14 Schimtt Triger – (4 in number)
- Module for Infrared Sensors - (24 in number)
- Module Transmitter - (24 in number)
- Stepper Motor (MACT) – 1K and 5K resistances (2 in number)
- A 9-volt battery is a battery with a voltage of 9 volts.

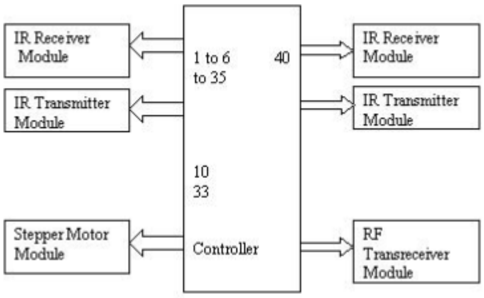

Fig. 8.System's overall electronic & control block picture

9. MICRO-MICE PIN DIAGRAMS

We use a microcontroller, the 89C51RD2, to control the micro mice, 1 for every micro mice displayed in the maze solving problem. The 89C51RD2 could be a CMOS flashed version of the 80C51 CMOS solo chip 8 bit micro controller with outstanding performance. For code and data, it has a 64 kb of flash memory's block. With the ISP capabilities or software, the 64kb flash memory can be programmed in serial mode or in parallel mode. The programmed volts can be generated internally using the supply voltage of the Vcc pins. The following are the characteristics of 89C51 [13]:

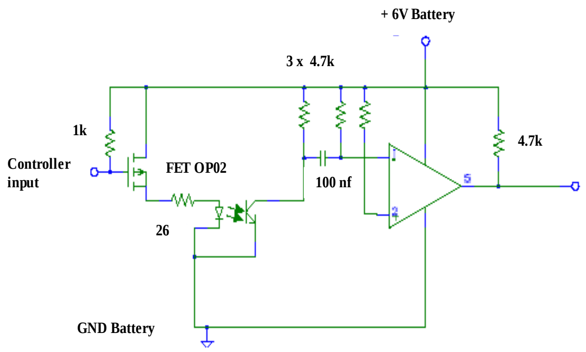

Fig. 9.Schematic diagram of a single sensor stage circuitry

- I/O ports that are 4 bit parallel.
- Scratch pad RAM of 256 bytes
- XRAM with an enhanced size of 1792 bytes
- EEPROM with a capacity of 2K bytes
- 9 interrupts, each with a different priority level
- Watchdog timer is a device that allows you to keep track of how long your dog
- 3 16-bit counters and timers
- Power controlling mode : Idling mode or the Power Downed modes in the in-system programming facility (ISP)

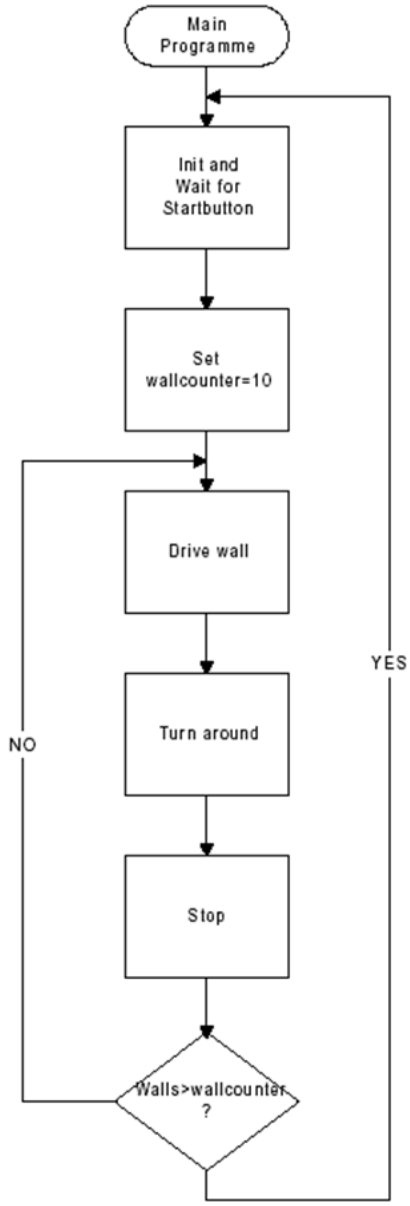

Fig. 10.Obstacle detection software algorithm

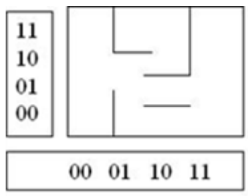

Fig. 11.The maze problems in digital form of control

We are using all four of the controller's ports here, which is displayed in the following paragraphs [14].

- External crystals are attached to pin no. 19 & 18 for programming
- Pin nos. 11 & 10 are utilized to programme the controllers in a serial mode into the flashed RAM, which could be of normally 64 kilo bytes.
- For resetting the micro mice system, a high voltage of TTL could be given to the pin 9 of the MCU.

- On-Off keyed modulation is used in this module, which is based on a crystal tuned PLL.
- PLL is used to create the Local Oscillator.
- The module is high-performance, easy-to-use, and small.

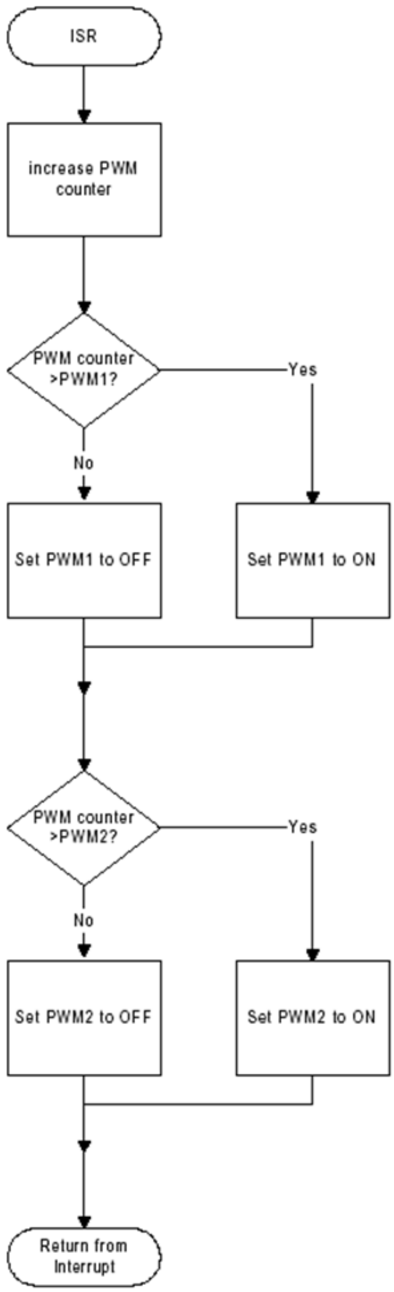

Fig. 12.An software algorithm for controlling motors using PWM.

10. SCHMITT TRIGGER

It removes noise while providing TTL compatibility. It has Schmitt trigger operation and 6 inverting buffers. They can convert gradually changing input signals into precisely defined, o/p free undistorted signals. It's a current amplifying system IC, the ULN2803. Stepper motors must have a current rating of 0.7 ampere per phase. A single ULN can provide current ratings ranging from.22 to.28 amperes. As a result, three ULNs are stacked one on top of the other to provide the required is 7 amprating. The ULN2803 is a low-cost, 18-pin IC that provides current stability [15].

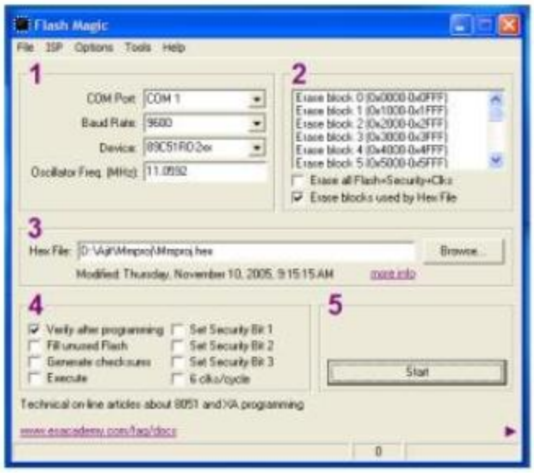

Fig. 13.A Flash / Keil graphical user interface

Captions should be Times New Roman 9-point bold. They should be numbered (e.g., “Table 1” or “Figure 2”), please note that the word for Table and Figure are spelled out. Figure's captions should be centered beneath the image or picture, and Table captions should be centered above the table body [16].

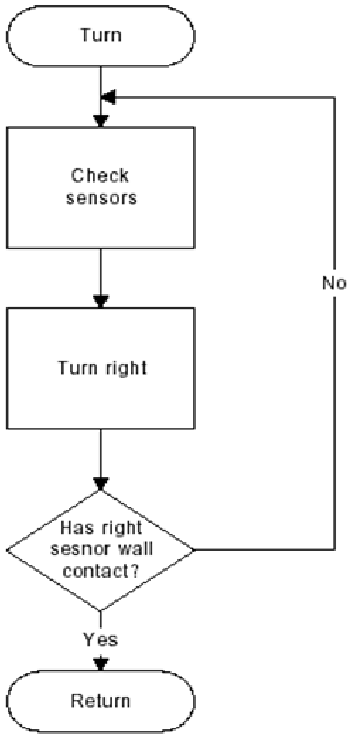

Fig. 14.Software algorithm for left/right turning

11. PCB LAYOUT & CIRCUIT DIAG

Here, we present the PCB layout & the overall circuit diagram of the project [17].

12. SENSORS

The electronic circuit to control one particular sensor module is shown above. The MOSFET pulses the IR-Diode (small duration pulses are given). The comparator's i/p LM339 (extremely large stability of the current & operating as a comparting unit) could be grounded or ground pulled, when the infra red based sensing unit could detect the light which is reflected (which could signify a wall or a obstacle), and a high impulse happens at the comparator's output. DC and low-frequency signals are blocked by the 100nF coupling capacitor. As a result, ambient light has no effect. We're working with standard anode sensors. Infrared sensors are what these are. TSOP series IR DIODES is the no. of infra red sensors. The infra-red sensor's volts rating is 3.3 volts. We utilise these sensors since they are inexpensive and have good sensitivity. Actually, we require precision rather than range, hence the sensor should not detect anything beyond a range of 2.5cm [18].

12.1 SENSOR ARRANGEMENTS

- One micromice contains 12 sensors.
- Five for the left stepper motor and five for the right stepper motor are on the front side.
- The middle sensor, out of the five, is utilised to turn right or left.
- Aside from the centre sensor, the other two sensors are utilised to control the straight.
- The two extreme sensors are utilised for corner point detection and are generally not used.

12.2 COMMUNICATION MODULE

A Crystal Tuned PLL Based ASK Module is used to communicate between the two mice [19].

13. SOFTWARE DEVELOPMENT

The vehicle's software must be capable of driving the mouse straight ahead as well as turning right around the corner. The software must control the motors in an appropriate manner in order to drive straight ahead. As a result, for each wheel, a P-W-M (Pulse Width based Modulated Concept) with an high resolution of 64 bits could be devised. The programme must examine sensing units for operating the mice car by identifying the presence of wall as the obstacle. The outputs & the inputs are established during the initialization.

All of the necessary variables are also setup or clear & the P-W-M based Interrupted Service based Sub-Routine or the ISR is initiated. The programme then wait for the starting buttons (the controller's i/p pin RA-2) which has to be pressed to generate a signal. Then, finally, the micro controller directs the car close to the obstacle or the wall until none of the sensors will detects the wall and thus avoid the collision of the obstacle with the mice system. Then, the turning function is then invoked, and the wall - counter is reduced by one. The mouse comes to a halt, and if not all of the walls have been completed, the mouse moves on to the next straight driving phase [20].

14. MAIN PROGRAM WITH SUB-ROUTINES

The Main Program -

- Change the value of the wallcounter to ten.
- Climb the wall
- Walls>wallcounter? 4. Turn around
- YES - Init and wait for the Start button to appear
- NO - Do not continue.
- STEPS FOR THE ISR FOR THE PWM
- ISR raises the PWM counter

What is the difference between a PWM counter and a PWM1?

- Yes, turn PWM1 on.
- Set PWM1 to OFF if you don't want to use it.
- Is there a difference between PWM1 and PWM2?
- Set PWM2 to ON if you want to use it.
- Set PWM2 to OFF if you don't want to use it.
- Get back on track after the interruption

When a timer overflows, the ISR is triggered. A helpful counters are initially increasing in nature (high). The I-S-R (sub-routine) will determines whether the P-W-M desired value is greater than or < the helpful counter. If the intended PWM value is less than that, the relevant P-W-M o/p's are set for low values (TTL low), other wise it could be set to a high value (TTL high). Each time the sub routine is called, the timer must be reset. The diagram above depicts how the PWM truly works in an elegant manner. The bits Q1 through Q4 correspond to the PWM helping counter's equivalent bits. The ISR compares these to the intended PWM and, depending on the outcome of the comparison, switches the outputs high or low. Driving along the wall – here, the mouse must either travel straight or turn left or right, depending on the sensors. A modified bang-bang mechanism serves as the control algorithm. There are five stages in total [21]:

- Stage 1: only the middle sensor is in contact - go ahead and drive.
- Stage 2: contact between the mid and right sensors - drive slightly to the right.
- Stage 3: Only the right sensor is in touch; drive to the right.
- Stage 4: contact has been made between the mid and left sensors; drive slightly to the left.
- Stage 5: The left sensing unit is in touch now (active) & then it is driven to the left direction.

IN the case if none of the sensing circuits make a touch or detect the obstacle, then a gap in the counter mechanism could be decremented & if he counting circuit reads the value of zero, then the mice will initiates the halt and subsequently the turning operation. The turning technique is a straightforward subroutine that stops the right wheel while spinning the left until the first (right) wall sensor makes contact. Due to inertia and wheel-slip, the vehicle turns a bit further, but as soon as the straight driving routine is restarted, the car adjusts itself strait toward this wall [22].

The Matrix positional coordinate is used to resolve the Maze Logic, as seen in the diagram above. The Figure 12 gives the software algorithm for controlling motors using PWM. There are two sorts of software designs [23].

- KEIL - Keil has a simulator that includes a functionally extensive library as well as solid support and compatibility with the 89C51 microcontroller.
- CX51 combines the programming freedom of C with the code efficiency and speed of assembly language. It's a completely new implementation aimed at producing highly quick and compact code for the 8051 CPU.
- FLASH- FLASH is the software that we use to download programmes from the computer to the microcontroller over the RS232 line. The software's screen shot is given in the image below.

15. HOW THE SYSTEM WORKS ?

One Micromouse : The first micromouse is designed to follow the magnetic ink trail and propagate in the same direction. The micromouse has three sensors: one in the centre, one in the right, and one in the left. The micromouse will propagate a straight line path as long as the centre sensor is assorted. If one of the right or left sensors is asserted, the directional stepper motor will commence rotating motion, allowing the mouse to take a spin. The mouse will continue on a straight line course as soon as the right or the left sensors could be left out or made inactive if the obstacle is not detected so that the power could be saved as the mice is battery driven in nature. The 1st mice's action and motion are relayed via the transmitting mechanism [24].

Micromouse Two: Micromouse two gets the signals that micromouse one has sent. By sensing the position of micromouse one, micromouse two detects the shortest path to micromouse one and traverses it. Micromouse two is well-equipped with wall sensors, which assist it to direct its path to itself [25].

16. FINAL THOUGHTS / CONCLUSIVE REMARKS OF THE PAPER

Overall, the project was deemed a success in all aspects, including mechanics, electronics, and software. All of the primary objectives were met, as well as the bulk of the minor objectives. The project handled new design areas that necessitated creative thinking. Its construction has validated the design concepts used, and with a few minor tweaks and enhancements, it might be improved further to create an even better test bed. A probable project extension has been offered, and it involves the processing. The developed micromouse was examined for two uses.

Application 1 :The principle of our invention can be used to track cars across a defined area. This project was created in response to a request from the MUMBAI traffic police department, hence the programme has to be improved for a more realistic implementation. In terms of execution, an ordinance must be established mandating that all vehicles be fitted with an identification transmitting module. Cells specified and developed by private and government cellular communication providers can be used to establish reception. Because it is in the public interest, the police department is in the process of passing an ordinance, which will be fully implemented by 2025.

Application 2 :The principle of the project novel invention could be utilised in shopping malls, where the luggage-laden trolley can be steered toward the container's (luggage boxes) exit & could be utilized for automating the sequence of mismatched matches.

17. ORGANIZATION OF THE PAPER

The paper is organized as follows. To start with abstract is presented followed by the keywords. Then, the section 1 gives the introductory remarks about the project followed by a typical example in section 2. The objective is given in section 3. The physical dimensions in section 4. The ideas for the construction is presented in section 5. The construction of mechanical system of the micro-mouse is given in section 6 followed by the stepper motor usage in work in section 7. The block diagram is given in section 8 followed by the micro-mice pin diagrams in section 9. The Schmitt Trigger details is given in section 10 followed by the PCB layout & circuit diagram in section 11. Sensors follows next in section 12. Software development is given in section 13. The main program with sub-routines is given in section 14. How the system works is given in section 15. The final thoughts / conclusive remarks of the paper is given in section 16. Organization of the paper is given in section 17 followed by the exhaustive list of references in section 18.

18. REFERENCES

[1] Robert Schilling, Fundamentals of robotics, *Prentice hall*.

[2] Hodges Bernard, Industrial Robotics, *Jaico publication*.

[3] Klafter, Cheimieleswski, Negin, Robotics Engineering Approach , *Pretice hall.*

[4] Fu, Gonzales, Lee, Robotics-Control Sensing & Vision, *Mcgraw Hill*.

[5] T.C.Manjunath, Fundamentals of Robotics, 5th edition, *Nandu Publication*, Mumbai, India.

[6] T.C.Manjunath, Fast Track to Robotics, 3rd edition, *Nandu Publication*, Mumbai, India.

[7] *National Semiconductor*, Data sheets for linear IC's.

[8] Pavithra G., Dr. T.C.Manjunath, Rajanish N., "Design & Development of a novel 4-point minimal pick & place trajectory in robotics", *10th Annual KSTA National Conference, Decennial Celebration of Science & Technology for future of Humanity (Sponsored by IIA, DRSC, ISRO, KSCST, Start up Karnataka, KSTePS) Decennial Celebration of Science & Technology for future of Humanity, Dept. of Science & Technology, Govt. of Karnataka, Reva University*, Kattigenahalli, Bangalore-64, Karnataka, ISBN 978-81-936187-4-5, Paper id ES-12, Sl. No. 235, pg. 149, 18-19 Jan. 2018.

[9] Dr. T.C.Manjunath, Pavithra G., Rajasekar Koyyeda, "Mathematical formulation of a 2D path in the work space of the robot from the source to the destination", *International Journal of Innovative Research in Computer and Communication Engineering* (*IJIRCCE*), Citation indices : Since 2012 Citations-836, h-index-13, i10-index-19, ISSN (Online) : 2320-9801, ISSN (Print) : 2320-9798, Impact Factor : 6.557, Certificate No V5SI4C140, An ISO 3297: 2007 Certified Organization, Vol. 5, Special Issue 4, pp. 309-312, Jun. 2017.

[10] Dr. T.C.Manjunath, Pavithra G., R. Jagadisha, "Design & development of an efficient path planning mechanism for a Micro-Robot", *IEAE's International Journal of Emerging Research & Management* (*IJERMT*), ISSN : 2278-9359, DOI : 10.23956/ijermt, Vol. 6, Issue 5, pp. 727-733, Impact Factor: 3.969, IF by ISRA 1.492, UGC Approved Journal, May 2017.

[11] Dr. T.C.Manjunath, Dr. Vaibhav Meshram, Pavithra G., "Dynamic modelling of a robot arm", *Journal of Applied Engineering and Technologies* (JAET), ISSN-2278-1722, Paper id AET-012, Vol. 2, Issue 1, pp. 47 - 53, April 2013, India.

[12] Dr. T.C.Manjunath, Arunkumar G., Pavithra G., "Development of swarm intelligence in mobile robotic systems", *Journal of Applied Engg. & Technologies* (*AET-2014*), ISSN : 2278 – 1722, Vol. 3, Issue 1, Apr. 2014, pp. 109-112, Vidyalankar Inst. of Tech., Mumbai, Maharashtra, India.

[13] Dr. T.C. Manjunath, Pavithra G., "Application of Template Matching Algorithms for Robotic Systems Using computer Vision", *VTU* (*Belgaum*) *& University of Mysore sponsored Second Int. Conf. on Signal and Image Processing* (*ICSIP-2009*), Vidya Vikas Institute of Technology, Mysore, Karnataka, India, Paper No. 322, pp. 376 - 380, ISBN 978-93-80043-26-5, Aug. 12-14, 2009.

[14] Dr. T.C.Manjunath, Pavithra G., "Role of Uncertainty in Robot Task Planning", *Proc. 2nd Int. Conf. on Networks, Information & Communication* (ICNIC-2015), organized by Dept. of ECE of Sri Venkateshwara College of Engg. (SVCE), Bangalore, Karnataka, India, 18-20 May 2015.

[15] Dr. T.C. Manjunath, Pavithra G., Dr. B.G. Nagaraj, "Design & simulation of the workspace for a stationary robot system", *Proc. of the IEEE Region 10 Humanitarian Technological Conference* (*IEEE R10 HTC-2016*), Dayalbagh Educational Institute, Dayal Bagh Rd, Dayal Bagh, Agra, Uttar Pradesh- 282005, India, IEEE Conference ID 39702, paper id 119, Session 2C on 21st Dec. 2016 at 09:30 hrs, Electronic ISBN: 978-1-5090-4177-0, Print on Demand (PoD) ISBN: 978-1-5090-4178-7, INSPEC Accession Number: 16837058, DOI: 10.1109/R10-HTC.2016.7906828, Dec. 21-23, 2016.

[16] Dr. T.C.Manjunath, Pavithra G., Satvik M. Kuagur, "Recent advances in the development of nanotechnology for bio-medical robots", *Proc. of the IFERP's Int. Conf. on Chip, Circuitry, Current, Coding, Combustion & Composites* (i7c-2016), paper id 80, pg. 85-86, ISBN 9788192958026, organized by IFERP & Shirdi Sai College of Engg., Bangalore, Karnataka, India, & associated with Technocrate Group (Technocrate Research & Development Association), Conference Alerts, ECA, IERD, ISER, IIAR, pp. 85-86, (abstract booklet), 10-11 Nov. 2016.

[17] Dr. T.C.Manjunath, Pavithra G., "A review of the glaucoma detection using hardware based implementation using embedded systems", *2017 IEEE Int. Conf. on Intelligent Computing & Control* (*I2C2-2017*), Sponsored by IEEE Madras Section, IEEE Robotics & Automation Society, Karpagam College of Engg., Karpagam University, Coimbatore, Tamil Nadu, India, paper id IC038, IEEE Xplore ISBN : 978-1-5386-0373-4, Vol. 1, Sl. No. 14, pp. 75-83, 23-24 Jun. 2017.

[18] Dr. T.C.Manjunath, Pavithra G., Rashmi Jagadisha, "Design & development of an efficient path planning mechanism for a Micro-Robot", *IEAE's International Conference on Emerging Trends in Science & Engineering* (*ICETSE-2017*), Paper id ICETSE-219, Associated by Institute for Exploring Advances in Engg. (IEAE), Coorg Institute of Technology, Ponnampet, S. Kodagu, Coorg, Karnataka, India, Proceedings in Vol. 2, Electrical, Electronics & Communication Engg., ISBN : 978-93-84698-42-3, Publisher : IEAE Publishing House, Karnataka, India, Sl. No. 42, pp. 227-234, 11-12 May 2017.

[19] Dr. Arunkumar G., Dr. T.C. Manjunath, Pavithra G., "4-point minimal pick & place trajectory design in robotics", *Int. Conf. on Innovations In Communication Computing & Sciences*, ICCS-2019, Dept. of ECE, Chandigarh Group of Colleges, Kharar, Banur Hwy, Sector 112, Sahibzada Ajit Singh Nagar, Landran, Mohali, Punjab-140307, Paper id ICCS-011, pp. 145-150, 26-27 Jul. 2019.

[20] Dr. Pavithra G., Mahesh B. Neelagar, Dr. T.C.Manjunath, "Development of a robotic part fixture mechanism for a conveyer belt problem for doing PNP operation in an industrial scenario using a fixed robot", *5th IEEE International Conference on Communication and Electronics Systems* (*ICCES 2020*), PPG Institute of Technology, Coimbatore, TN, 10-12, June 2020.

[21] Dr. T.C.Manjunath, Dr. Chandrakumar K., Pavithra G., "Novel design & development of a medical nano-robot", *Nat. Conf. on Emerging Trends in Nano Applications* (NCETN-2015), Paper id p003 (OP-02), BMS Inst. of Tech (BMSIT), Bangalore, Karnataka, Organized by Dept. of Physics, Chemistry & ECE of BMSIT, ISBN No.:978-81-928203-8-5, pp. 16-18, 27-28 Mar. 2015. ©

[22] Dr. T.C. Manjunath, Pavithra G., Kavitha S. Guddad, "An overview of the design & development of safety features in robots in the industrial sector", *3rd Nat. Conf. on Recent Trends in Electronics & Communications* (*NCRTEC-2017*), Organized by Dept. of ECE, IETE, Gate Forum, Paper id RTEC116, Global Academy of Tech. (GAT), Bangalore, Karnataka, India, pp. 1-5, 12 May 2017.

[23] Dr. T.C.Manjunath, Pavithra G., Rajasekar Koyyeda, "Mathematical formulation of a 2D path in the work space of the robot from the source to the destination", *2nd Nat. Conf. on Recent Advances in Engg. & Tech.* (*NCRAET-2017*), Dept. of ECE, Basavakalyan Engg. College, NH-9, Bidar-585327, Bidar Dist., Karnataka, India, ISBN: 978-81-931739-4-7, ISSN (On-line) : 2320-9801, ISSN (Print) : 2320-9798, Certificate No. V5SI4C140, Paper id EC112, pp. 7 (abstract booklet), 27-28 May 2017.

[24] Dr. Arunkumar, Spoorti J. Jainar, Dr. T.C.Manjunath, Dr. Purohit Shirnivasacharya, "Micro-controller & Application Theory", *Subhas Stores*, *CBCS Scheme*, ISBN : 978-93-83214-83-9, 1st Edition, Rs. 180/- 2017.

[25] Dr. Arunkumar, Spoorti J. Jainar, Dr. Nagaraj B.G., Dr. T.C.Manjunath, "Basic Electronics", *CBCS Scheme, Subhas Stores*, ISBN : 978-93-83214-89-1, 1st Edition, Rs. 270/-, 2017.

[26] Sindushree, Dr. Dinesh Rangappa, "Silk fibre-multi wall carbon nanotube based micro nano fibre composite as conductive fiber and force sensor", *ACS Omega*, Vol. 7, Issue 24, 2022.

19. AUTHOR'S PROFILE

Prof. Sindhusree M. was born in Tirupathi, Andhra Pradesh, India on **Oct. 1, 1990**& received the **B.E.** Degree (Bachelor of Engg.) in Electronics & Communication Engineering stream **(ECE)** from **Chadalawada Ramanamma Engineering College** (**JNTU**, Ananthapur) in the year 2011, **M.Tech**. Degree in **ECE** branch with specialization in **Nano Technology** from the prestigious **Visvesvaraya Technological University (VTU)** in the year 2015 in **First Class with Distinction)** &**First Rank** (**Gold Medalist**) and is pursuing her doctorate - **Ph.D**. in the field of *Nano Technology* (Electrical & Electronic Engg. Sciences) on the topic entitled, "*Fabrication of silk cocoon nano-material based electrode for energy storage & sensing applications*" from the prestigious Visvesvaraya Technological

University (**VTUBelgaum**) since 2015 & has carried out the research under the supervision of Dr. Dinesh Rangappa, a doctorate from the prestigious Tohoko University, Japan. She was a DST Inspired Fellow @ VTU Muddenahalli Campus when she was pursuing her Ph.D. Programme and received 6 International awards for best papers, projects, posters & presentations. She has got a teaching (**academic**), **research** experience of more than **10**$^+$ years in various engineering colleges in the country where she worked in the levels of **Lecturer-Asst. Prof**. (**10**$^+$) in the Dept. of Electronics & Communication Engg. apart from having some industrial experience gained during her UG/PG project & internship tenures. Currently, she is working as an **Assistant Professor** in the Dept. of ECE of the 42-year-old renowned Dayananda Sagar College of Engg., Bangalore since Dec'2021. Till date, she has published more than **20**$^+$ papers in various National, International journals (Scopus indexed, web of science, UGC, impact factors) and Conferences in India & abroad along with couple of **book chapters** in the **Springer Book Series**. She has attended CEP / DEP courses, seminars, workshops, conferences, symposiums, FDPs & training programmes besides conducting a few courses in the institutions where she had worked/working. She has got **4 Indian** patents in various fields of her research. Her areas of **special interest** are – Nanoenergy, Nanotechnology, Nanosensors, VLSI Design, Embedded Systems, Robotics, Image processing, Semiconductor device physics.

Dr. Pavithra G. was born in Bangalore, Karnataka, India on Saturday, September 8, 1984 (38 years old) & received the B.E. Degree (Bachelor of Engineering) in Electronics & Communication Engineering stream (ECE) from *the* prestigious Acharya Institute of Tech., Bangalore (VTU, Belgaum) in the year 2006, M.Tech. Degree in ECE branch with specialization in RF Communications from the prestigious Jain University in the year 2012 in First Class with Distinction & First Rank (Gold Medalist) and obtained her doctorate - Ph.D. in the field of Image Processing (Electrical & Electronic Engg. Sciences Stream) from the prestigious Visvesvaraya Technological University (VTU Belgaum) in the year Feb. 2020 Convocation respectively & carried out the research in VTU RRC Belagavi. She did her entire schooling (from 1st standard to 10th standard) in New Public School in Vijayanagar in Bangalore, Karnataka and her college (1st PUC & 2nd PUC) in the reputed KLE Institutions in Rajajinagar in Bangalore. She has also passed her Sanskrit (Prarambha & Balabodha exams) from Bharatiya Sanskrithi Vidya Peetha, Mumbai in First Class with Distinction. She is also a trained Bharatha Natyam dancer & is well-versed in some of the natya shastras and reciting all slokas. She has got a teaching (academic), research & administrative experience of more than 15+ years in various engineering colleges in the Karnataka State. She has worked in the levels of Lecturer-Asst. Prof. (15+) in the colleges where she was a faculty in the Dept. of Electronics & Communication Engg. apart from having some industrial experience gained during her UG/PG project & internship tenures (CDAC). Currently, she is working as an Associate Professor in the Dept. of ECE of the 42-year-old renowned Dayananda Sagar College of Engg., Bangalore, since 2 years. Till date, she has published more than 300+ papers in various National, International Journals (Scopus indexed, Web of Science, IEEE, Springer, UGC, Impact Factors, etc) and Conferences in India & abroad (at the rate of 20 papers per year) along with couple of book chapters in the Springer Book Series. She is a valued member of IEEE since 6 years. She has given a couple of guest lectures / expert talks and seminars in couple of institutions across the country, attended CEP / DEP courses, seminars, workshops, conferences, symposiums, FDPs & training programmes besides conducting a few courses in the institutions where she had worked/working. She has got 10 times prizes in various competitions, on 6 occasions acted as a resource person, chaired 6 sessions in conferences, acted as volunteers on 6 occasions, attended more than 50 Workshops, FDPs & 50+ conferences presenting the research papers. She is also a UHV Certified trainer from AICTE. She has developed a number of lab manuals, notes modules, question banks, etc. w.r.t. VTU curriculum & in the Autonomous Curriculums. She has given a number of Technical Webinars (6) in AI, Robotics & IP streams to various institutions, which were live streamed on you-tube & other channels apart from organizing a number of webinars, FDPs, workshops, seminars in the college where she worked & currently working. She has guided a number of B.E. (20) & M.Tech. (10) projects and all of them are being converted in to research papers that was being published in refereed conferences & in journals. She was a chair person / judge for a number of conferences and gave a number of invited talks & keynote lectures to various engineering colleges. She was a coordinator of many activities like the mini project coordinator, technical seminar coordinator, research coordinator, NAAC, NBA & NIRF coordinator under different criterias. She has published 20 text-books in various fields of engineering right from 1st year of BE to 4th year of BE & from 1st year of M.Tech. to 4th year of M.Tech. She has got a total of 60 Indian & Australian patents in various fields of science, engineering & technology, few of them are filed, published & granted. She also got the best paper award (5 times) in couple of conferences where she went as a paper presenter to present her research papers. She has trained a number of project students and made them to get awards, prizes, best projects, etc… in many of the project exhibitions, techfests, paper presentations, etc… She got the best Academic Research Publication (ARP) award from the prestigious Karnataka State Govt's Vision Group of Science & Tech (VGST) in the year 2021 apart from getting funded projects from KSCST. She has also got couple of best researcher awards to her credit from various organizations. She has got a valued copyright from the Govt. of India for her unique work on the topic, "A system and method for watermark embedding and detection". She is also a life member of IETE, ISTE, Associate member of KSTA. She has taught a number of subjects both for the UG & PG courses in her teaching career along with good programming knowledge in Matlab. Her areas of special interest are - DSP, Fundamentals of IP, Biomedical Image Processing, Signals & Systems, Basic Electronics, Network Analysis, Electromagnetics, Field Theory, Deep Learning, AI, ML, Computational Intelligence, Computer Vision, Management, Robotics, Wireless Sensor & Mobile Networks, Circuits & Networks, Matlab, Research Methodologies, IPR, Networks & circuits, Advanced Digital Communications, RF & Microwaves, Satellite Communications, Basic Electrical Engg., Analog & Digital Communications, etc..….