Automated Wireless Master Slave Path Following Robot System (April 2019)

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Abstract- **The objective of this paper was to establish a wireless communication between robots which operate in master-slave architecture. The proposed approach helped in achieving the desired outcome using RF communication concepts. Multiple robots grouping together to perform a task allows robots to achieve the result in less time and reduced complexity and also reduces human interaction.This ideology was exploited and put to use in this very project. The key idea was to create individual bots amidst which one of the bots serves as the Master bot and the other bot serve as the Slave bots and as per the definition the Master bot serves its purpose of executing the main task. A PID controller was designed to accomplish a straight path motion. The communication between the bots was achieved using wireless RF transmission technique. An intelligent slave bot was built that adopts collision preventive methods. Hence the bots work in tandem to achieve a common goal and accomplish the task without the need for human intervention other than the supervision of the master bot.**

Keywords—Master bot,Slave bot,RF communication, PID controller;

1. INTRODUCTION

The advancement in the world of electronics has led to an exponential rise in the usage of robots to do our tasks and execute them with extreme precision and diligence. Robots perform repetitive tasks and tasks which require no new decision making. Hence these tasks can be executed by robots with versatility and robustness at a very low error rates as compared to human workmanship. Swarm robotics is a new approach to the coordination of multi-robot systems which consist of large numbers of simple physical robots. The desired collective behaviour emerges from the interactions between the robots and interactions of robots with the environment.

It is easier to build multiple robots for multiple tasks than one robot that can do everything. Helping robots to collaborate, thus, would allow a small team of specialized robots to coordinate their specialized abilities to accomplish a complex task together. A team of robots would also be more robust because, if one robot breaks, it can be replaced without affecting the other members of the team. We are working on creating robots that communicate with each other, allowing them to collaborate on moving in tandem. The master robot which stays at the front makes movement which is acknowledged by the robots which follow its commands. Thus they “follow” the master robot and hence the name. The robots do not speak a language like English. Rather, they speak a computer language that allows them to receive and transmit commands. For example, they can coordinate their timing when completing a task that they need to do together.

In fields such as factories tasks such as carrying goods from one storage facility to another in a definite path is a tedious yet a repetitive job and this is a key factor at which robots excel in, hence bots can be programmed to transport the goods from one place to another without human intervention as the source and the destination address does not change during the execution of the process. In such cases often one bot is not sufficient to address the issue and many such bots may be required to carry out the necessary work and this is where the coordination between the bots and intercommunication between them comes into picture. The communication system is wireless and uses a common domain language to transmit and receive commands, which allows the robots to converse about the task, allowing them to better optimize their performance.

II. OBJECTIVE

Follower bot idea is mainly concerned with building robots which wirelessly communicate with each other and move in a path autonomously in a master-slave(s) relation. The master Robot is controlled by the userand is made to move based on their command. These commands are then transmitted wirelessly that are received by the slave robot(s) which follow the master robot intelligently. The main objective of the project is to minimize the repetitive human intervention in fields such as industries, military operations, agriculture and further more where multiple robots and locomotives are monitored individually.With the implementation of this idea, only monitoring the Master would be sufficient to handle the same task executed by all the robots, provided all the other constraints are brought under control.

III. LITERATURE SURVEY

Hardware implementation of the project is based on the Master-Slave relationship. Studyabout the locomotion, wireless communication, directional movement etc has been extensively done in the paper “A Novel Approach to Swarm Bot Architecture by Vinay Kumar Pilania ,Subrat Panda , Shaunak Mishra and Aurosish Mishra” [1] . It shows how the efficiency of the project can be verified. It consists of block diagrams regarding the control system of the master and slave bots. However the paper only gives us broad idea of how one can approach such a Master-Slave relationship, and no information regarding the implementation of the same.

Idea about how the communication between the bots can be established, the consequences after establishing thatcommunication, the different kind of sensors that can be used for the project with detailed explanation has been given in the paper “A Survey on Intelligent Interaction and Cooperative Control of Multi-robot Systems” authored by Anmin Zhu and Simon X. Yang [2] .

The paper “Smart Collision Avoidance and Driver Alert Recognition (SCADAR) System” written by Kalaivani. P ,Pretheep Kumar R, Thrshan J, Shakthi Kolapan R [3] briefs the idea about pre-emptive measures that could be taken regarding the formation of the prototype of a multi robot system. It provides a rough hardware block diagram and working of certain components along with the problems that can be faced.It consists of functional block of the smart collision avoidance and driver alert recognition system.But the paper only focuses on the avoidance of the obstacles and has no information regarding movement of the bot or the communication between the bots and no information has been discussed regarding how the project has been implemented.

“Robotics, Vision and control” [4] authored by Peter Corke is a text book on robotics. It provides us the mathematical equations and PID controllers required for the control of the bots.It also states about error handling methods to overcome the challenges that would occur. .

The paper “Implementation of RF Communication with TDMA Algorithm in Swarm Robots” authored by Prasanna Gautam and Sagar Bhandar [6] gives us the idea about how the communication can be established between master and slave bots. The RF specifications required for smooth interaction between the bots along with its working is obtained from this paper.It mainly focused on the TDMA algorithm which is used to establish communication among the bots which is an advanced algorithm to be implemented in our project. And it doesn’t contain any information about RF module to Arduino interface.

Details on the movement and co-ordination of the master and slave bots has been explained in “Swarm Bot: System design for ECHOLOCATION written by Gautham Wahi, Alex Noel Joseph Rag and Zhun Fan” [8] and “Swarm Bot: From Concept to Implementation by F.Mendada ,A.Guignard , M. Bonani , D.Bar ,M.Lauria and D.Floreano” [9]. It provides information about their design which suits for movement of the bots without undergoing any kind of collision. However it just lays an overview of the locomotion and doesn’t provide detailed explanation on which kind of communication that has to be established.

“New Detection of Peer-to-Peer Controlled Bots on the Host” authored by A. Anand, M. Nithya and TSB Sudarshan[10] is a paper that gives the idea about the communication among the bots over the LAN or any kind of shared medium among them. This prevents the miscommunication of master and slave. As per the paper it is suggested that the system should be indoor. Hence cannot be used for all kind of applications.

“A New Approach for Line Following Robot Using Radius of Path Curvature and Dierential Drive Kinematics” by Jitendra Singh and Prashant Singh Chouhan[8] , “Bluetooth controlled spy robot” by Akash Singh ,Tanisha Gupta and Manish Korde [9], “Swarm Bot: From Concept to Implementation” by F.Mendada , A.Guignard , M. Bonani , D.Bar ,M.Lauria and D.Floreano[10] ,“Leader-follower formation control for multiple mobile robots by a designed sliding mode controller based on kinematic control method” by Yudong Zhao , Dongju Park , Dongju Park , Jangmyung Lee[11] , “Humans Socially Attune to Their Follower Robot” by Agnieska Wykowska, David De Tomasso and Francesca Ciardo[12] were some of the other papers referred which relate to our project. The resources used in the implementation of our project reflect in eliminating the concepts covered in these papers.

IV METHODOLOGY

Movement of the bots can be made possible easily by incorporating DC motors and driving them through motor drivers. But the challenging part is to make them move in an un-deviated path i.e straight line. The PWM of each of the DC motors needs to be controlled to achieve this. Thus designing a PID controller is necessary and a gyroscopic sensor is utilized to design the controller.

When the bot is powered up, gyroscope is initiated for its action. Gyroscope has its own calibration time and its manufacture oriented. Therefore it has to be tested manually and calculate delay required for it to calibrate. By practical testing it was found that gyroscope takes average time about 22seconds. Once the gyroscope is set, the value will never change until reset is pressed. Output of gyroscope will be in radians which will be ranging from -3.142 to +3.142 to complete a circle, which is then converted into degrees to range from 0 to 180 and -180 to 0 in degrees using the formula:

$$gyro(deg) = gyro(rad) \times 180/pi$$

The resulted value is then changed from value to vary from 0 to 360. The communication data rate between the transmitter and receiver is set to 370 bits/second for smooth operation. . At this data rate, the RF pair provides a maximum communicable distance of upto 40 metres which is quite sufficient for our application as the bots will not be separated by a distance more than 30cm. The obstacle detection is handled by the ultrasonic sensor which operates for a range of upto 4 metres which suffices our requirements as our obstacle sensing distance is less than 30 to 35 centimetres.

The PID controller designed for the straight path motion of the bots has a set of equations which are implemented on the values provided by the gyro sensor. Any PID controller has three PID constants namely proportional constant(K_P), Integral constant(K_I) and a differential constant(K_D). These equations are defined in the control system domain as follows:

- proportional = 1
- differential = error

In our application, we are not dealing with sum of errors of the values provided by the gyro sensor. Thus the integral part of the PID is neglected and hence our controller is defined as a PD controller. We have fixed these values for the respective constants:

- Proportional constant, Kp = 200
- Integral constant, KI = 0
- Differential constant, KD = −5

The PD equations involving these constants that are used for our application are:

For left wheel,

$$P\ D\ valuel = Kp \times proportional + KD \times differential$$

For right wheel,

$$P\ D\ valuer = Kp \times proportional - KD \times differential$$

Ultrasonic signal gets bounced back when it hits the object. Distance can be calculated on the basis of time taken by the signal. Time is calculated from the time of the trigger to the time when the echo pin becomes high. This time should be divided by 2 because time recorded would be for the total trip of the signal (Two way). Equation for the calculation of the distance of the object is given below.

$$Distance = time \times velocity$$

where,
time = Time taken by the signal to bounce back/2
velocity = Velocity of sound (340 m/s)

To make the slave bot to take exact turn, there is a requirement of delay. The delay has to be calculated based on the safe distance which is assigned to them. For example, if we keep 30 cm as the safe distance and consider 7cm as the diameterof the wheel. Then distance covered in in one rotation would be 22cm approximately. The speed of the bot is 60 rpm equals 1 rotation per second then the bot covers 22 cm in1 second.

$$delay\ before\ turn(in\ seconds) = distance \times Pi \times diameter \times 60rpm$$

Hence for the above mentioned example, to cover 30 cm, we require 1.336 seconds of delay before turning.

V PROPOSED SYSTEM

The master bot can either be controlled manually by a user or its working can be predefined and the slave bots mimic the master bot with accuracy and robustness.

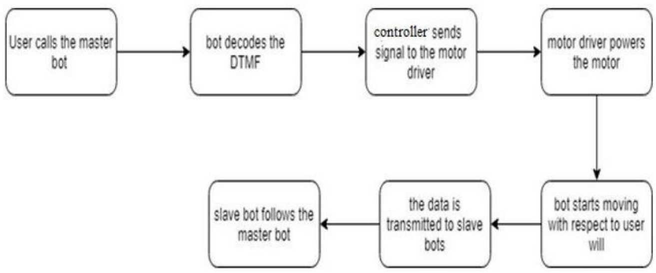

Figure 1: Block Diagram

A user controlled system is shown in the above block diagram. A gyro sensor is used to calibrate the bots that marks the initial orientation of the bots. The movement of the bots will be with respect to the calibrated reference axis. After calibration, the user calls and communicates with the master bot via the phone connected to it. The user commands the master to move either in forward, rightward, leftward or backward direction using the dialer keypad. This information is decoded by the DTMF decoder module which forwards the information to the microcontroller. Accordingly the microcontroller drives the corresponding motors connected to the driver shield to make the bot follow the user’s commands. At the same time, the master transmits the user’s commands to the slave bot through an RF transmitter.

On the other side, the slave bot equipped with an RF receiver on its body, detects the signals and forwards the received information to microcontroller. The microcontroller drives the corresponding motors connected to the shield to match the movement of the slave with the master.

The load on the bots can be variable thus could potentially make the bots to deviate from following a straight path. Thus the PD controller designed for the system using gyroscope sensor restricts the bots to move in a straight path. The sensor continuously provides the angle values that it reads while the bot moves. The bots are programmed to calculate the error in angle with respect to the calibrated axis and align themselves back into the straight path. The error calculation schema is showed in figure 2(i).

Avoiding collision of the bots and detecting obstacles is a challenging task and it has been implemented in this project using ultrasonic sensor. The slave bot detects any obstacle ahead of it within a minimum specified distance and stops moving if an obstacle is encountered. Later when the obstacle is eliminated, the slave bot catches up to the master and maintains a constant distance between itself and the master. This can be clearly seen in figure 2(ii) where the bots lie along the calibrated axis and the collision detection of slave bot is achieved through the ultrasonic sensor placed at its front.

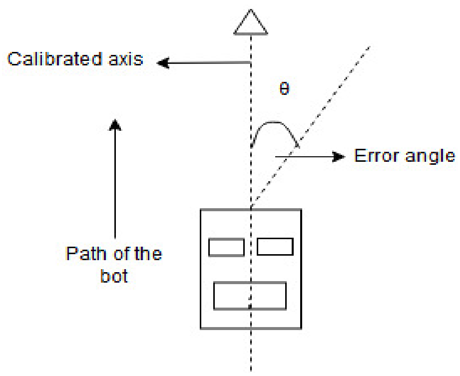

Figure 2: (i)) Error calculation in PID to avoid deviation from straight path

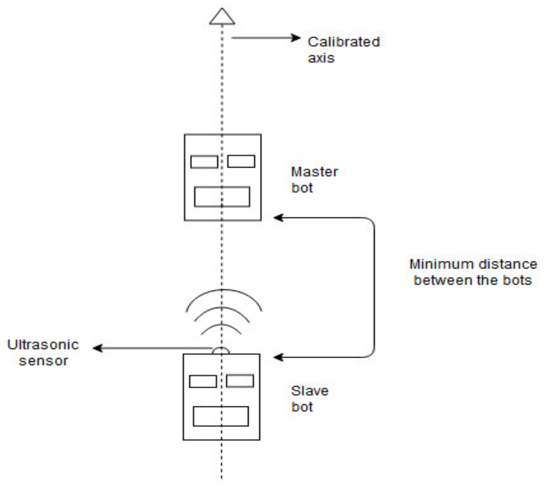

Figure 2: (ii) Alignment of bots in a straight line with PD control and collision detection

Next up while a turn taking scenario arises, the user commands the master to take a turn. The master acknowledges the command and takes a turn immediately. But the slave bot should not take the command to turn simultaneously. Thus a delay time is calculated for the slave bot by taking into account the minimum distance to be maintained between the two bots and also the+ speed of the motors of the bots. The slave bot is made to wait the calculated amount of delay time before it takes the turn in the direction which the master turned to. After a turn is taken the slave moves forward and aligns itself with the master's line.

VI RESULTS

The project was carried out and results were tested and analysed in three phases. Building the Master bot and testing its working with PD controller was the analysis made in first phase. Constructing a slave bot and establishing an RF communication between the bots was made during phase two. The final phase analysis was made on negotiating turns with collision detection capability of the slave bot.

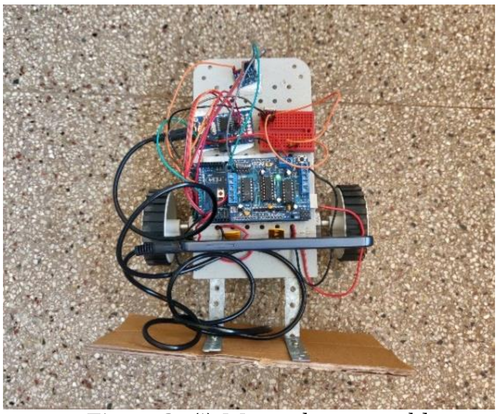

Figure 3: (i) Master bot assembly

Figure 3(i) depicts the testing result of phase one. The completely built master bot has been powered up and its response to user commands were tested. The user calls the mobile phone connected to the Master bot and directs the Master to move. The Master bot successfully performs the desired actions. The PD controller test for the Master was also done in this phase where it follows a straight path motion with no deviation from the straight path.

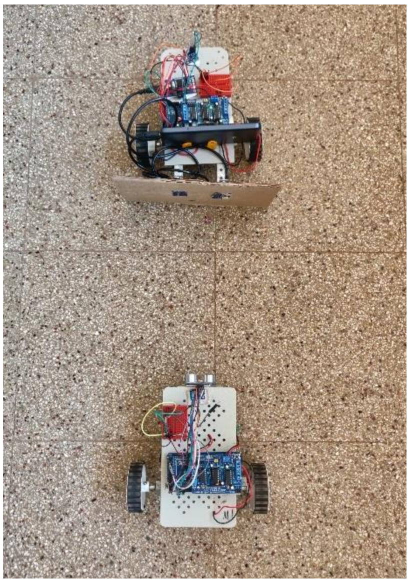

Figure 3: (ii) Communication established between the Master and Slave bots

Figure 3(ii) represents the analysis of second phase of testing where two completely built bots i.e Master and Slave are placed along a line and the communication between them is established. When the user calls the Master bot and commands it to move in any specific direction, the Master bot obeys it. Along with that the Slave bot follows the movements made by the Master bot with the help of RF communication. Both the bots are incorporated with the PD controller. Thus they follow a straight path during their motion.

Figure 3: (iii) Left turn negotiation

Figure 3(iii), Figure 3(iv) and Figure 3(v) show the third and final phase of the built system which deals with the turn taking part of the bots. In figure(iii), the user has commanded the Master bot to take a left turn and the Master adheres to it by instantly taking a left turn. The Slave bot receives this command from the Master bot and waits for the Master to complete its turn for a calculated amount of delay. Once the Master finishes the turn, the Slave bot traces to the point where the Master took a turn and takes a right turn and aligns itself behind the Master bot. The bots continue their motion until the next command is given by the user to the Master bot.

Figure 3: (iv) Right turn negotiation

Similarly, a right turn negotiation is shown in figure(iv) where the user commands the Master bot to take a right turn. Similar to how the left turn action was accomplished by both the bots, right turn also takes place in the same way.

Figure 3(v) marks the testing of aftermath of both the turns and collision prevention for Slave bot. The slave bot avoids any kind of collision with the Master bot with the help of ultrasonic sensor placed at its front end. The Master bot begins to move forward ordering the command given by the user. The Slave bot begins to move

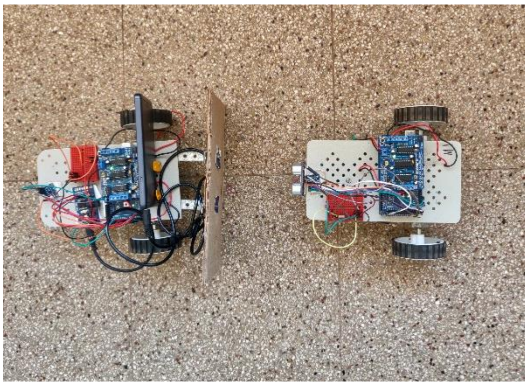

Figure 3: (v) After turn negotiations with collision detection

behind the Master bot and if the Master bot happens to be closer than the specified distance ahead of the Slave bot, the Slave bot halts its motion and resumes moving after the required separation in distance is achieved. Likewise, if the separation in distance between the Master bot and the Slave bot is greater than the specified distance, the Slave bot increases its speed and catches up with the Master bot and maintains the desired separation. Thus collision preventive measures are implemented and the entire objective of the project was accomplished with satisfactory results.

VII CONCLUSION

This project was an attempt to establish a wireless leader-follower robot system between two robots and make one of them follows the leader which is first of its kind with using inexpensive components. In this project autonomy of the slave bot is obtained and this opens up a lot of possibilities for further research and development in this field. Projects like these find huge applications is areas like the defense, warehouses for stock replacement and management, can be implemented in autonomy of automobiles, the applications are umpteen. Robotics has ushered a new feat of possibilities for mankind and science is taking us closer to the sophisticated way of living day by day and this project serves as a testimony for the same. Master Slave controlled Robotics system is an example of how robotics has evolved over the time to make the human life simpler and easier and this project hopes to find it's applications well. Further this project can be made much more robust and efficiency of slave bot following the master's movements can be notched up by adopting image processing techniques. Digital image processing opens up the project into new dimensions where intelligence of the robots can be made to reach a higher peak than to what it achieves now in this presented prototype. We look forward to achieve that efficiency in the future.

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