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Interactive Multi-Robot System Design

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ABSTRACT
Interactive robots are electromagnetic systems that can take autonomous decisions and transmit what they have learned to another robot or other robots through wired/wireless communication methods.
Two interactive robots were designed and developed within the scope of this study. The first robot drew the point-based map of a 5x5 maze, the entrance and exit of which were specified, starting from the line of entrance until the point of exit. It then calculated the shortest path between entrance and exit points using its recursive algorithm and wall following algorithm, and transmitted this information to another robot via RF wireless communication. The second robot, on the other hand, travelled from the entrance to the exit of the maze using the shortest path information it received from the first robot.
The control unit of the designed interactive robots was developed with a PIC 18F4550 microcontroller. The microcontrollers were programmed with PICc software; two step engines were used to ensure robot mobility; three infrared range sensors were used for identifying obstacles; and an RF transceiver module was used to transmit the determined shortest path information to the other robot.
When the transmitter robot was placed in the maze, it learned the shortest path and dead-ends, and formed a point map of the maze. It transmitted this information to the receiver robot - which was designed with identical hardware properties - through an RF communication module and with RF wake-up/encryption methods. After receiving the map information, the receiver robot completed the maze by taking the shortest path with the aid the data and experience it acquired.
Keywords -Interactive robot, Point mapping, Transmitter robot, Wireless communication using RF.

I. INTRODUCTION

Nowadays, robots are widely used in industry, control systems, medical applications, and in environments that may be hazardous to human health. In many robotic applications, a mobile robot is expected to move or to go from one location to another within the workspace while fulfilling its assigned tasks [1-2]. In such applications, robots may encounter objects that restricts their mobility, or alternative paths where it must decide which direction to follow. To be able to fulfil their tasks within the shortest time possible by following the most suitable path and without colliding with obstacles in these types of workspaces, autonomous mobile robots need to recognize the environment in which they operate [3]. As a prerequisite for fulfilling an assigned task partially or completely on its own, an autonomous robot must be able to accurately determine its location and learn the environment in which it operates [4].

II. ROBOT POSITIONING AND MAZE MAPPING/RESOLVING METHODS

For autonomous robots, the noises that occur during positioning and mapping may pose certain basic problems. Measurement noises emerge in parallel with the motion of the robot. They consequently tend to increase and become louder as the robot navigates, causing an inaccurate mapping of the space. Other issues related with positioning and mapping in autonomous robots are the changes that occur in the environment, and data association during autonomous navigation of the robot [5].

2.1. Robot positioning

Robots' ability to map their surroundings by accurately and reliably sensing the environment in which they are located, and their ability to locate their own positions within the maps they form are vitally important for the next step. Therefore, the distance information received from the external environment should be stable and reliable [6-7]. Distance sensors used in robots include infrared (optical) sensors, ultrasonic sensors, laser sensors, and camera sensors.

Infrared (optical) sensors are frequently used in industrial practices. Fundamentally, they are based on the principal of sending a light beam of specific wavelength from a source to the obstacle whose distance will be measured, and then detecting the reflected light beam with a sensor. Major problems for sensors include the scattering and non-reflection of the light sent by the source as the distance increases, and the absorption of light by dark surfaces [8].

Laser sensors are essentially based on the same working principle as infrared sensors. The light used in laser sensors has a very high wavelength. Laser sensors can be utilized very effectively in dark environments. Their major disadvantages include having a high price compared to other sensors, and their inability to sense objects such as glass [9].

Ultrasonic sensors mainly operate based on the principle of sending an acoustic beam from the source to the obstacle whose distance will be measured, and then detecting with a sensor the acoustic beam reflected back to the source. However, if acoustic beams are sent towards rough surfaces, the reflections will be erroneous. The incidence angle of acoustic beams to the surface whose distance will be measured affects the accuracy of the measurement. Since ultrasonic sensors are cheap and easily applicable, they are frequently used in mobile robot applications [7].

Camera sensors are used for the detection of objects and obstacles through image processing techniques. In applications involving cameras, data obtained from a single camera may not be sufficient to obtain accurate results. For example, using stereo (dual) cameras is imperative for applications that require depth (distance) information [10].

2.2. Maze mapping and solving methods

While mapping and solving a maze whose plan is not known in advance, mobile robots make use of random mouse, wall follower, pledge, tremaux, dead-end filling and recursive algorithms [11].

Random mouse algorithm: Assumes that the robot in the maze proceeds along a straight line. It is a slow algorithm, since the robot moves randomly and chooses a random direction whenever it runs into an obstacle or junction.

Wall follower algorithm: Assumes that the robot in the maze will find the exit by always following the right-hand side of the wall (right-hand method). This algorithm may fail to provide successful results if the entrance and exit to the maze is within the internal region.

Pledge algorithm: The robot in the maze proceeds forward by choosing a random direction. All alternative paths are tried by increasing the counter by one when an obstacle is met on the right side, and decreasing the counter by one when an obstacle is met on the left side of the robot during its movement. When the total counter value is equal to zero, the robot will clear the obstacle. Positive results are obtained with this algorithm when the entrance/exit of the maze is within the internal region.

Random Tremaux's algorithm: Based on marking the used paths while moving within the maze. If the mobile robot meets a dead-end, it turns around and walk backs to the last node passed. When an unmarked node is reached in the maze, the exit is sought by selecting a random direction.

Dead-end filling algorithm: This algorithm is the opposite of the random Tremaux's algorithm. Dead-ends and nodes in the maze are marked. While proceeding in the maze, the mobile robot seeks the exit by following the unmarked paths.

Recursive algorithm: Pictures the starting points in the maze as an [x, y] coordinate plane. The algorithm initially assigns starting values to [x, y] points. After ensuring that it did not already use the following [x, y] point, the robot uses this point and calls itself recurrently. If the initial [x, y] values entered into the algorithm as parameters are equal to the end value, algorithm will end.

III. DESCRIPTION OF THE SYSTEM

In the current study, two interactive robots with identical properties were designed and developed (Fig. 1). One of these robots operated as transmitter, while the other one operated as receiver.

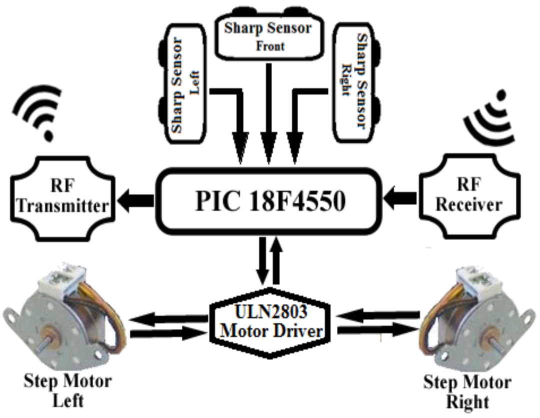

Fig.1. Block diagram of the developed interactive robots.

3.1. Structure and design of the interactive robots

To develop the interactive robots, we used two step motors to ensure the mobility of robots; three sharp infrared range measuring sensors to detect obstacles and directions on the right, left and front; RF transceiver module for enabling the robots to communicate with each other; and a PIC 18F4550 microcontroller, which allows the control of these hardwares.

Circuit diagram of the interactive robots developed is illustrated in Fig. 2. Port A of the PIC 18F4550 microcontroller shown in Fig. 2 was used to control the ultrasonic infrared distance measuring sensors; port B was used to control both step motors separately; port C was used to control RF wireless communication modules; and port D was used to control both ICSP and buzzer connections.

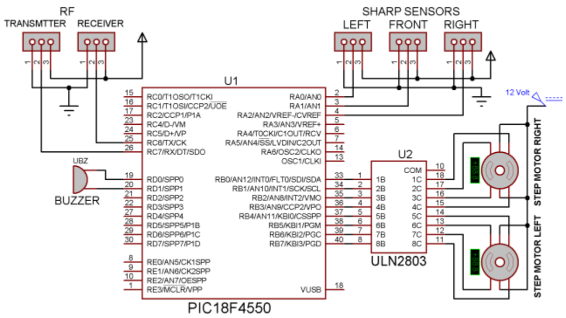

Fig.2. Circuit diagram of the developed interactive robots.

3.2. Movement of the interactive robots in the maze.

A 5 x 5 maze built from 20 x 8 cm square wood blocks was used in the study (Fig. 3).

Fig.3. 5x5 maze.

During the charting of the maze plan, the instantaneous detection of the mobile robot's movement across the maze is of crucial importance. For this reason, it is necessary to determine the distance covered by the robot and the directions of its movements.

The distance covered by the developed interactive robots within the maze were recorded by incremental optical encoders installed on the wheels. When the encoder completes a full rotation, 512 increments are obtained. Therefore, the total number of rotations of the wheels was calculated by dividing the data transmitted by encoders between two intervals with 512 (equation (1)) [12].

$$ts = \frac{encoder_{(t)} - encoder_{(t-1)}}{512} \qquad (1)$$

Since the perimeter of a wheel is 2×π×r, the distance covered by the robot in the maze is calculated according to equation (2).

$$Distance = ts \times 2 \times \pi \times r \qquad (2)$$

Many contingencies may arise during the movement of mobile robots at the nodal points of the maze. Therefore, priorities must be set to avoid ambiguity when the robot has more than one choice [13]. In the present study, priority was given to the right when the front path was closed and the right and left paths were open; to the front when front, right and left paths were open; and to the front when the right path was closed and front and left paths were open (Fig. 4). This ensured that any uncertainties the mobile robots might have encountered at the nodal points of the maze were avoided.

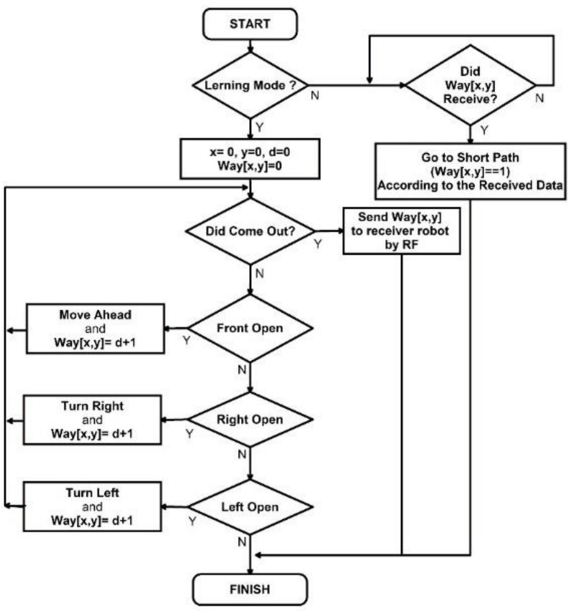

Fig.4. Algorithm of the developed interactive robots.

For example, the maze illustrated in Fig. 5 has 2 nodal points. When the mobile robot reaches nodal point 1, it moves forward based on the priority “if the front and right paths are open, move to the front;” and when it reaches to nodal point 2, it moves forward based on the priority “if the front, right and left paths are open, move to the front”. Since the mobile robot enters into a dead-end after nodal point 2, it moves back to node 2. When the mobile robot arrives at node 2 for the second time and encounters a path it did not enter before, it would give priority to that direction and proceed towards that path.

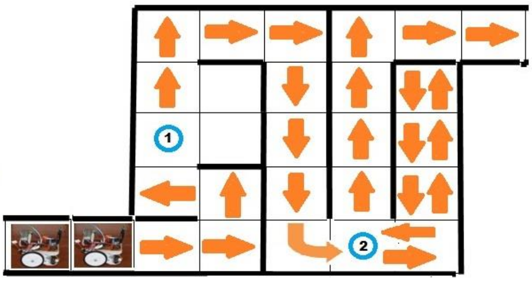

Fig.5. Paths followed from start to finish.

3.3 Maze learning

In the present study, the wall following method was employed in order to learn and map the maze. In this context, based on their pre-defined starting/ending positions, the robots detected the shortest path from the start to the end according to wall following and priority theory.

Fig. 6 shows transmitter and receiver robots side by side. The receiver robot waited for the transmitter robot to solve the maze and transmit the information to itself.

In the maze solving procedure, the maze was symbolically divided into cells in a tabular form, and the initial values of the cells were accepted to hold 0 (zero) information (Fig. 6). If the mobile robot passed through the cells of this symbolically depicted table, the value of the relevant cell was increased by 1.

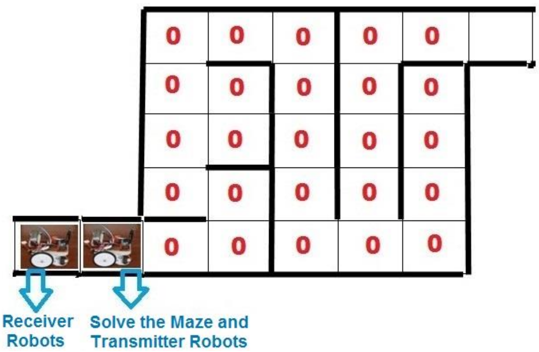

Fig.6. Initial values assigned to the maze.

For example, since the mobile robot passed only once and unconditionally until the nodal point 1 of the maze, the values assigned to these cells were increased by 1 (Fig. 7).

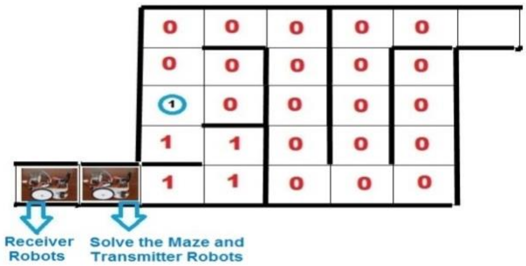

Fig.7. 1. Assigning values to cells through which the robot passed until the nodal point.

Due to its priority settings, the mobile robot proceeded straight ahead without turning right at nodal point 1. Therefore, the values of symbolic cells in the table through which the robot passed from nodal point 1 to nodal point 2 were increased by 1 (Fig. 8).

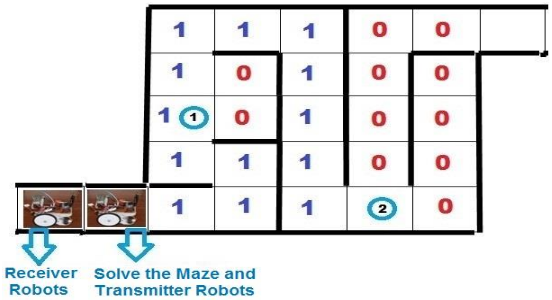

Fig.8. Assigning values to the cells through which the robot passed from nodal point 1 to nodal point 2.

Due to its priority settings, mobile robot proceeded straight ahead without turning left at nodal point 2. The values of symbolic cells in the table through which mobile robot passed after node 2 were increased by 1, and when the robot passed through the same cells, their values were increased once again, making the total value 2 (Fig. 9).

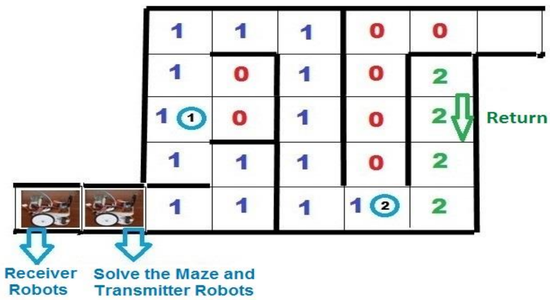

Fig.9. Assigning values to cells through which the robot passed after nodal point 2.

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When the mobile robot arrived at node 2 once again, if it met another path other than those it took before according to its prioritized motions (the front of the mobile robot was 1, whereas the right-hand side was 0), it would move in that direction and complete the maze by increasing the values of each symbolic cell it passed through by 1, as shown in Fig. 10.

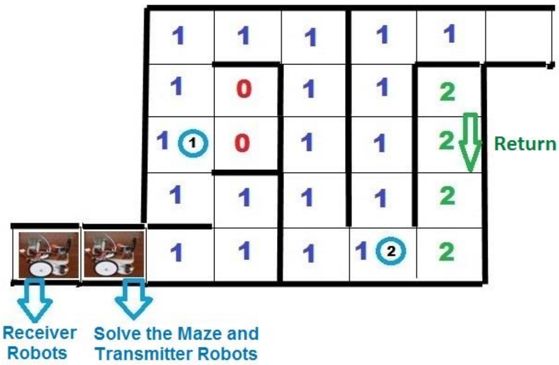

Fig.10. Values assigned to all cells the robot passed through from start to finish.

3.4. Transmission of path information regarding the maze to the other interactive robot

The transmitter robot transmitted through RF wireless communication to the receiver robot, which had identical properties as the transmitter robot, the information on 1s (one) it saved as an [x][y] array. After verifying the coordinate information, the receiver robot found the exit from the shortest path by following these coordinates (Fig. 11).

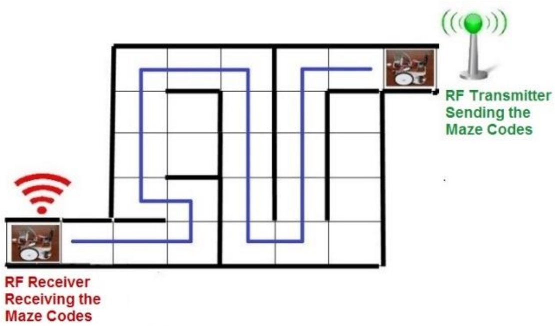

Fig.11. The location where transmitter robot transmitted information through RF.

IV. RESULTS AND DISCUSSION

In this study, we designed and developed a transmitter robot, which recognized and mapped its environment and transmitted this experience through RF wireless communication to a similar robot; and a receiver robot, which received such information and experience from the transmitter robot (Fig. 12).

Fig.12. Developed interactive robots.

A complex 5x5 maze was also designed within the scope of the study. The robot placed in this maze was capable of learning, recognizing and analyzing its environment; as a result, over a certain period of time, it was able to acquire information on the environment, the maze, and its map. In other words, the robot was able to learn the shortest paths and dead-ends, and to form the map of the maze. Subsequently, it transmitted this information to another robot, which had identical hardware properties, through RF wireless communication. After receiving the map information, the receiver robot completed the maze by taking the shortest path based on the data and experience it was transmitted.

Such studies that enable robots to transfer their experiences are crucial for applications where time is important. Learning and teaching functions take place at every stage of life. It is rather unnecessary to constantly repeat these experiences in the same way. However, gaining teaching functions as a result of learning would improve the interaction of robots. Interactivity implies not only being able sense, but also acquiring the abilities to assess, analyze and transmit the information gathered through sensing.

Therefore, multiple sensors should be used on the robot in other studies that will be conducted along the same lines. The behavior of sensors can become unstable under changing environments. Using multiple sensors in order to prevent such instability is key to solving this problem. Furthermore, robot learning can be facilitated by developing better learning algorithms.

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REFERENCES

[1] S. Yavuz, M. F. Amasyalı, M. Balcilar, G. Bilgin, T. Dinç, and Z. Kurt, Eş zamanli konum belirleme ve harita oluşturma amaçli otonom bir robot, *Elektronik ve Bilgisayar Mühendisliği Sempozyumu ve Fuarı ELECO2006, Bursa, Turkey,* 2006, 28-31.

[2] A. Pervez, J. Ryu, Safe physical human robot interaction-past, present and future, *Journal of Mechanical Science and Technology, 22 (3)*, 2008, 469-483.

[3] Ü. Yücel and T. Yildirim, Gezgin robot tasarimi ve kendi kendine organize olan haritalar ile robotun engellerden uzaklaşmasi, *Elektrik-Elektronik-Bilgisayar Mühendisliği 11. Ulusal Kongresi ve Fuarı, İstanbul, Turkey,* 2005, 203-206.

[4] P. Hansen, H. Alismail, P. Rander, and B. Browning, Visual mapping for natural gas pipe inspection, *The International Journal of Robotics Research, 34 (4-5),* 2015, 532-558.

[5] H. Ankışhan and M. Efe, Eş zamanlı konum belirleme ve harita oluşturmaya kalman filter yaklaşımları, *Dicle University Journal of the Engineering Faculty, Diyarbakır, Turkey, 1 (1),* 2010, 13-20.

[6] X. Zhu, C. Qiu, and M. A. Minor, Terrain inclination aided three-dimensional localization and mapping for an outdoor mobile robot, *International Journal of Advanced Robotic Systems, 76 (10),*2013.

[7] E. Eroğlu, *Gezgin robotlarda ultrasonic mesafe algılayıcılarla robot davranışlarının kontrolü ve çevre haritalama*, M.Sc., Osmangazi University, Institute of Science and Technology, Eskişehir, Turkey, 2006.

[8] X. Yan, Q. Wu, J. Yan, and L. Kang, A fast evolutionary algorithm for robot path planning, *In Control and Automation, ICCA 2007*, Singapore, 2007, 84-87.

[9] J. Jung, S. Yoon, S. Ju, and J. Heo, Development of kinematic 3d laser scanning system for indoor mapping and as-built bim using constrained SLAM, *Sensors, 15(10),* 2015, 26430-26456.

[10] K. Schmid, T. Tomic, F. Ruess, H. Hirschmuller, and M. Suppa, Stereo vision based indoor/outdoor navigation for flying robots, *In Intelligent Robots and Systems (IROS) 2013 IEEE/RSJ*, 2013, 3955-3962.

[11] Codesenior, Maze solving techniques, http://www.codesenior.com/tutorial/Labirent-Cozme-Algoritmalari, (2014), Date of access: 30.07.2015.

[12] A. Habibov, *Gezgin robotlarla eş zamanlı konum belirleme ve haritalama*, M.Sc., Yildiz Technical University, Institute of Science and Technology, İstanbul, Turkey 2011, 70.

[13] S. Nissimov, J. Goldberger, and V. Alchanatis, Obstacle detection in a greenhouse environment using the Kinect sensor, *Computers and Electronics in Agriculture, 113*, 2015, 104-115.