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Shortest Distance Orientation Algorithm for Robot Path Planning using Low-Cost IR Sensor System

Israa S. AL-Furati
Electrical Engineering Department
University of Basrah
Basrah Iraq
israa.subri.1@gmail.com

Abdulmuttalib T. Rashid
Electrical Engineering Department
University of Basrah
Basrah Iraq
abdturky@gmail.com

***Abstract*— This paper demonstrates a new algorithm in the path planning field for indoor robot navigation, focusing on finding the shortest and most safe path from the robot source position to its target. Robot localization matters are solved by using an IR transmitter fixed to the robot and a low-cost IR sensor array that is regularly distributed in the environment. The robot location depends on a group of IR receiver sensors that sense the IR transmitter signal where the location of each IR receiver is dependent on it is the location in the IR receivers array. The robot initial position is computed by using the modified binary search algorithm to scan the IR receivers array. A path planning problem is solved by using a new algorithm called the shortest distance orientation algorithm. A chain of the IR receivers within the sensing range of the virtual path is activated to be scan through the robot moves to the target. This process helps in reducing the localization time when the robot moves toward the target. At each step of the robot movement, it is direction is corrected dependent on the angle between its orientation and the direction of the line between its location and the target location. The simulation results for different types of IR array environments are shown good performance for this algorithm.**

Keywords*— *Binary search algorithm, Localization, Path planning.

I. Introduction

The robot is a computer programmable device that can automate certain behaviors. Much attention has been paid to because it can replace a person in some tasks including decision making and physical activity Special and dangerous applications. The science that deals with the study of the intellectual relationship between perception and movement were called robotics [1]. The path planning field is one of the most important fields for robots. The pathfinder tracks the best collision-free path from source to destination and applies it to various applications such as [2], robots [3], military applications [4, 5], computer games [6-8], services, etc. It will be logistics [9], family services [10]. The concept of path planning is identical and very simple. The mobile robot must start from an initial position and reach the final destination. Path planning algorithms fall into two types depending on the amount of information the robot knows about the environment: offline and online path planning algorithms. In the offline path planning algorithm, the robot has global information about the environment. Since the robot knows the position, shape, and size of each obstacle, the robot can know in advance if it can reach the target and calculate the shortest path. When using the online path planning algorithm, the robot gets information about the environment from the sensors as it moves, so it is not known whether this robot at the starting point can reach the target and whether it can always reach the shortest path [11]. sensors such as infrared sensors, laser scanner, and ultrasonic can be prepared on a mobile robot for remoteness measurement [12]. The low-cost sensors in many applications are used for determining the distance as a replacement for the expensive sensors such as camera and laser scanner [13-18]. Conversely, not only the distance scheming design is required for localization; the character of the source and receiver of the Localization algorithms also required to estimate the nodes' locations and depended on the connectivity between the nodes. Again, we are looking for cheap sensors for an indoor system to realize the communication among nodes which are the infrared sensors [19].

Several types of sensors are used in localization and path planning systems, such as WiFi positioning, RFID, ultrasonic positioning, vision sensors, Bluetooth technology, LRF, infrared IR transmitters and receivers, VLC visible light communication technology. Although the device must have Bluetooth [20,21] and Wi-Fi [22] but will be integrated only in mobile policy, Bluetooth, and Wi-Fi localization system, due to interference from the additional signal to be interfered with, This reduces the accuracy of the device. LRF [23] and ultrasound system [24] are equipped with high-precision trimming systems. Now, the sensors in the two rankings are still unable to properly detect the internal mobile robot if the robot is surrounded by a few moving things. LRFs is restricted with transparent walls in an environment, and it is only used in an indoor environment. RFID systems with high-intensity IC tags [25] can be used to accurately locate in a reasonable configuration. In this paper, to fit the requirement of the research area, we propose an indoor path planning algorithm system using an IR receiver sensors to solve the problem of positioning, orientation, and achievement of the target location. In the first step, the robot initial position is computed using the modified binary search algorithm. Then a new algorithm called the shortest orientation distance algorithm is a practice to transfer the robot from its prior place to the target location. This

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algorithm is designed to control the orientation of the robot through the robot movement and also, to reduce the active IR receivers sensors that scanned through the process of the robot localization. This leads to reducing the localization time. The paper is ordered as follows: in Section (II) explains the shortest distance orientation system, Simulation results are presented in section (III) To finish, in (IV) conclusions are conferred.

II. SHORTEST DISTANCE ORIENTATION SYSTEM

In this paper, we introduce a new algorithm of the indoor path planning structure based on the activation of the infrared receiver sensors that are regularly distributed in the work environment. Using infrared sensors to determine the location of the robot through the robot moving towards the target. The primary position of the robot depends on using the modified binary search algorithm to scan the environment. The default path represents the path that the robot follows to determine the target range. The infrared receiver sensors are fully activated within the default path sensor range. The robot follows the trajectory represents by these activated IR sensors and it is the location at each step of movement is compute by scanning only these activated IR receiver sensors.

A. The Initial Position of the Mobile Robot

The planned system consists of a two-dimensional environment with several uniformly distributed holes (Fig. 1) equipped with a set of infrared sensors. The infrared sensors in this system are divided into two groups: The first represents an infrared transmitting sensor located at the base of the mobile robot, and the second represents a different set of dimensions of the infrared sensor that are regularly distributed in the environment. The central unit scans the array of IR receiver sensors row by row to identify signals from the robot's IR transmitter. Only infrared receiver sensors that are within range of the infrared transmitter are identified. Next, the identified sensors are instantiated as a group, and the robot is located from the identified receiver sensor scene using the centroid algorithm. The initial localization process relies on scanning all columns of the IR receiver array using a modified binary search algorithm. The calculation of the binary search algorithm is suitable for finding decimal numbers in an organized display of information. It works in logarithmic times, is a simple calculation, and can be improved. Search development is accomplished by separating clusters into equal parts over and over. If the search value is smaller than the middle entry in the array, the search has been limited to a smaller part. It is continually checked until the required number occurs or the array is filled. At each stage of the algorithm procedure, the start and end of the last part of the array must be recalled. For this calculation, the benefits of a multifaceted nature depend on the logarithm of the listing size [26]. In this paper, the localization process is based on the use of the modified binary search algorithm. The differences between the proposed algorithm and the binary search algorithm are summarized in the resulting steps:

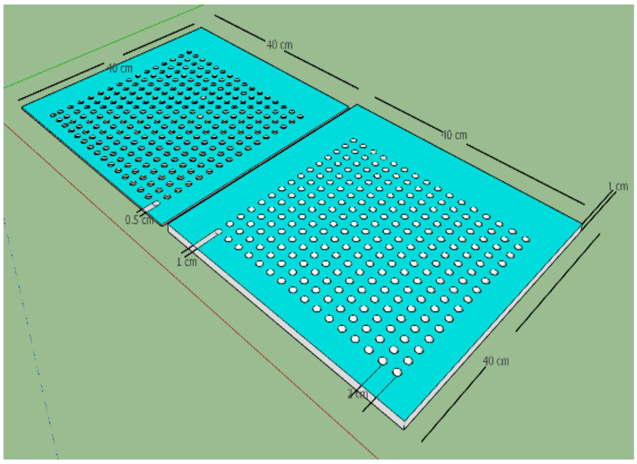

Fig. 1. map of (16*16) an empty-hole environment.

- The binary search algorithm is created using decimal numbers, and as a result, the sort sequence is the first period in this algorithm. But in this system, two states of logical principles are used (one for the active infrared receiver or zero for the inactive infrared sensor). As a result, the sorting sequence is not required for this stage.
- The infrared receiver sensor is organized into the two-dimensional array; Therefore, the matrix search algorithm is applied to each row and column of this array.
- In this environment, some IR receiver sensors are used as a result. The search procedure is a practice on multiple values at once. Since the location of each IR receiver sensor is known, the robot's position can be estimated using an information sensor consisting of the robot's IR transmitter.
- The localization process begins to progress. In this paper, the conversion process is based on the use of a modified binary search algorithm. The differences between the proposed algorithm and the binary search algorithm are summarized in the resulting steps. Cross the rows of the IR receiver sensor array. The IR receiver sensor symbolizes each row within the detection range by one and then by zero. This procedure is repeated until each IR sensor in the sensing area is labeled with the value 1. As a result, information from the active IR receiver sensor is sent to the microcontroller to determine the position of the robot.

B. Estimation of Robot Orientation

The current orientation of the robot is very important for drawing line follower paths. For this purpose, the robot first moves forward one step. This is shown in Fig. 2. Calculates the position of a new robot using a modified binary search algorithm. Knowing the last and current positions, you can estimate the orientation of the robot according to the following equation:

$$\theta = \tan^{-1}((y_R^1 - y_R^o) / (x_R^1 - x_R^o)) \quad (1)$$

Where θ is the robot orientation. (x_R^o, y_R^o) is the coordinate axis for the robot at position o and (x_R^1, y_R^1) is the coordinate axis for the robot at position 1.

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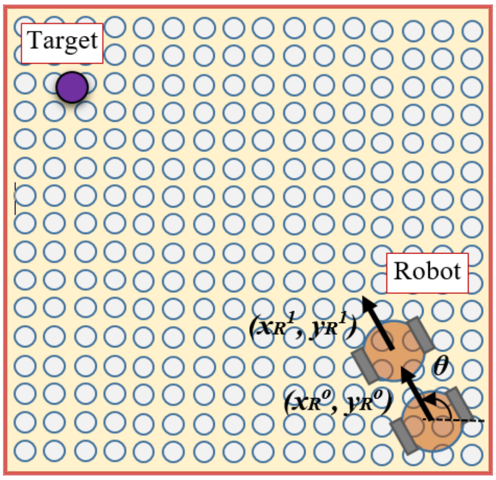

Fig. 2. Estimate the robot orientation.

C. Robot orientation adjustment

This section defines the procedure used to adjust the orientation of the mobile robot toward the target. This process needs several steps starting from distinguishing the active IR receiver sensors that must be scanned, estimate the current location of the robot, compute the direction of the straight line between the robot and the target locations and finally compare the straight-line direction with the orientation of the robot to decide for the direction of the robot orientation adjustment. The following steps describe the robot orientation adjustment.

Step1: Firstly, distinguish the active IR receiver sensors that must be scanned. This process is achieved by measuring the distances between the current location of the robot and the locations of all IR receiver sensors.

$$Di = Sqrt\,((y_{ir}^{i} - y_R^{j})^2 - (x_{ir}^{i} - x_R^{j})^2) \qquad (2)$$

Where Di is the distance between the IR sensor i and the robot at position j. (x_{ir}^i, y_{ir}^i) is the coordinate axis for the IR sensor i and (x_R^j, y_R^j) is the coordinate axis for the robot at position j.

The IR sensor with distance less than it is sensing range must be activated as shown in Fig. 3.

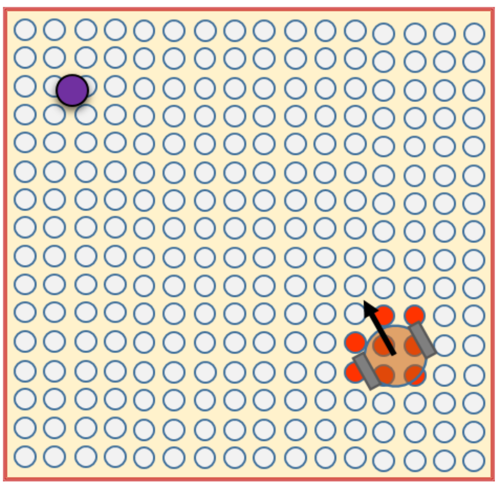

Fig. 3. Estimate the active IR receiver sensors.

Step2: In this step, the current location of the mobile robot must be estimated. This process is accomplished by using the linear search algorithm. In this algorithm, the active IR sensors are scanned sequentially and any IR sensor has the smallest distance that can be treated as a current location to the mobile robot (Fig. 4).

Step3: The orientation of the direct line between the current location of the mobile robot and the target location must be computed using the following equation.

$$\phi = tan^{-1}\,((y_t - y_{Rj}) / (x_t - x_{Rj})) \qquad (3)$$

Where ϕ is the direct line orientation between the target position and the robot in position *j* as shown in Fig. 5. (x_t, y_t) is the coordinate axis for the target.

Step4: This step is used to adjust the orientation of the mobile robot when it moves toward the target position. The adjustment depends on the comparison between the current orientation of the mobile robot and the direction of the path between the robot and the target locations. The decision of adjustment is dependent on the following equations.

$$\theta = \theta + \delta \quad \{\theta < \phi\} \qquad (4)$$

$$\theta = \theta - \delta \quad \{\theta > \phi\} \qquad (5)$$

where δ is the magnitude of changing in the direction of the robot at each step of the movement. when $\{\theta = \phi\}$ then the robot continues to move in the same direction without changing the orientation angle.

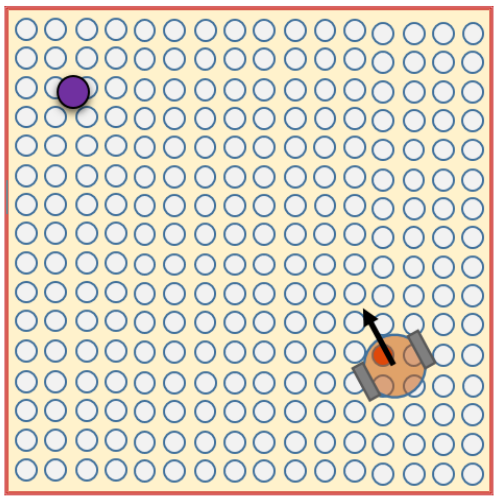

Fig. 4. Estimate the current location of the mobile robot.

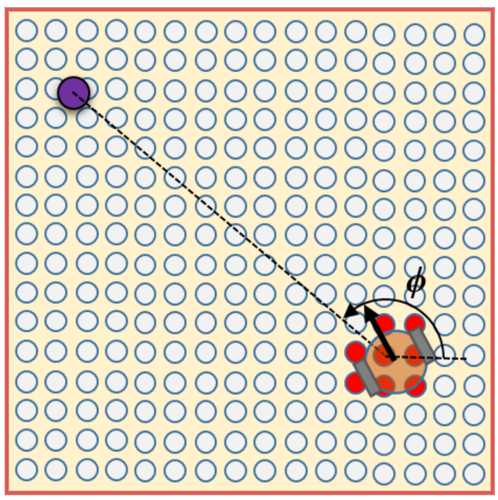

Fig. 5. The orientation of the direct path between the robot and the target.

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D. *Robot trajectory planning*

Two steps are used in this section to build the trajectory of the mobile robot. At first, the new position of the robot must be computed and after that, the last section and the first step in this section are repeated until the robot reaches the target.

Step1: Dependent on the current position and orientation of the mobile robot, the next position is computed using Eq. (6) and (7).

$$x_R^{j+1} = x_R^{j+1} + L * Cos\ (\theta) \qquad (6)$$

$$y_R^{j+1} = y_R^{j+1} + L * Sin\ (\theta) \qquad (7)$$

Where L is the increment distance at each step of the robot movement. (x_R^{j+1}, y_R^{j+1}) is the coordinate axis of the mobile robot at the next movement. Fig. 6 shows the movement of the robot to the next location.

Step2: In this step, the new orientation of the robot which computed in the last section and the computation of the next location (step 1) are repeated until the robot reaches the target. Equation 8 is used for this propose.

$$R_i = Sqrt\ ((yt - y_R^j)^2 - (xt - x_R^j)^2) \qquad (8)$$

Where R_i is the current distance between the robot and the target locations. Fig. 7 shows the complete trajectory of the robot moves from the start position to the target point.

III. THE SIMULATION RESULTS

The strategic indoor path planning algorithm is simulated with Visual Basic programming language on Windows operating system using a computer with Intel Core i7-7500 CPU 7th Gen. 2.90 GHz processor. The environment consists of various infrared sensors (16 * 16, 32 * 32 and 64 * 64) with presumed dimensions (1000 * 1000) pixels which scattered regularly in the environment, The first step in this procedure is to find the robot position using a scanning process that uses a new algorithm called the modified binary search algorithm. A new path planning algorithm called the shortest distance orientation algorithm is used to determine the path plan from the robot source to the target location.

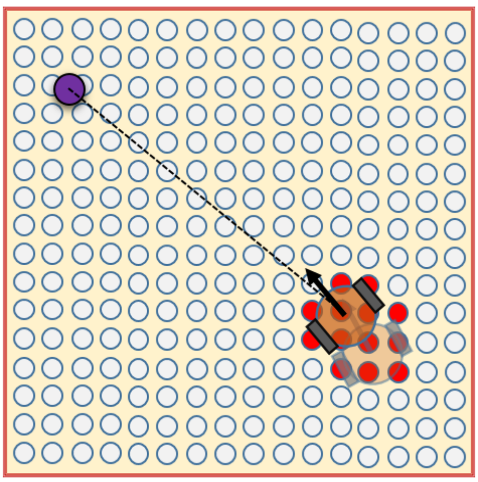

Fig. 6. The movement of the mobile robot to the next position.

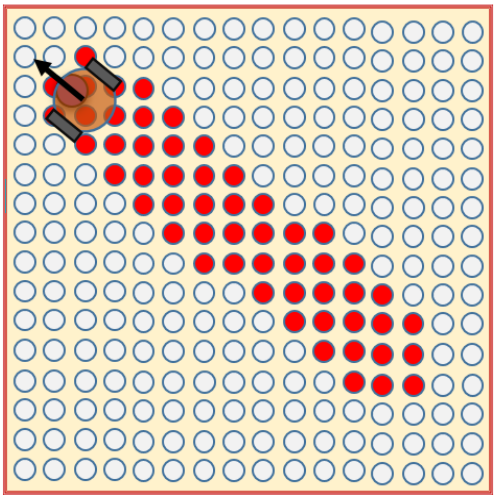

Fig. 7. The complete trajectory planning of the mobile robot.

Active IR receiver sensors are not able to reduce the processing time of the new localization method. Change the detection range of the IR receiver, by changing the dimensions of the IR receiver sensor, repeat simulation on the modified topology indicating the position of the different robot. The three different parameters used in this scheme are:

- A different number of IR receiver sensors in the environment.
- Execution time (in seconds) to reach the target with different detection ranges and different environments.
- The different target location comparisons in the shortest path and arrival time between the arc of the circle construction algorithm and the shortest orientation distance algorithm for different target locations.

Fig. 8 shows a snapshot of the robot's path plan in a 32 * 32-pixel environment. The purpose of this simulation is to show the execution times of different path plans in different types of environments and different detection ranges of IR sensors. Fig. 9. shows the average error occurred through the robot path planning among different types of the environment.

The different sensing range for the IR receiver sensors does not affect the average error because the robot chooses the nearest active IR sensor. but. Table.1. shows the comparison in the shortest path and the time of arrival in both the arc of the circle tangent construction algorithm [27] and the shortest distance orientation algorithm. The shortest distance orientation algorithm is defeated because it has the best short path with a minimum arrival time in comparison with the arc of the circle tangent construction algorithm through the path trajectory from source to target. Fig. 10. shows the complete robot path planning for different dimensional environments. Fig.11. shows the comparison of the arrival time for the robot path planning using the shortest orientation distance with different dimensional environments. (8*8)IR environment has the best(minimum) arrival time while (64*64) has the long arrival time because as the environment increases the number of IR sensor also increase and the scan process takes more time. while the 64*64 IR sensors environment produces a more accurate path planning than the other types of the environment as shown in Fig. 11. Also, the accuracy is increased in path planning as the IR receiver sensing range is increased, and for all types of the environments.

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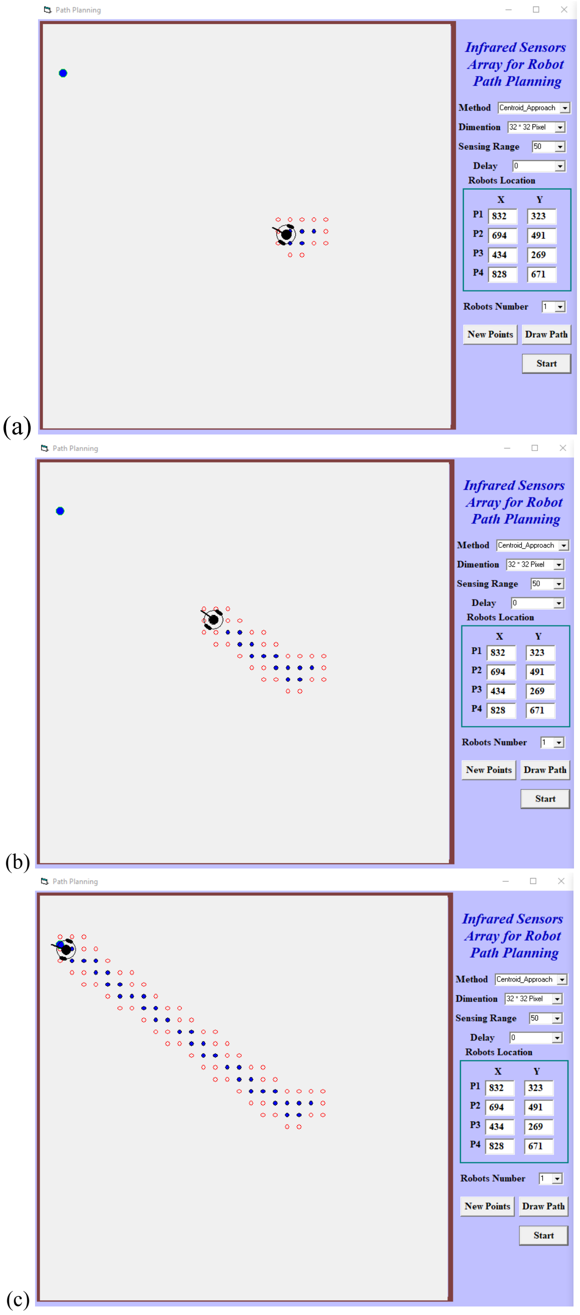

Fig.8. Snapshot for robot path planning in a 32*32 Pixels environment.

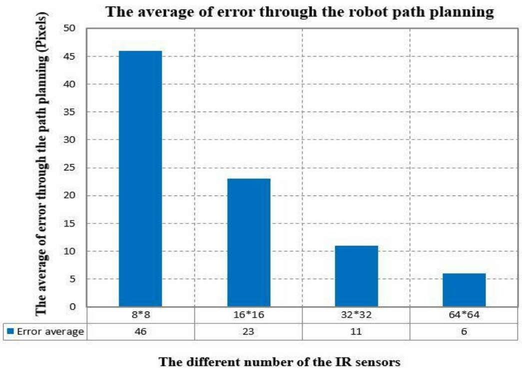

Fig.9. The comparison of the average error for different dimensional environments.

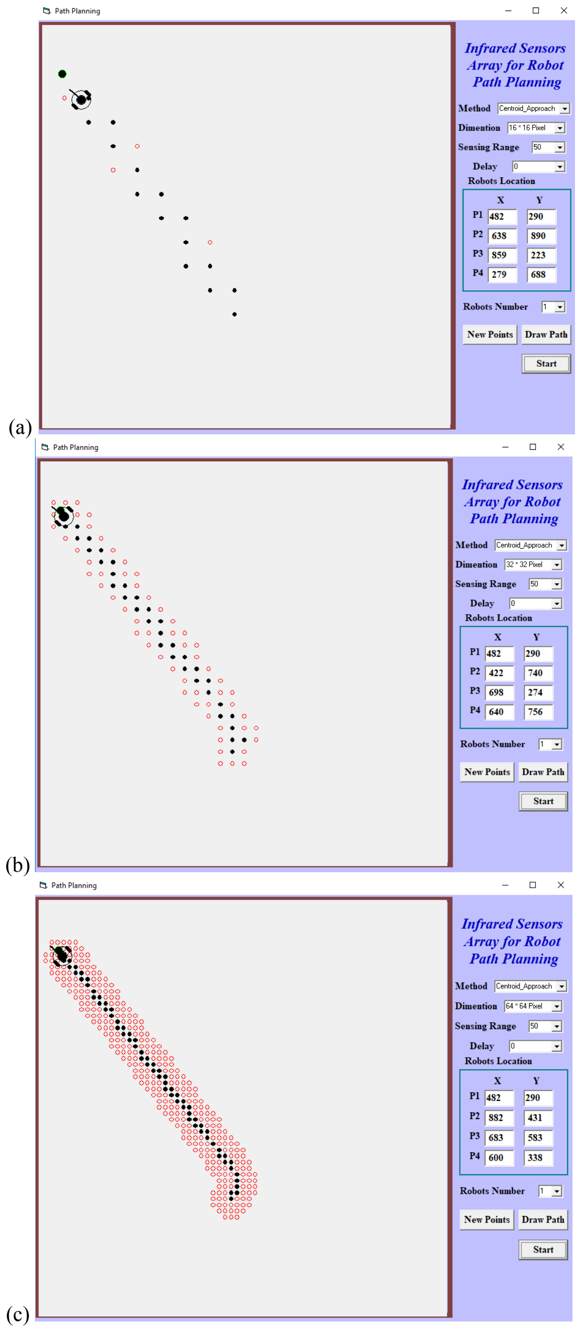

Fig.10. The complete robot path planning in different environments.(a) 16*16.(b) 32*32.(c) 64*64.

Table 1. compartion between the arc of circle tangent construction and the shortest orientation distance algorithms in distance and time.

Target location point (pixels)	Arc of circle tangent construction algorithm		Shortest distance orientation algorithm	
	The path length from source to target (Pixels)	Time of arrival (Sec)	The path length from source to target (Pixels)	Time of arrival (Sec)
(260,550)	271	2.413	260	2.275
(550,470)	496	5.225	490	5.150
(700,310)	623	6.813	620	6.775
(590,30)	567	6.113	564	6.075

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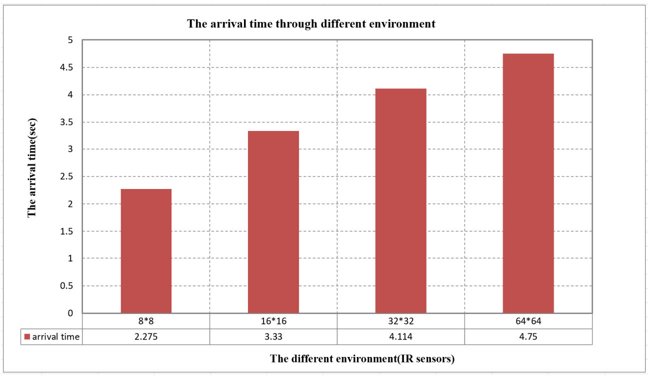

Fig.11. The comparison of the arrival time for the various dimensional environments.

IV. CONCLUSION

This paper proposed a new technique using low-cost IR transmitter-receiver sensors to solve the path planning of an indoor mobile robot system. The IR transmitter is fixed on the robot and the IR receivers are distributed uniformly in the environment with various dimensions. Two simulation results are discussed in this paper: The average error estimation through the path planning process and the execution time for the robot path planning. The results show that as the IR sensor in the environment increase, the execution time also increased while the average error is decreased. This happens because the larger number of IR sensors means higher computation time. And the sensing range in these simulations is not affected absolutely. Also, increasing the dimensional of the environment leads to increase the accuracy in path planning. The second simulation is the comparison between our previous arc of circle tangent algorithm with the proposed shortest distance orientation algorithm in the shortest path and the time of arrival and the result shows that the best one is the new algorithm which has less time in the robot arrivals time and shortest path for the robot trajectory.

REFERENCES

[1] B.Siciliano, L.Sciavicco, L.Villani, and G.Oriolo, "Robotics modeling and control, " Springer, ISBN: 978-1-84628-641-4 ,2008.

[2] J.v.den Berg, R.Shah, A.Huang, and K.Goldberg, "ANA*: Anytime nonparametric A*," Association for the Advancement of Artificial Intelligence, 2011.

[3] M. K. Jha, G. A. Karri, and M. Kang, " A military path planning algorithm using visualization and dynamic GIS," Recent advances in computer engineering and application, pp. 188-193, 2010.

[4] J.Kaur, Dr. V. K. Banga and G.Singh, "Robotic path planning using the intelligent control", International conference on advances in electrical and electronics engineering, 2011.

[5] N.R. Sturtevant, and R. Geisberger, "A comparison of high-level approaches for speeding up pathfinding," Association for the advancement of artificial intelligence, pp. 76–82, 2010.

[6] A.Botea, B.Bouzy, M.Buro, C.Bauckhage, and D.Nau, " A*-based Pathfinding in Modern Computer Games, " International journal of computer science and network security, vol.11, no.1, 2011.

[7] Ting.Wang, Q.Dang, P.Pan, "Path planning approach in an unknown environment," International Journal of automation and Computing, vol.7, no.3, pp. 310-316, 2010.

[8] B. Bonet, and H. Geffner, "Planning as a heuristic search", Artificial Intelligence-journal Elsevier, vol.129, pp. 5-33, 2001.

[9] E.Galceran, and M.Carreras, " A survey on coverage path planning for robotics", Robotics and autonomous systems, vol.61, pp. 1258–1276, 2013.

[10] M. Shahab Alam, M. Usman Rafique, and M. Umer Khan, "Mobile robot path planning in static environments using particle swarm optimization," International journal of computer science and electronics engineering, vol.3, 2015.

[11] H.Adeli, M.H.N. Tabrizi, A.Mazloomain, E.Hajipour, and M.Jahed, "Path Planning for mobile robots using iterative artificial potential field method," International Journal of Computer Science, vol.8, no.2, (2011).

[12] M.Hamani, and A. Hassan, "Mobile robot navigation in an unknown environment using improved APF method," The 13 the International Arab Conference on Information Technology ACIT, 2012.

[13] I. S. Alfurati, and Abdulmuttalib T. Rashid, "Performance Comparison of Three Types of Sensor Matrices for Indoor Multi-Robot Localization, " International Journal of Computer Applications (0975 - 8887), vol. 181, no. 26, pp. 22-29, 2018.

[14] O. A. Hasan, R. S. Ali, A. T. Rashid, "Centralized approach for multi-node localization and identification", Iraq J. Electrical and Electronic Engineering, vol.12, no. 2, pp. 178-187, 2016.

[15] I. S. Alfurati and Abdulmuttalib T. Rashid, "Multi-Robot localization system using an array of LEDs and LDR sensors," International Journal of Computer Applications (0975 – 8887), Vol. 176, no. 10, April 2020.

[16] J. Guivant, E. Nebot , and S. Baiker, "Localization and map building using laser range sensors in outdoor applications," Journal of Robotic Systems, vol.17, no.10, pp. 565-583, 2000.

[17] J. Guivant, F. Masson, and E. Nebot, " Simultaneous localization and map building using natural features and absolute information," Robotics and Autonomous Systems, vol.40, pp. 79–90, 2002.

[18] I. S. Alfurati and Abdulmuttalib T. Rashid, "Practical Implementation of an Indoor Robot Localization and Identification System using an Array of Anchor Nodes," Iraqi Journal of Electrical and Electronic Engineering, DOI: 10.37917/ijeee.16.1.2.

[19] V. Jungnickel, V. Pohl, S. Nönnig, and C. V. Helmolt, "A Physical Model of the Wireless Infrared Communication Channel ", IEEE Journal On Selected Areas In Communications, vol. 20, no. 3, pp.159-209, 2002.

[20] C. Galvan, I. G. Tejada, and R. Brena R, "Wifi Bluetooth based combined positioning algorithm," Proc Eng 35:101–108, 2012.

[21] Raghavan AN, Ananthapadmanaban H, Sivamurugan MS, Ravindran B, "Accurate mobile robot localization in indoor environments using Bluetooth," In 2010 IEEE international conference on robotics and automation, pp 4391–4396, 2010.

[22] G. Jekabsons, and V. Kairish, "An analysis of wi-fi based indoor positioning accuracy," Appl Comput Syst., vol. 44, pp. 131–137, 2011.

[23] Cho SH, and Hong S, " Map-based indoor robot navigation and localization using a laser range finder," 11th international conference on control automation robotics vision, pp 1559–1564, 2010.

[24] Yayan U, Yucel H, and Yazıcı A, "A low cost ultrasonic based positioning system for the indoor navigation of mobile robots," J Intell Robot Syst, vol. 78, no. 3, pp. 541–552, 2015.

[25] Mi J, and Takahashi Y, " Performance analysis of mobile robot self-localization based on different configurations of the RFID system," IEEE international conference on advanced intelligent mechatronics (AIM), Busan, Korea, pp 1591–1596, July 2015.

[26] I. S. Alfurati and Abdulmuttalib T. Rashid, " Design and Implementation an Indoor Robot Localization System Using Minimum Bounded Circle Algorithm," The 8th International Conference on Modeling, Simulation and Applied Optimization (ICMSAO'2019), 2019.

[27] I. S. Alfurati and Abdulmuttalib T. Rashid (2020), " An Algorithms for Robot Localization and Path Planning Using Low-Cost IR Sensors System, " The 2nd International Conference on Electrical, Communication, and Computer Engineering (ICECCE).(in press)

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