The 3rd Scientific Conference of Electrical and Electronic Engineering Researches (SCEEER) | (15-16) JUNE 2020 | BASRAH / IRAQ
DOI: 10.37917/ijeee.sceeer.3rd.7 (15-16) June 2020

Open Access

Iraqi Journal for Electrical and Electronic Engineering
Conference Article

# Robotics Path Planning Algorithms using Low-Cost IR Sensor

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**Abstract**
***A robot is a smart machine that can help people in their daily lives and keep everyone safe. the three general sequences to accomplish any robot task is mapping the environment, the localization, and the navigation (path planning with obstacle avoidance). Since the goal of the robot is to reach its target without colliding, the most important and challenging task of the mobile robot is the navigation. In this paper, the robot navigation problem is solved by proposed two algorithms using low-cost IR receiver sensors arranged as an array, and a robot has been equipped with one IR transmitter. Firstly, the shortest orientation algorithm is proposed, the robot direction is corrected at each step of movement depending on the angle calculation. secondly, an Active orientation algorithm is presented to solve the weakness in the preceding algorithm. A chain of the active sensors in the environment within the sensing range of the virtual path is activated to be scan through the robot movement. In each algorithm, the initial position of the robot is detected using the modified binary search algorithm, various stages are used to avoid obstacles through suitable equations focusing on finding the shortest and the safer path of the robot. Simulation results with multi-resolution environment explained the efficiency of the algorithms, they are compatible with the designed environment, it provides safe movements (without hitting obstacles) and a good system control performance. A Comparison table is also provided.***

**KEYWORDS: IR Sensors, obstacle avoidance, path planning Algorithms, Robotics.**

## I. INTRODUCTION

Robots are computer programmable devices that can automate certain actions. Much attention is paid to being able to replace a person with some tasks such as physical activity, decision making, and Special with the dangerous application. In the robotics field, one of the most important requirements is autonomous navigation. Robotic navigation is a strategic approach to the target position. this process includes four main components [1]: firstly is perception.it Extracts profit-related information via robots using sensors, the localization is the secondly, it is the process of locating the robot position in the employed environment; thirdly is the path planning, The robot achieves its goal by defining how to drive; finally is the motion control, The robot realizes the desired path by adjusting its movement. Nowadays, with the rapid increase in information technologies and multimedia facilities, localization and path planning techniques have improved greatly [2]. clearly in indoor environment, such as supermarkets, airport lobbies, exposition rooms, garages, etc. Robots are currently performing various tasks. The most basic requirement is localization technique. It is used to estimate the position and orientation of the robot depending on the environment and previous knowledge of the system such as the original position chart. Localization Techniques It is important because it is difficult to accomplish autonomous tasks without precise information about the location in an indoor environment. Path planning technique is defined as an organized sequence of transformation and alternation after the current position of the robot to the destination in the whole environment. however, there are two techniques: global and local path planning [3,4]. Typically, a global path developer creates a complex path that is built with low resolution on a specific environmental map on the other hand, the local path planning algorithm creates low-level paths and does not need to know the existing environment in advance based on the information obtained from the sensors. Works well in a dynamic environment range. However, this method is not suitable if the target location is identified. In general, mixing both approaches can remove some of their weaknesses and improve the benefits of mixing [5–7]. Robot systems can use sensors for communication, obstacle detection, distance measurement, etc. [8, 9]. Localization and path planning were the most important issues in choosing the right sensor for distance measurement in an automaton system [10]. Sensors such as infrared sensors, laser scanners and ultrasonic can be prepared by mobile robots for telemetry. [11-13]. As an alternative to expensive sensors such as cameras and laser scanners, low cost sensors in many applications are used to determine distance [14-16]. However, not only the design of the distance diagram is required for localization; the identity of the source and recipient of the localization algorithms is required to estimate contract locations and depends on the communication between the nodes. Still the main challenge is to looking for cheap internal system sensors to achieve communication between nodes which are the infrared sensors [17]. Some types of sensors have been used for the localization and path planning systems, such as LRFs, WiFi positioning, the RFID, ultrasonic positioning, Bluetooth technology, vision sensors, an infrared IR transmitter and receiver, and VLC visible light communication technology. Although the hardware required Bluetooth [18, 19] and WiFi [20] it is simply combined into mobile policies, both Bluetooth localization Systems and WiFi are simply disturbed because interfering with extra signals disturbs their precision. LRF [21] positioning and Ultrasonic [22] systems have the benefit of high precision and simple system construction. Even now, the two categories of sensors are still unable to detect indoor mobile robots correctly when the robot is surrounded by certain influences. LRF is limited by the transparent walls in the environment and is used in indoor environments. An accurate localization can be obtained using an RFID radio frequency identification system with dense and IC tags [23] in a reasonable configuration. In this paper, two algorithms were proposed to solved the path planning system using low-cost IR sensors. First of all, the robot position is detected using the modified binary search algorithm then two algorithms where proposed: Shortest orientation algorithm and active orientation algorithm to move the robot safely from its original place over its trajectory to the target. The paper is ordered as follows: Section (II) path planning algorithms using IR sensor system, Simulation results are presented in section (III) To finish, in (IV) conclusions are conferred.

## II. PATH PLANNING ALGORITHMS USING AN IR SYSTEM

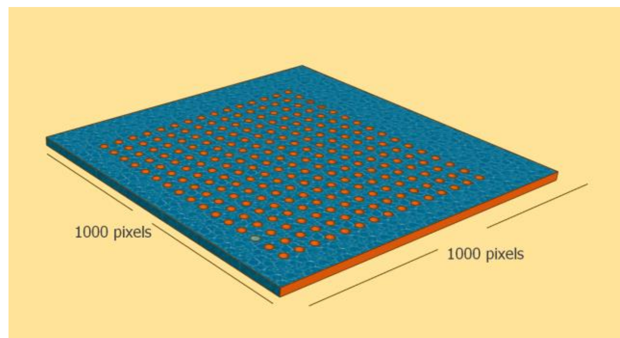
This section introduces a proposed algorithm for indoor path planning structure built on the activation of IR receiver sensors that are regularly distributed in the work environment. These IR sensors are used to locate the robot's position through the robot moving towards the target. The robot's primary location is detected by scanning the environment using a modified binary search algorithm. Virtual trajectories represent the paths that a robot follows to scope a target. As a result, the IR receiver sensor within the detection range of the virtual orbit becomes active. The robot follows the trajectory represented by these activated IR sensors and scans only these activated IR receiver sensors to calculate the position at each step of the move.

### A. *The Initial Position of The Mobile Robot*

The planned system consists of a 2-D environment with several holes distributed regularly. In Fig. 1, each hole is equipped with one IR receiver sensor. The IR sensors in this system arranged into two groups. The first represents one IR transmitter sensor equipped with the base of the mobile robot, and the second represents an array of IR receiver sensors of various sizes regularly placed in the environment. The central unit scans rows of IR receiver sensors row by row to identify signals from IR transmitters on the robot.

Fig. 1: Environment of (16*16) array of holes.

Only IR receiver sensors that are within range of the IR transmitter are identified. The identified sensors are then instantiated as a group and the centroid algorithm is used to detect the robot's position from the identified receiver sensor scene. The first localization process relies on scanning every column of the IR receiver array using a modified binary




search algorithm. It works in logarithmic time, it is a simple calculator technique and can be improved. Search development is good at splitting a cluster many times. The search limited the exhibit to the lower part if the search volume value was less than the middle entry in the array. Others were limited to the higher parts. It will be checked continuously until the required number is encountered or the array is filled. At each stage of the algorithm procedure, the beginning and end of the last part of the array must be recalled. This calculation is multifaceted and depends on the logarithm of the exhibit size [24]. In this paper, the localization process relies on the use of a modified binary search algorithm to find the initial position of the mobile robot. The differences between the proposed algorithm and the binary search algorithm are summarized in the resulting steps.

### B. *The Modified Binary Search Algorithm*

In this paper, the localization process relies on the use of a modified binary search algorithm to find the initial position of the mobile robot. The differences between the proposed algorithm and the binary search algorithm are summarized in the resulting steps.

*1) The Binary Search Algorithm:* is built using decimal numbers, so the sort order is the first period of the algorithm. However, this system uses two logical principle states. One is for the active IR receiver sensor, 0 is inactive. As a result, no sorting sequence is needed at this stage. The (Infrared sensor) IR receiver sensor is arranged in the 2D array; consequently, the matrix search algorithm is applied to each row and the column of this array.

*2) In This Environment*: several IR receiver sensors are used later and the search procedure is a convention for multiple values at once. Since the position of each IR receiver sensor is known, it can be used to estimate the position of the information robot, which consists of the robot IR transmitter sensor.

*3) The Progress of the Localization Process:* begins with a modified binary search algorithm, crossing the rows of the IR receiver sensor array. The IR receiver sensor symbolizes each column within the sensing range, one by one, plus zero. This technique is repeated until each IR is labeled. A sensor within the detection range with a value of 1. As a result, the information from the active IR receiver sensor is sent to the microcontroller to detect the robot's position.

## C. *The Robot Orientation Estimation*

The robot's current orientation is very important for drawing the line follower path. To do that, the robot will take a step forward which is shown in Fig. 2, Use the modified binary search algorithm to compute the proposed location of the robot. By knowing the last and the current location we can estimate the robot orientation according to (1).

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

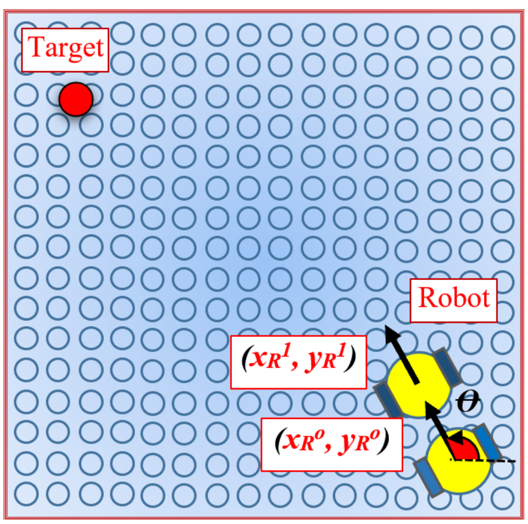



Fig. 2: Estimate the robot orientation.

Where $\theta$ is the robot orientation. (xRo, yRo) is the coordinate axis for the robot at position o and (xR1, yR1) is the coordinate axis for the robot at position 1.

## D. *The Robot Path Planning Algorithms*

This section proposed two algorithms for the robot path planning of the mobile robot toward the target.

### 1) *Shortest Orientation Algorithm*

This algorithm distinguishes the active IR receiver sensors that need to be scanned, estimates the robot's current position, calculates the direction of the straight line between the robot's and the target's position, and finally detected the direction of the straight line. The flow chart that describe the algorithm is shown in Fig.3.

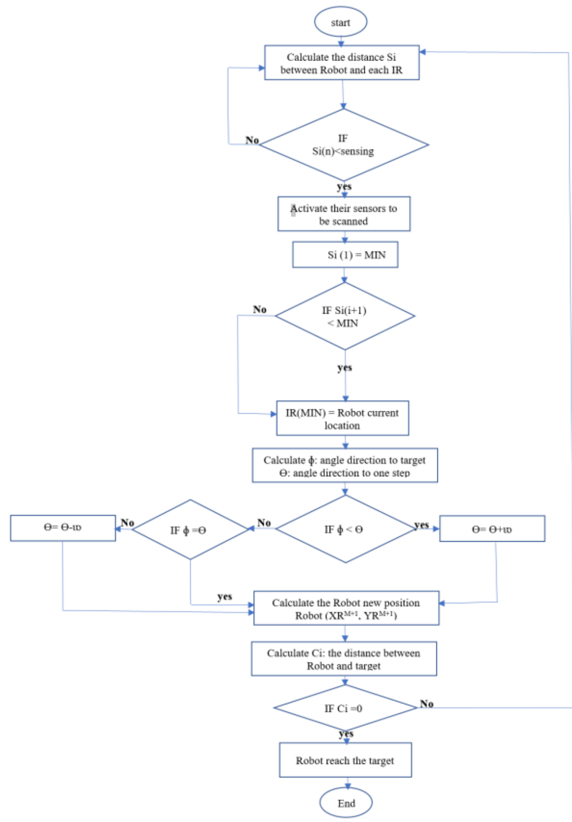



Fig. 3: The flow chart describes Shortest Orientation Algorithm

This algorithm requires some steps to compare with Robot orientation or adjustment to determine robot orientation. The following steps describe the robot orientation adjustment.

**Step1:** First, identify the active IR receiver sensor that needs to be scanned. This process is accomplished by measuring the distance between the robot's current position and the position of all IR receiver sensors using (2).

$$S_i = \mathrm{Sqrt}((y_{ir}^N - y_R^M)^2 - (x_{ir}^N - x_R^M)^2) \qquad (2)$$

Where Si is the distance between the IR sensor N and the robot at position M. (xirN, yirN) is the coordinate axis for the IR sensor N and (xRM, yRM) is the coordinate axis for the robot at position M. The IR sensor with distance less than it in the sensing range must be activated as shown in Fig. 4.

**Step2:** In this step, we need to estimate the current status of the mobile robot. This process is performed using a linear search algorithm. The algorithm may check the active infrared sensor and treat the nearest infrared sensor as a current position of the mobile robot that is shown in Fig. 5.

**Step3:** The orientation of the direct line between the current location of the mobile robot and the target location must be computed using (3).

$$\phi = \tan^{-1}\left((y_g - y_R^{M}) / (x_g - x_R^{M})\right) \quad (3)$$

Where $\phi$ is the direct line orientation between the target position and the robot in position j as shown in Fig. 6. (xg, yg) is the coordinate axis for the target.

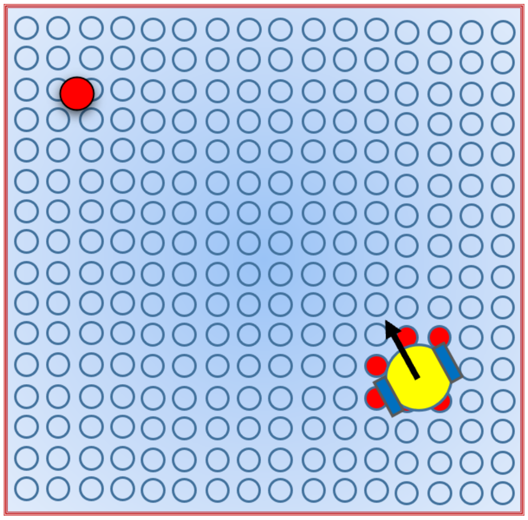


Fig. 4: Estimate the active IR receiver sensors.

**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 (4) and (5).

$$\theta = \theta + \omega \quad \{\theta < \phi\} \quad (4)$$
$$\theta = \theta - \omega \quad \{\theta > \phi\} \quad (5)$$

where $\omega$ is the magnitude of changing in the direction of the robot at each step of the movement.

**Step5:** Dependent on the current position and orientation of the mobile robot, the next position is computed using (6) and (7).

$$x_R^{M+1} = x_R^{M+1} + L * \cos(\theta) \quad (6)$$
$$y_R^{M+1} = y_R^{M+1} + L * \sin(\theta) \quad (7)$$

Where L is the increment distance at each step of the robot movement. (xRM+1, yRM+1) is the coordinate axis of the mobile robot at the next movement.

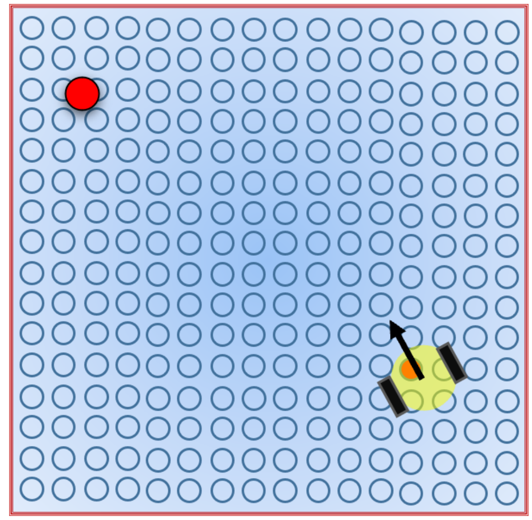


Fig. 5: Estimate the current location of the mobile robot.

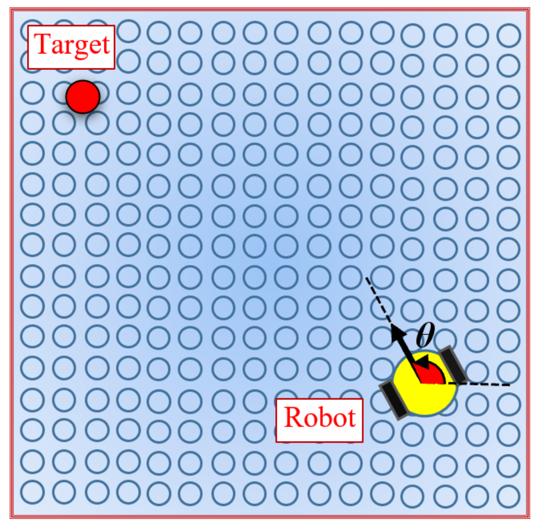



Fig. 6: The orientation of the direct path between the robot and the target.

**Step6:** In this step, the proposed orientation of the robot calculated in the previous section and the calculation of the next location (step 1) are repeated until the robot reaches the target. (8) is used for this proposal.

$$C_i = \mathrm{Sqrt}\left((y_t - y_R^{M})^2 - (x_t - x_R^{M})^2\right) \quad (8)$$

Where Ci is the current distance between the robot and the target position.

*2) Active Orientation Algorithm*

This algorithm defines the phases for construction a virtual trajectory from the initial position to the destination for the mobile robot using the algorithm of a tangent visibility graph. The flow chart that describe the algorithm is shown in Fig.7.

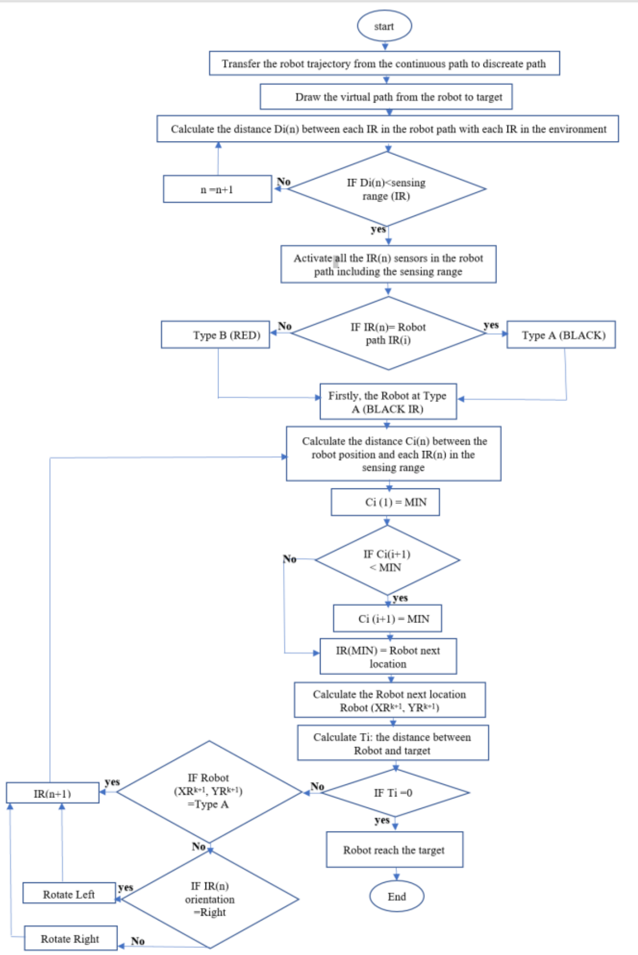



Fig. 7: The flow chart describes Active Orientation Algorithm

The process is summarized by searching for the shortest path for the mobile robot by assuming the shortest path between the robot trajectory path to the destination. The investigation of this method is characterized:

**Step 1:** First, the trajectory of the robot is transferred from the continuous path to the discrete path. This discrete path simplifies the process of distinguishing adjacent IR receiver sensors.

**Step 2:** Activate the IR receiver within the detection range of the individual arguments of the robot trajectory described in Fig.8. This process helps reduce localization time by reducing the number of IR receiver sensors that are scanned.

**Step 3:** classified two types of active infrared receiver sensors: The infrared sensor (black) on the robot path is marked as type A, and the infrared sensor (red) near the robot path is marked as type B. Fig. 9. This arrangement helps control the robot orientation during the moving process.

**Step 4**: At first, the robot location is at the first A-type IR receiver sensors. Use equation 1 to compute the orientation of the line between the first and the second A-type of IR sensors. If the orientation of this line is greater than the robot orientation then the robot orientation must be enlarged to its first step movement, else it must be decreased.

**Step 5:** At the current position, if the closeness active IR sensor is from A-type then the robot must repeat step one. If the closeness active IR sensor is from B type and located at the right side of the A-type active IR sensor that is shown in Fig. 10, the robot must turn left at it is next movement step else it must rotate right.

**Step 6:** Repeat Step one and step two until the robot scopes the target point.

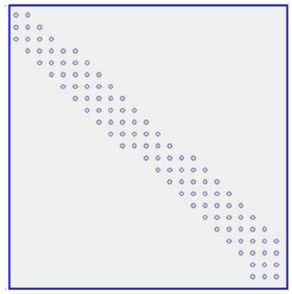


Fig. 8: Discretion the robot trajectory.

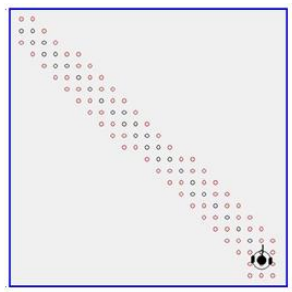


Fig. 9: Separate The active IR sensors into two types.

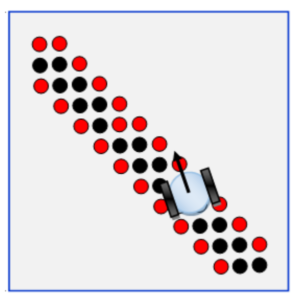


Fig. 10: Control the robot's orientation.

## III. THE SIMULATION RESULTS

The proposed indoor path planning algorithms are simulated using the VB programming language. The simulated environment consists of various (8*8, 16*16, 32*32 and 64*64) IR receiver sensors with (1000*1000) pixels dimensions which distributed regularly in the environment, the first step in this procedure is to find the robot position by using the scan process using a proposed algorithm called the modified binary search algorithm.

A proposed path planning algorithm called the shortest orientation and the active orientation algorithms are used to determine the path planning from the robot source to the target location. An active IR receiver sensor are distinguished to reduce the processing time of localization proposed techniques. The simulations are repetitive for changed topologies illustrative a different robot position, by changing the dimensionally for the IR receiver sensors. The parameters used in this scheme are:

*1) The Various Number of IR Receiver Sensors in the Environment.*

*2) The Execution Time (second) for the Robot to Reach the Target for Different Sensing Rang and Different Environments.*

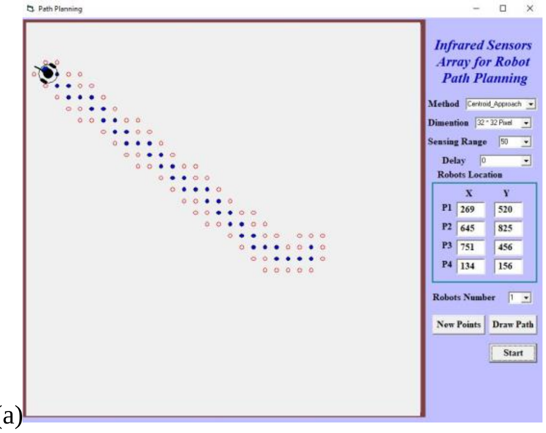
Table.1. shows the comparison in the path distance and the time of arrival between the active orientation algorithm and the shortest orientation algorithm, each of them wok in a multi-resolution environment without obstacle colliding their path.

the shortest orientation algorithm is the best because it has a minimum distance path with low arrival time in comparison with the active orientation algorithm through the path trajectory from source to target.Fig.11, and Fig. 12, shows the snapshot for robot path planning in a 32*32 Pixels environment using the shortest orientation and the active orientation algorithms. The goal of these simulations is to show the different path planning execution times in different types of environments.

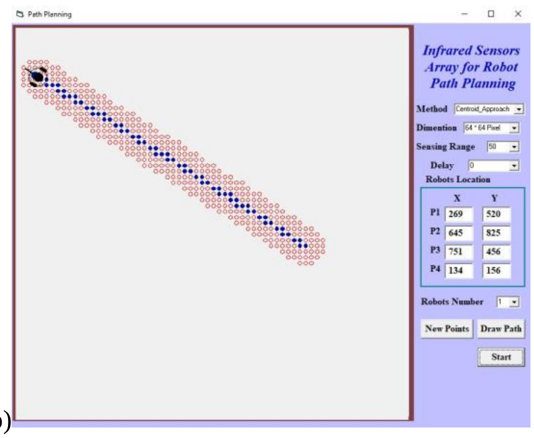
TABLE I

PERFORMANCE COMPARISON WITH DIFFERENT TARGET LOCATIONS FOR BOTH THE ACTIVE ORIENTATION ALGORITHM AND THE SHORTEST ORIENTATION ALGORITHMS.

| Target location (pixels) | active orientation algorithm | | shortest orientation algorithm | |
|---|---|---|---|---|
| | The shortest path (Pixels) | Time of arrival (Sec) | The shortest path (Pixels) | Time of arrival (Sec) |
| (360,650) | 279 | 2.741 | 253 | 2.013 |
| (650,570) | 503 | 5.533 | 430 | 4.21 |
| (800,410) | 634 | 7.32 | 520 | 5.442 |
| (690,130) | 598 | 6.617 | 407 | 5.79 |



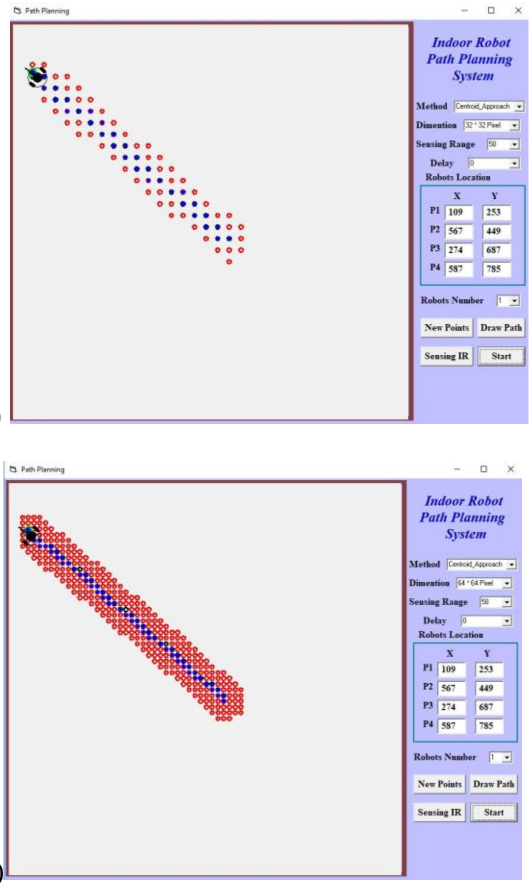

(a)




(b)

Fig. 11: Shortest orientation path planning algorithm in 32*32 and 64*64 Pixels

Fig. 13, shows the robot path planning comparison among different types of the environment and different path planning algorithms. The execution time is increased as the number of the IR sensors increase and also, the shortest orientation algorithm has less execution time than the other algorithm. the second simulation shown in Fig. 14, and Fig. 15, shows the complete robot path planning for different dimensional environments. Fig. 16, shows that the (64*64) IR sensors environment produces a more accurate path planning than the other types of the environment. Also, the shortest orientation algorithm has more accuracy than the other algorithm.




(a)

(b)

Fig. 12: Active orientation path planning algorithm in 32*32 and 64*64 Pixels environment.

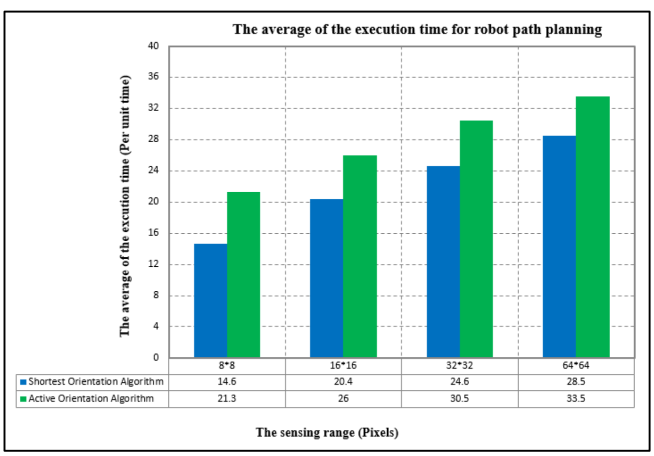
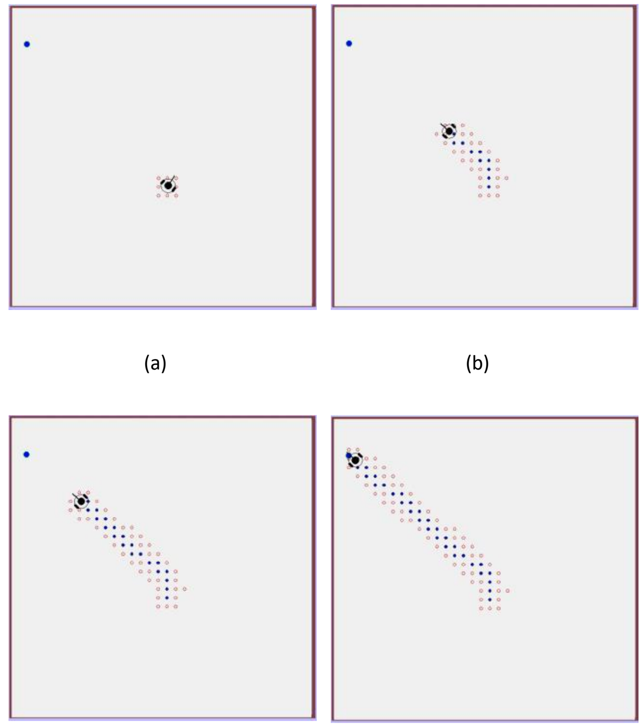


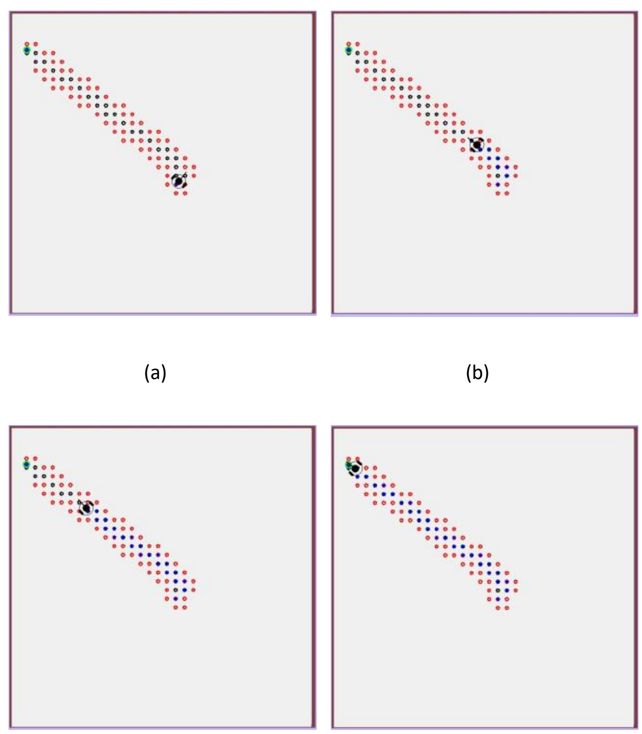

Fig. 13: The execution time comparison for different environments.



(a) (b)

(c) (d)

Fig. 14: The snapshot for the shortest orientation path planning algorithm.



(a) (b)

(c) (d)

Fig. 15: The snapshot for active orientation path planning algorithm.

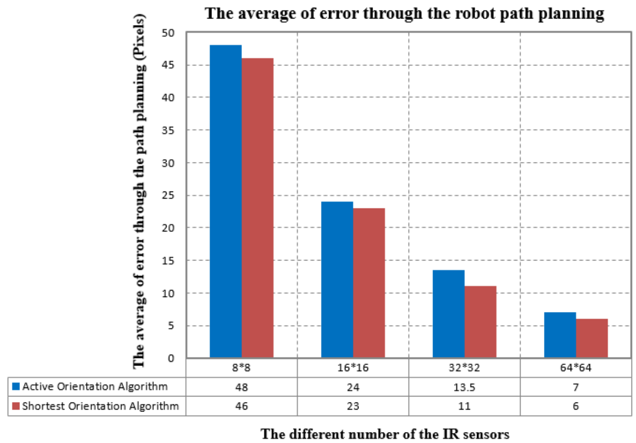



Fig. 16: The average of the error comparison between the shortest orientation and the active orientation algorithm.

## IV Conclusion

This paper proposed a new technology using low-cost transmitters and receivers for path planning of an internal mobile robot system. The IR transmitter is installed on the robot and the IR receivers are uniformly distributed in the environment in various dimensions. Two simulation results are discussed in this paper: The execution time for the path planning and the error estimation through the path planning process. Table of comparison also applied. In general, the results show that as the sensing range of the IR receive sensor increased, the execution time is increased and when the dimension of the environment increases the execution time also increases. This happens because the larger number of IR sensors means higher computation time. The second simulation results show that as the IR receiver sensing range rises the average of estimated error is reduced. Also, increasing the dimensional of the environment leads to increase the accuracy in path planning. furthermore, the shortest orientation algorithm is the best in comparison with the active orientation algorithm, which has less execution time and less average errors in a different environment during the robot simulation.

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