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Smart Navigation with Static Polygons and Dynamic Robots

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Abstract
Due to the last increase in data and information technology, the need to use robots in many life areas is increased. There is a great diversity in this field, depending on the type of task required, as the robot enters the parcels of air, land, and water. In this paper, a robot's mission designed to move things is concentrated, relying on line-tracing technology that makes it easy to track its path safely, the RFID is distributed in its approach. When the robot reads the RFID tag, it stops until it raises the load from above, the robot continues its path toward the target. When an obstacle obstructs the robot path, the robot deviates and returns after a while to its previous approach. All this technology is implemented using a new algorithm which is programmed using the visual basic program. The robot designed to transfer the stored material is used according to a site known as an identifier that is identified by the RFID value, where the robot is programmed through a microcontroller and a unique store program that determines the current location and the desired location, then is given the task for the robot to do it as required. The robot is controlled using an ATmega controller to control other parts connected to the electronic circuit, the particular infrared sensor, and ultrasound to avoid potential obstacles within the robot's path to reach the target safely. In addition to this, the robot is made up of an RFID sensor to give unique to each desired target site. Through the console, it is possible to know the link indicated by the target. The H-bridge is also used to obtain a particular command and guide the robot as needed to move freely in all directions and a DC motor which is unique for moving wheels at the desired speed, and Bluetooth for programmable and secure wireless transmission and reception with all these parts through a unique program that also uses application inventory. The robot has proven to be a great success in performing the required task through several tests that have been practically performed.

KEYWORDS: Robot Auto Movement, Navigation System, Line-Tracing Technology, RFID.

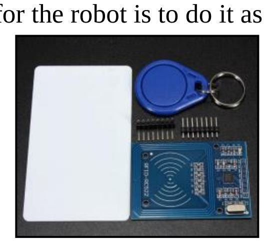
I. Introduction

Robot navigation is a strategic approach to your target location. Automatic steering is one of the most critical requirements of smart cars [1]. Autopilot is one of the most important aspects required to use in an intelligent robot application. Robot steering is a deliberate approach to the target location, with smart technology, observing sensors that can detect real remoteness. It should also be a low-slung cost [2]. Positioning mobile robots have proven to be a difficult job due to numerous physical restrictions. The field of moveable robots, robot localization systems, and formations are essential. The Multi-robot team can be used for a variety of responsibilities, such as monitoring, inspection, or organization. In such a way, robots' scenarios may be needed to direct data and recover route development [3]. The famous method of localization is the Global Positioning System (GPS). Still, it is difficult to use this method regularly due to its power consumption, high cost, and considerable size constraints. Furthermore, since GPS is not used in indoor environments, this is attracted to increased attention to suggest procedures that discourse indoor location needs [4]. The wireless sensors network (WSN) consists of numerous protuberances of distinctly separated sensors to coordinately display conservational conditions, including ship navigation, traffic monitoring, ship navigation, object tracking, ship navigation, and radiation level measurements from reactors [5]. There are various applications in the (WSN) such as 24-hour care volcanic outbursts. The sensor is an inconsequential instrument used to degree or intelligence of approximately the usual amount. It converts it into a new signal through some relationship that a man can read for display or subsequent processing. It is also used for various gauges such as distance, sound, movement, pressure, temperature, and light intensity [6]. With smart technology, sensors that can distinguish precise distances are needed. It must provide a low-cost. LED sensors are of low cost, and accuracy is valuable. Additionally, the lights are expected to last for many years. Moreover, unlike infrared and laser, the light is harmless to the human body and does not intersect with electronics' effects in the same environment [7]. The above features make LEDs a very suitable option for use in localization scenarios. In a hands-on trial, you can use a low-cost LED and LDR to test an optical sensor. Several methods of indoor positioning are used, including ultra-wideband based systems, Wi-Fi [8], RFID [9], Bluetooth [10], infrared, and ultrasound [11]. Given the urgent need to use robots in multiple areas of life, there is a great diversity in this field, depending on the type of task required, as the robot enters the air, ground, and water fields [12]. In this research, the mission of the robot designed to move objects is concentrated, depending on the technology of line follower, which make it easy to track its path safely, RFID is distributed in its way, and when the robot read the RFID tag, it then stops until Lift the load from above then the robot continuo its path toward the target point. When an obstacle obstructs the robot path, it deviates and returns after a while to its previous track. All this technique is done through the ultrasonic sensor. The robot designed to transport stored materials is used according to a site known as the ID specified by RFID value. It is Program the robot through a microcontroller and a unique store program that determines the current location and the desired location. The mission is given to the robot to perform it as required [13] [14]. Given the urgent need to use robots in multiple areas of life, there is a great diversity in this field, depending on the type of task required, as the robot enters the air, ground, and water fields [15]. Many researchers use traditional actuators, multiple motors, pistons, joints, links, hinges, and more to build underwater robots to meet biomimetic design and analysis-based motion requirements [16]. Also, many underwater robots have it. Developed robots work well, but robots are gigantic because they require many actuators and other additional components to achieve performance or meet specific requirements. The robot has proven an essential success in performing the required task through several tests that have been conducted in practice [17]. Today, robotics is one of the best technologies for robot control, information processing robots, computer system design, work, and application. This technology also handles automated machines and is very useful in the manufacturing process [18]. As a result, many show great interest in this technology from the engineering level [19].

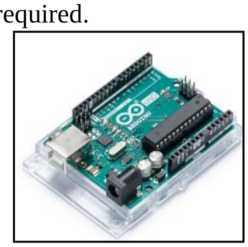
Additionally, these robotic systems help reduce stress-related health issues. Most of the work in this area has been carried out using sensor networks. One of the earliest examples of this type is nursery [20], an interactive playground for children. The robot is controlled by the Arduino Uno, who controls other parts related to the electronic circuit, a unique infrared sensor, and an ultrasound sensor to avoid possible obstacles within the robot's path to reach the target safely [21]. In this paper, a robot's mission to move things is concentrated, relying on line-tracing technology that makes it easy to safely track its path; the RFID is distributed in its way. When the robot reads the RFID tag, it stops until it raises the load from above, the robot continues its path to reach the target [22]. When the robot finds an obstacle in its way, the robot deviates and returns after a while to its previous path. All this technology is implemented through the ultrasonic sensor, the robot designed to transfer the stored material is used according to a site known as the identifier identified by the RFID value, where the robot is programmed through a microcontroller and a unique store program that determines the current location and the desired location. It is given the task for the robot to do it as required [23]. An ATmega controller controls the robot to prevent other parts connected to the electronic circuit, the particular infrared sensor, and ultrasound to avoid potential obstacles within the robot's path to reach the target safely [24]. In addition to this, the robot is made up of an RFID sensor to give unique to each desired target site. Through the console, it is possible to know the link indicated by the target. The H-bridge is also used to obtain a particular command and guide the robot as needed to move freely in all directions and a DC motor which is unusual for moving wheels at the desired speed and Bluetooth for programmable and secure wireless transmission and reception with all these parts through a unique program that also uses application inventory. The robot has proven to be a great success in performing the required task through several tests that have been practically performed. The rest of the paper is ordered as Section (II) describe the building and the structure of the mobile robot, section (III) explain the navigation algorithm in a static and dynamic environment; Simulation is offered in section (IV). Finally, conclusions are conferred in (V).

II. The Mobile Robot Design Structure

In this paper, a robot's mission designed to move things is concentrated, relying on line-tracing technology that makes it easy to track its path safely; the RFID is distributed in its way. When the robot reads the RFID tag, it stops until it raises the load from above, the robot continues its path toward the target point. When an obstacle obstructs the robot path, the robot deviates and returns after its previous course. Fig. 1. shows the components used inbuilt the mobile robot. All this technology is implemented through the ultrasonic sensor, the robot designed to transfer the stored material is used according to a site known as the identifier identified by the RFID value, where the robot is programmed through a microcontroller and a unique store program that determines the current location and the desired location, then is given the task for the robot is to do it as required.



(a)



(b)

Fig. 1: The component used inbuilt the mobile robot: (a) the RFID tag and reader system, (b) the Arduino Uno microcontroller, (c) the ultrasonic sensor, and (d) the H-bridge drivers.

(c)

(d)

Fig. 1: Continued

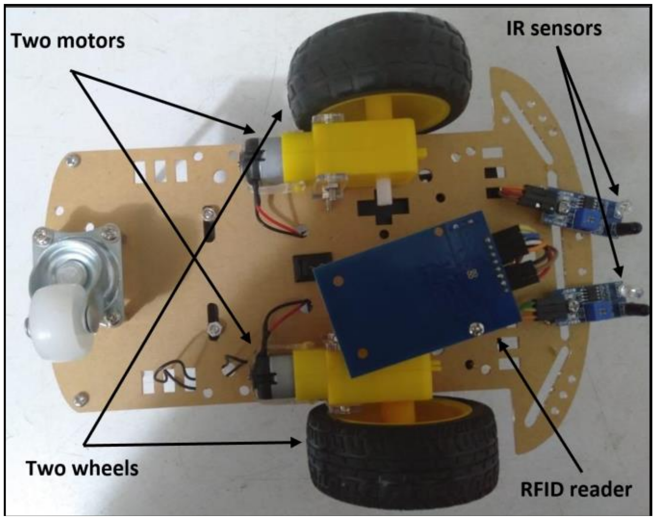


Fig. 2: Robot (lower view design).

In addition to this, the robot is made up of an RFID sensor to give unique to each desired target site. Through the console, it is possible to know the link indicated by the target. The H-bridge is also used to obtain a particular command and guide the robot as needed to move freely in all directions and a DC motor which is unique for moving Wheels at the desired speed, and Bluetooth for programmable and secure wireless transmission and reception with all these parts through a unique program that also uses application inventory. The robot's upper view design is shown in Fig. 3.

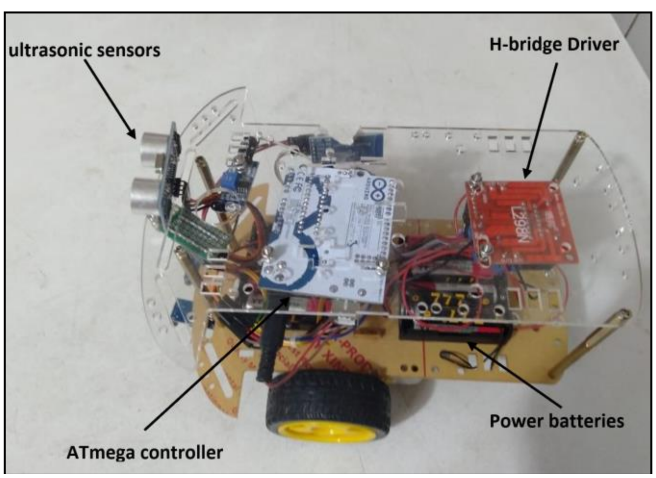


Fig. 3: The robot upper view design.

III. Navigation Algorithm In A Static And Dynamic Surrounding

This section explained the proposed algorithm that is compatible with using it with the proposed simple robot design. The environment is built using the RFID tags that are distributed regularly in the surroundings to design an RFID radio frequency identification system that the robot uses to move onto it concerning the RFID reader on the robot lower side. The robot's initial position is defined randomly using an order from the proposed algorithm to detecting it; on the other hand, the goal position is also determined using the same scenario. The RFID sensors in the work environment are used for detecting the robot position in real-time. The robot movement in the background is obtained using the digital differential analyzer algorithm [25]. The collision is prevented using a new suggested technique. There are two types of colliding in the crash: the polygon obstacles and the dynamic robot’s movement. The proposed algorithm is used in an indoor static environment, where the goal position is assumed to be fixed [26].

A. The Digital Differential Analyzer line drawing

This section deals with drawing the robot's path line from the source point of departure until reaching the goal point—the robot follows the proposed path marked using the DDA algorithm. With the digital differential analyzer algorithm, the robot's travel along a straight or curved line is carried out securely (DDA). This algorithm is an exponential process, and the outcome from the previous step is used for the next steps and so on at each point before the target is achieved. They coordinate with a higher shift by a unit step in the DDA algorithm, and then the step value in another coordinate is determined according to the algorithm protocol. In calculating the line pixels, the DDA algorithm is more straightforward than the direct line equation since it reduces the number of multiplications using the raster functions. The roundoff error in successive floating-point increment adds that the measured pixel locations may drift away from the correct line direction for long line segments. In comparison, in procedure line DDA, the rounding operations and floating-point arithmetic are still time-consuming. The line drawing process in the DDA algorithm begins with the line equation:

$$Y = nx + c \tag{1}$$

Where the slope of the line is n, and the phase value is c. The line (n) slope is a significant element used to draw the bar centred on it [27]. We have 2 cases depending on the value of m:

1) Case 1: (C <1):

When x increases more than y, as seen in Fig. 4, the derivative value of ((dy/dx) (c)) is less than one. In such cases, the line is drawn using the steps below:

- Draw the first point (x_1, y_1) on the line and let $x=x_1$ and $y=y_1$.
- Calculated the new values (to x and y) using the following equations:

$$x_{k+1} = x_k + \frac{dy}{dx} x_{k+1} \quad (2)$$

$$y_{k+1} = y_k + (\frac{dy}{dx} y_{k+1}) * C \quad (3)$$

- Draw the new calculated point (x, round(y).
- If x $\neq$ x2, then go to step 2.

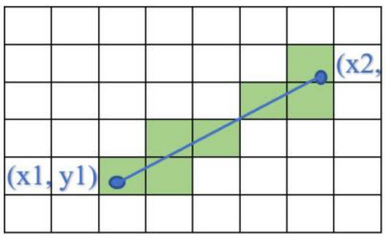


Fig. 4: The line drawing algorithm (DDA) (C < 1).

2) Case 2: (C >1):

When y increases more than x, as seen in Fig. 5, the derivative value of ((dy/dx) (c)) is greater than one. In that case, the line is drawn using the measures below:

- Draw the first point (x_1, y_1) on the line, and let $x=x_1$ and $y=y_1$.
- Calculate the new values (to x and y) using the following equations:

$$y_{k+1} = xy_k + \frac{dy}{dx} y_{k+1} \quad (4)$$

$$x_{k+1} = x_k + (\frac{dy}{dx} x_{k+1})/c \quad (5)$$

- Draw the new calculated point (round (x), y).
- If y $\neq$y2 then go to step 2.

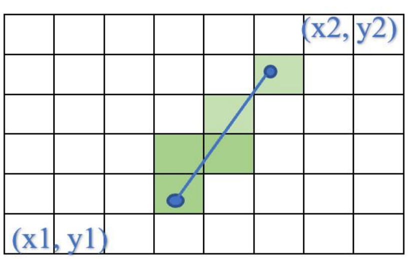


Fig. 4: The line drawing algorithm DDA (C > 1).

Where (k) is the integer number beginning from (1) and increases by (1) for each step before the target point is reached and (dx/dy) (k+1) and (dy/dx) (k+1) are the number of pixels in the direction of the x-axis and y-axis, depending on the speed of the robot. By splitting the increments (c) and (l/c) into integer and fractional sections, the DDA algorithm's output can be enhanced so that all calculations are reduced to integer operations. As an integer operation, the incrementation of (y) by (c) and x by (1/c) can be performed. Since the ratio of two integers equals the slope (c=dy/dx), By setting the counter to zero and increasing it by (dx) each time a new pixel is computed, the increment of (x) by (dx/dy) can then be achieved. If the counter is equal to or greater than (dy), so the points of intersection of (x) are expanded by one, and the counter decreases by one (dy).

B. The surrounded vertices algorithm (SVA)

The proposed algorithm is used to calculate the minimized circle that is surrounded by the polygon vertices for all the obstacles in the work environment. This circle is assumed to be enclosed to all the points of vertices. At first, the circle is contained zero points and then the point is increasing by one (in a randomized manner) until reaching the (q) points that are enclosed to all the vertices of the polygon. Then the polygon obstacles are assumed to be consist of (ss) vertices and the circle that is surrounding the obstacles is consists of at least two-point to define the initial diameter of the circle. In a spatial case when there is more than two-point, the solution is used to subdivide the circle into many arcs and each arc is defined by (π/number of the point). Let the surrounding system consist of a set of polygons and each one consists of o vertices, where O= {o1, o2, o3, … …, o_{ss}}, then the smallest circle is calculated using the following steps:

1) The center of the first circle (C_1) is chosen in a randomized manner from the set of o vertices, and the initial radius is assumed to be zero.
2) The next vertices are chosen randomly from the set of O vertices (from i=2 to i=ss), then a new dimeter is calculated between two vertices and the new center is assumed to be (C_{i-1}).
3) The new circle boundary is updated according to the last diameter and last center until all the surrounding vertices are enclosed by the last circle as shown in Fig.5.

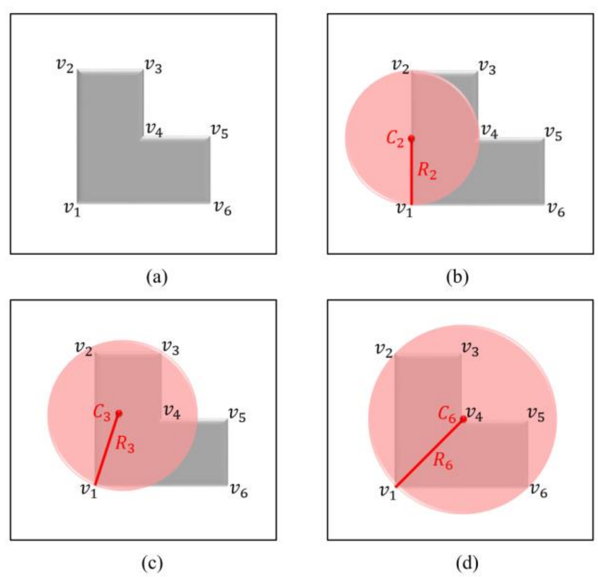


Fig. 5: SVA steps algorithm: (a) polygonal (with 6 vertices), (b) The minutest circle (enclosed the v1 and v2 vertices), (c) The minutest circle (enclosing v1, v2, and v3) vertices, and (d) The minutest circle (enclosing the whole polygonal).

C. *The Robot speed control*

The mobile robot's speed in this segment is regulated based on the robot's source location and the measured distance between the robot and the target point [28]. The rotation speed is believed to be negligible, so when the robot hits the tangent vertex point to change the direction of rotation towards the target, the robot speed is decreased (Smin). Let (Inial-Tangent-Dis) is the distance between the robot's source location and the target point, and the suggested mobile robot speed control strategies are:Calculate the length of the line (between the source position of the robot and the tangent point) with the vertices in the robot way (Sor_ Tan _Length).

1) When the actual range between the source position of the robot and the target position is greater than 2/3 of the original size, the speed of the robot must increase. The robot's speed is increased by a small amount (S1) of pixel/unit time, so the robot's speed at each stage is equal to:

$$Sr = Sr + S1 \tag{6}$$

The robot speed is then increased until reaching the maximum speed and at these speeds the robot keeping it persistent.

When the actual range between the source position of the robot and the target position reaches (2/3) of the original size, the speed of the robot must increase.

The robot speed is increased by a small amount of (S1) pixel/unit time, and the robot speed at each step is equal to:

$$Sr = Sr + S2 \tag{7}$$

Where (S2) is less than (S1). Also, the robot speed is then increased until reaching the maximum speed and at these speeds the robot keeping it constant.

2) Steps (2 and 3) are repeated until the distance between the source position of the robot and the tangent is minimum than half the starting distance.

3) step 4 is repeated until the tangent point is reached, and so on toward the goal point.

A. *The collision-free path*

In this section, the collision predicated between any two robots is prevented by calculated the predicted trajectory of the robot and estimate the point of intersections using the following steps:

1) The source position and velocity of the mobile robot and all other robots are calculated.

2) The next position for all of them is calculated using the following equations:

$$x(t) = x0 - vt \sin \emptyset \tag{8}$$

$$y(t) = y0 - vt \cos \emptyset \tag{9}$$

$$d(t) = \sqrt{(y2 - y1)^2 + (x2 - x1)^2} \tag{10}$$

where (t) is the time interval, and (xo, yo, θo) are the source position and direction of the robot.

3) While the robot is moving in the work environment, the distance between all the robots is calculated using the equations (8), (9), and (10) until reaching the smallest distance.

4) The robot starts moving in a straight line while the smallest calculated distance is more than the sum of two robot radiuses as in step3.

5) When the smallest distance between two robots is less than the sum of two robot radiuses, then the robot is changing its directions in a circular path in two-time intervals and then repeated to step 3. The complete strategies are explained in Fig. 6.

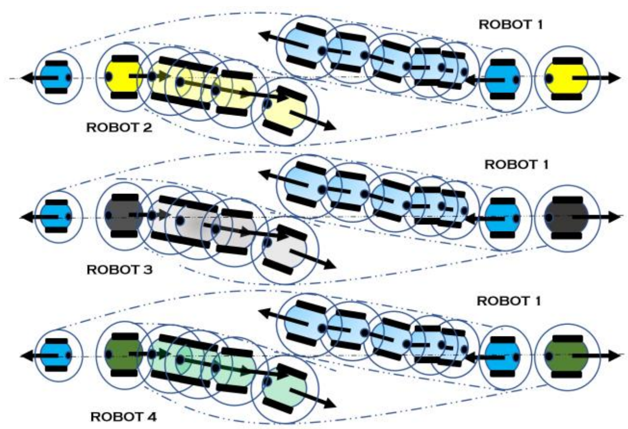


Fig. 6: The collision-free path estimation.

IV. The Simulation Results

This simulation's navigation process is completed using the essential visual software with a different number of static polygon obstacles (from 1 to 12) that obstruct the robot way to the goal point. Furthermore, various numbers of robots (from 1 to 6) are moving in the robot’s surrounding.

A robot's mission designed to move things is concentrated, relying on line-tracing technology that makes it easy to track its path safely, the RFID is distributed in its way, and when the robot reads the RFID tag, it stops until it raises the load from above, the robot continues its path toward the target point. When an obstacle obstructs the robot path, the robot will deviate and returns after a while to its previous way.

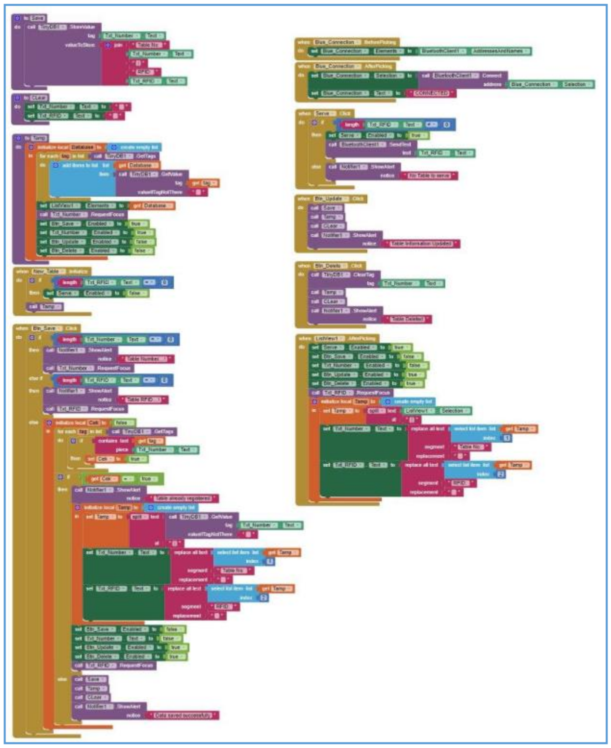


Fig. 7: The App inventory with a specific code for the robot system.

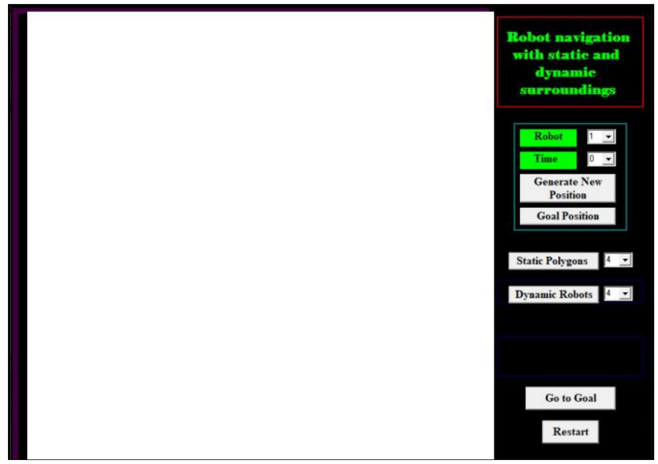
All this technology is implemented through the ultrasonic sensor, the robot designed to transfer the stored material is used according to a site known as the identifier identified by the RFID value, where the robot is programmed through a microcontroller and a unique store program that determines the current location and the desired location, then is given the task for the robot is to do it as required.

App inventory is design with a specific code, as shown in Fig. 7, Where it prepares a list. When it starts taking it, you will configure the table, which is shown in Fig 8, where the list takes two entries and stores them and then is selected "after saving" option to It sends orders via Bluetooth.

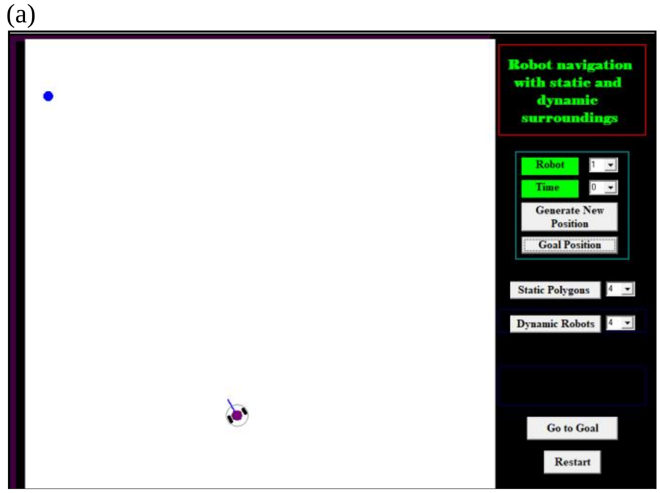
Fig. 7: The App inventory with a specific code for the robot system.

Fig. 8: The table connected with App inventory.

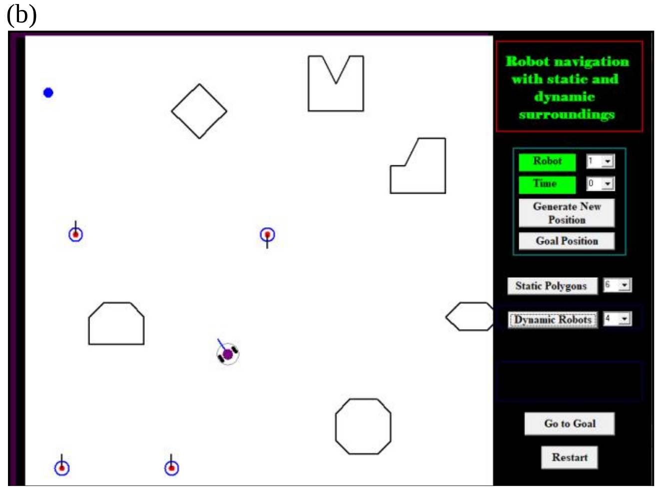
At first, the source point of the robot and the goal point is assumed in a random location at the surrounding at each iteration, then the algorithm generates the static polygon obstacles with a random position, also the robots are generated as shown in Fig.9.



(a)



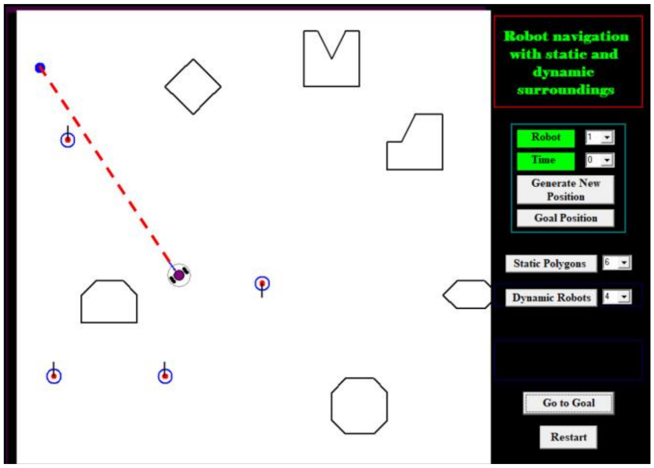
(b)



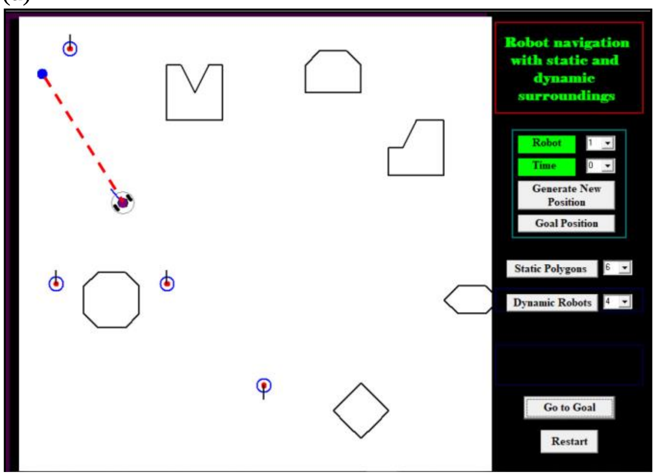
(c)

Fig. 9: The stages of generating the static polygons and dynamic robots.

Then the robot starts moving toward the goal with other moving robots and polygons obstacles till reaching the goal (as shown in Fig. 10).



(a)



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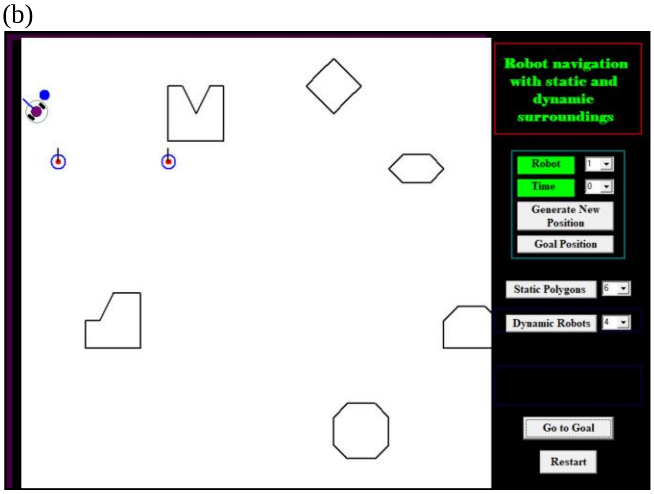

(c)

Fig. 10: The complete steps to reaching the goal point.

The time to complete is studied concerning the number of polygons and robots as shown in Fig. 11. It is clear that increasing the polygons in the surrounding leads to maximize the time to accomplishment, and so on with increasing the robot's number in the surrounding.

This is because maximizing the numbers of obstructing need more time of calculations and taking the right decision of selecting the safe way to the goal. On the other hand, the moving robots in real-time need a complex calculation in the mathematical model design because at each point of moving the process is changed according to the new mathematical calculations.

The length of the way that the robot uses it is also studied in this simulation as shown in Fig. 12.

Where the length of the path is maximized when there are more robots in the suggested way, and so on when there are more polygons obstruct the robot's way to the goal.

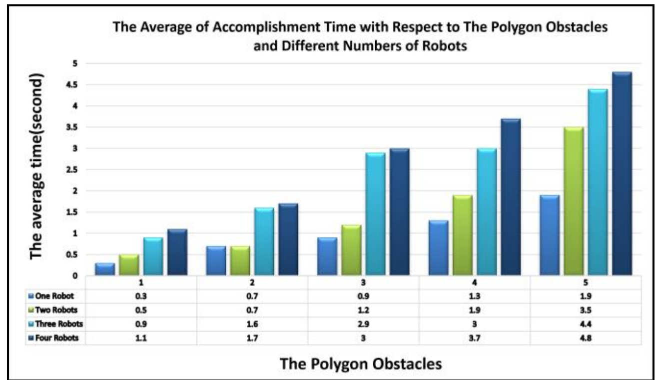

Fig. 11: The complete time VS the polygons and robots' numbers in the surrounding.

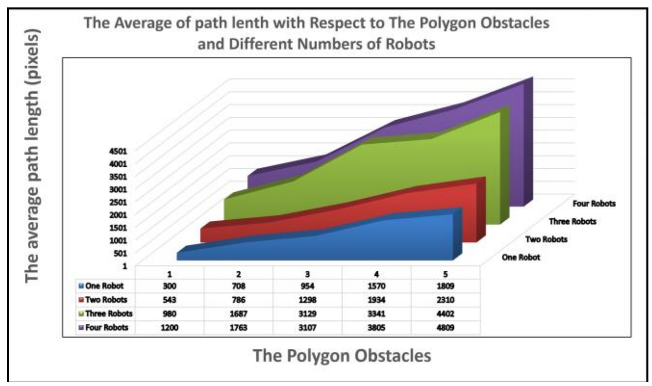

Fig. 12: The length of the path VS the polygons and robots' numbers in the surrounding.

V. Conclusions

In this paper, a robot's mission to move things is concentrated, relying on line-tracing technology that makes it easy to track its path safely; the RFID is distributed in its direction. When the robot reads the RFID tag, it stops until it raises the load from above, the robot continues its path toward the target point. When an obstacle obstructs the robot path, the robot deviates and returns after a while to its previous way. All this technology is implemented through the ultrasonic sensor, the robot designed to transfer the stored material is used according to a site known as the identifier identified by the RFID value, where the robot is programmed through a microcontroller and a unique store program that determines the current location and the desired location, then it is given the task for the robot is to do it as required.

Two simulation results are discussed using essential visual software: The accomplishment and the length of the way to the target concerning the number of polygons and robots. Generally, increasing the static polygons and dynamic robots in the surroundings leads to an increase in the accomplish time and path length.

This happens because maximizing the polygons and robots needs more computational time, and the mission of reaching the goal will take more time. Finally, in the future work, the research limitations is not limited to use a different mobile robot rather than using the differential drive mobile robot for the control purposes. In the future work an optimization algorithm can be used to optimize the path of the robot to choose the minimum one.

CONFLICT OF INTEREST

The authors have no conflict of relevant interest to this article.

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