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# Maze Maneuvering and Colored Object Tracking for Differential Drive Mobile Robot

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***Abstract*** *In maze maneuvering, it is needed for a mobile robot to feasibly plan the shortest path from its initial posture to the desired destination in a given environment. To achieve that, the mobile robot is combined with multiple distance sensors to assist the navigation while avoiding obstructing obstacles and following the shortest path toward the target. Additionally, a vision sensor is used to detect and track colored objects. A new algorithm is proposed based on different type of utilized sensors to aid the maneuvering of differential drive mobile robot in an unknown environment. In the proposed algorithm, the robot has the ability to traverse surrounding hindrances and seek for a particular object based on its color. Six infrared sensors are used to detect any located obstacles and one color detection sensor is used to locate the colored object. The Mobile Robotics Simulation Toolbox in Matlab is used to test the proposed algorithm. Three different scenarios are studied to prove the efficiency of the proposed algorithm. The simulation results demonstrate that the mobile robot has successfully accomplished the tracking and locating of a colored object without collision with hurdles.*

***Index Terms*— Obstacle avoidance, Object locating, Differential drives mobile robot, Maze maneuvering.**

## I. Introduction

Mobile robots can be used in different applications related to industrial and daily life applications and such as military usage, space exploration, assisting disabled people, dangerous and repetitive applications. Therefore, many pieces of research have been conducted to improve the navigation process by obtaining an optimal path and avoiding obstructing obstacles in unknown environments. Another important application of mobile robots is to track and locate objects, thus, object location privilege can be added robotic platform to intelligently assist mobile robot to reach specific locations. For instance, in wheelchair robotic platform, when the colored detection sensor is added, this can facilitate the localization by tracking a required destination based on a colored object placed at that position. Different types of distance sensors can be utilized for this purpose, such as ultrasonic range or infrared sensors. The latter is integrated with the wheelchair to detect surrounding obstacles while navigating.

In recent years, many researchers have proposed different types of navigation algorithms to assist mobile robots in its maneuvering in a given workspace and to reach its target. In the state of the art, a new potential field method was proposed for motion planning of a mobile robot to overcome the drawbacks in a dynamic environment [1]. The path planning problem was solved by representing the irregular contour of obstacles based on segments in order to avoid them when the robot commences its navigation [2]. In addition, the Dijkstra's algorithm was used to find the shortest path between the source and destination points with creating free collision paths [3]. A visibility graph algorithm was also proposed to find the free obstacles route so that a mobile robot can navigate from its initial posture to a required goal [4]. Another algorithm was introduced by using the tangent vector based on an artificial potential field method in which its optimization model was developed using particle swarm optimization to find a free-obstacles path for the mobile robot [5]. Moreover, a virtual circle tangent algorithm was presented for mobile robot navigation in an environment that was filled with polygonal shaped obstacles [6]. Furthermore, prediction based path planning with obstacle avoidance for the dynamic target was proposed to navigate the mobile robot [7].

Although the problem of path planning and obstacle avoidance have been studied in the literature, there are still some rooms to improve the overall performance of the navigation process for mobile robots. In this paper, a new proposed obstacle avoidance algorithm is introduced. In addition, an object detection sensor is added to enhance the operation of the mobile robot. Hence, the contribution of this paper can be understood by firstly obtaining a new algorithm makes the robot navigates feasibly and efficiently in a given maze without being collided with obstructing obstacles. Secondly, a vision sensor is embedded with the proposed algorithm, thus, the mobile robot can recognize colored objects and localize a particular object based on its color. To examine the effectiveness of the proposed algorithm, different scenarios are studied by providing different locations of a colored object and validating the tracking of that object.

The rest of the paper is delivered as follows: Section II provides the modeling of the differential drive mobile robot. Section III illustrates the proposed object finding, and obstacle avoidance algorithm. The simulation results are conducted as shown in Section IV. Finally, the conclusion is introduced in Section V.

## II. DIFFERENTIAL DRIVE MOBILE ROBOT MODEL

Many researches are introduced the model of differential drive mobile robot based on analyzing the kinematic characteristics [8-12]. The differential drive means that the mobile robot has two controlled sides of wheels which they are driven independently and one balance wheel as shown in Fig. 1. To navigate the mobile robot in any environment, two main variables need to be controlled, i.e. a linear velocity $v(t)$ and orientation $\theta(t)$ of independently driven wheels.

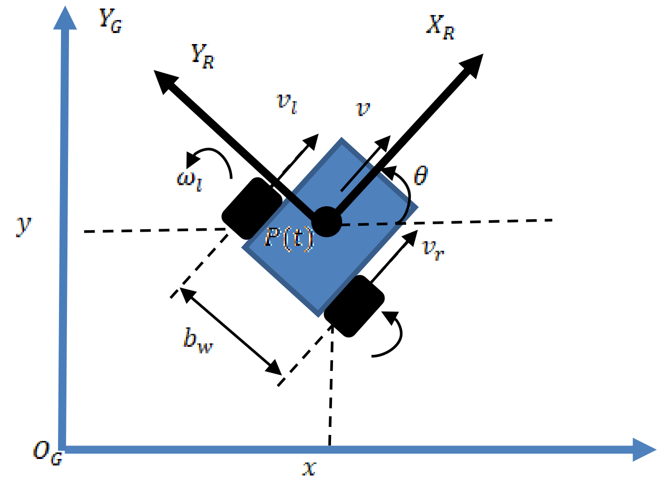


Fig.1. Schematic diagram of differential drive mobile robot.

To derive the mathematical model of differential drive mobile robot, the following assumptions are considered:

- The mobile robot moves in the forward direction in a given XY-plane.
- The mobile robot moves on a flat surface.
- The rotation angle of the mobile robot is limited.

To describe the position of the mobile robot as a function of time, three variables $P(t)$ should be computed.

where, $P(t)$ is the position vector and can be given as in the following:

$$P(t) = [x(t) \quad y(t) \quad \theta(t)]^T \qquad (1)$$

where $(x(t), y(t))$ is the center coordinates of the mobile robot and $\theta(t)$ is the robot orientation.
The angular velocities of both wheels are given below (relation between angular velocity and linear velocity is shown in Fig. 2):

$$\omega_r(t) = \frac{1}{R} v_r(t) \qquad (2)$$

$$\omega_l(t) = \frac{1}{R} v_l(t) \qquad (3)$$

where $v_r(t)$ is the linear velocity of the right wheel,

$v_l(t)$ is the linear velocity of the left wheel,

$R$ is a radius of the robot's wheel.

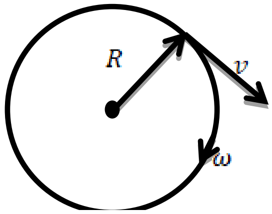


Fig.2. The relation between angular velocity and linear velocity.

The linear velocity of the right and left wheels can be given with respect to the overall linear velocity of the robot $v(t)$ and its angular velocity $\omega(t)$ as shown below in the following equation based on inverse kinematics.

$$v_r(t) = v(t) + \frac{b_w}{2}\,\omega(t) \quad (4)$$

$$v_l(t) = v(t) - \frac{b_w}{2}\,\omega(t) \quad (5)$$

where $b_w$ is the distance between the right and left wheels.

From Equations 2, 3, 4 and 5, the linear velocity of the robot $v(t)$ and its angular velocity $\omega(t)$ can be computed from the following equations based on forward kinematics.

$$v(t) = \frac{R}{2}(\omega_r(t) + \omega_l(t)) \quad (6)$$

$$\omega(t) = \frac{R}{b_w}(\omega_r(t) - \omega_l(t)) \quad (7)$$

After obtaining the linear and angular velocities, the following equations (Equations 8, 9 and 10) can be determined from which the position vector can be calculated (Equations 11, 12 and 13).

$$\dot{x}(t) = v(t)cos\theta(t) \quad (8)$$

$$\dot{y}(t) = v(t)sin\theta(t) \quad (9)$$

$$\dot{\theta}(t) = \omega(t) \quad (10)$$

$$x(t) = \int v(t)cos\theta(t)dt \quad (11)$$

$$y(t) = \int v(t)sin\theta(t)dt \quad (12)$$

$$\theta(t) = \int \omega(t)dt \quad (13)$$

## III. Finding Object and Obstacle Avoidance Algorithm

In this work, two types of sensors are embedded with the platform of the differential drive mobile robot. The first type of sensors is a group of infrared sensors which are used to detect surrounding obstacles facing the path of the mobile robot. Depending on the reading of distance sensors, an avoiding collision algorithm is used to avoid colliding with obstructing obstacles. The second type of sensors is a color detection sensor that is used to guide the mobile robot moving toward a specific colored object. Depending on the reading of a color detection sensor, a finding object algorithm is introduced to track the object depends on its color. The new proposed algorithm is a combination of the two algorithms which can be an effective solution to achieve maze maneuvering and locating of colored objects in an unknown environment.

The operation of the developed algorithm is firstly based on reading several parameters, i.e. the initial position of the robot $P(x, y, \theta)$, the color of the wanted object, and the initial values of all sensors. Then, secondly, the robot starts moving forward randomly from its starting point and attempting to find the desired colored object. Regularly, the differential drive mobile robot scans the environment, timely based to find the colored object. If the mobile robot detects any obstacle placed in its path, the algorithm gives the priority for avoiding that obstacle rather than finding the targeted object.

The average angle is computed based on the following equation:

$$aveang = \frac{Number\ of\ sensors\ that\ detect\ the\ obsacle}{Total\ no.of\ sensors * valid\ ranges} \quad (14)$$

If the value of $aveang$ is less than zero, the mobile robot turns left, otherwise, the mobile robot turns right to avoid the obstructing obstacle. Then, the mobile robot moves forward and scan the environment again to find the targeted object. If the mobile robot finds the colored object, it moves directly toward it and it will stop near it. In overall, the principle operation of the proposed is based on a switching mechanism between the two introduced algorithms discussed earlier. Fig. 3 demonstrates the flowchart of the proposed algorithm.

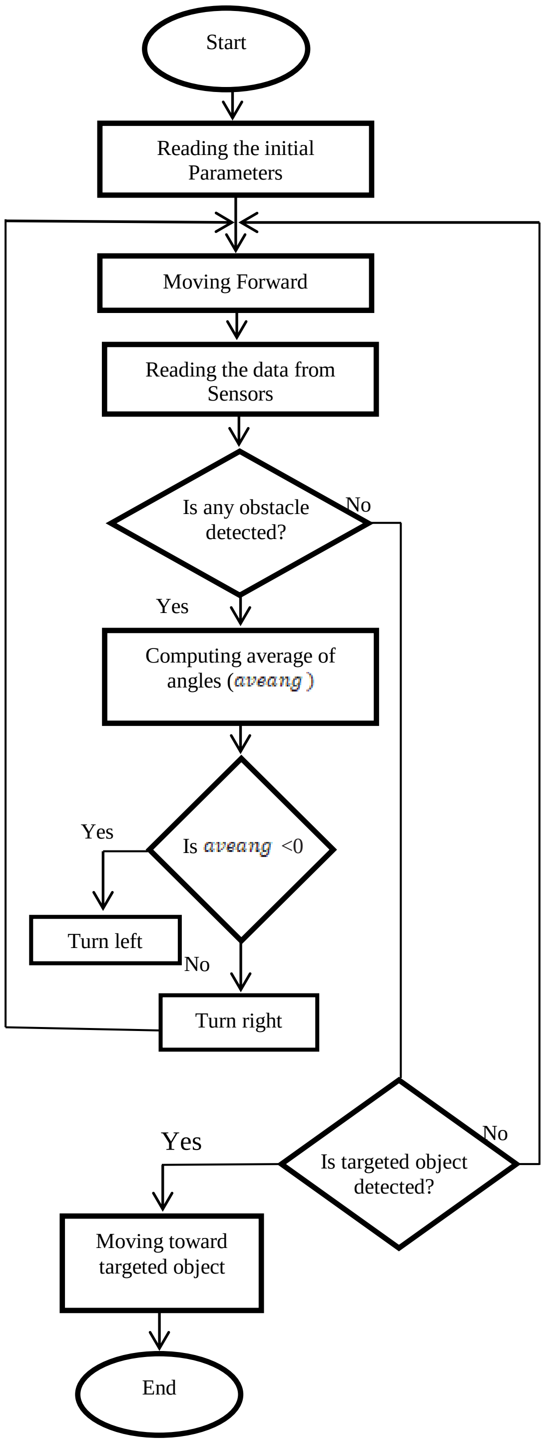


Fig.3. Flowchart of finding object and obstacle avoidance algorithm.

The proposed algorithm has two capabilities, i.e. the ability of the mobile robot to traverse surrounding hindrances and seeking for a particular object based on its color. This represents the main advantage of our algorithm which in turn leads improve the operational performance of the mobile robot.

## IV. Simulation Results

In this paper, the navigation of the mobile robot driven differently in an unknown environment for finding the object is studied. The mobile robot is constructed with six infrared sensors placed around the front of the platform with $30^o$ between each other. One color detection sensor is placed in front of the mobile robot. To validate the effectiveness of the proposed algorithm, three different scenarios are conducted. In the first scenario shown in Fig. 4, the initial position of the mobile robot is $P(2,2,0)$ and color of the targeted object is red located at the point $(9,6)$ in an XY-plane. Two other colored objects are placed in this environment, one has a blue color located at the point $(3,10)$ and the other has a green color located at the point$(10,8)$. The dimension of the searching environment is $(13 \times 13m)$ meters. Fig. 5 shows the searching path of the mobile robot in which the robot navigates randomly trying to reach the red object until the goal has been reached. Similarly, the moving environment of the second scenario is shown in Fig. 6. The initial position of the mobile robot is $P(2,2,0)$ and color of the targeted object is blue located at the point $(10,12)$ in the same XY-plane. The red object located at the point $(2,8)$ and the green object located at the point $(8,4)$. Again, the mobile robot has successfully reached the targeted color as shown in Fig. 7. Finally, this third scenario is shown in Fig. 8, the initial position of the robot is placed at the coordinates $P(2,2,0)$ and the color of the targeted object is specified to a green color located at the point $(12,7)$ in the same XY-plane. The red object located at the point $(8,2)$ and the blue object located at the point $(8,8)$. The mobile robot starts navigating likewise the two other scenarios and it was successful and efficient of reaching its target and detect the blue color. Fig. 9 shows the searching path of the mobile robot for the third scenario in which the maneuvering has been completed feasibly and smoothly without hitting any of the surrounding hurdles.

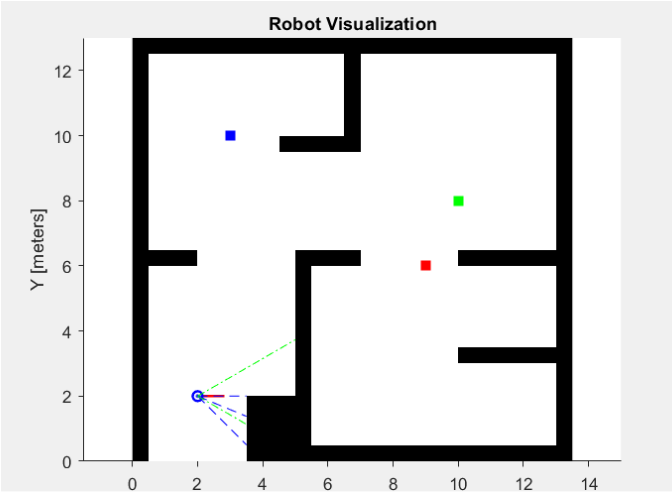


Fig. 4 The initial position of the mobile robot in first scenario.

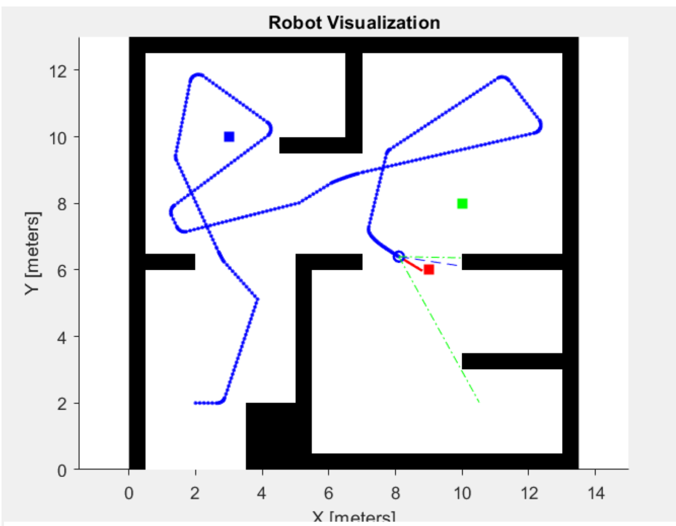


Fig. 5 The searching path of the mobile robot of the first scenario.

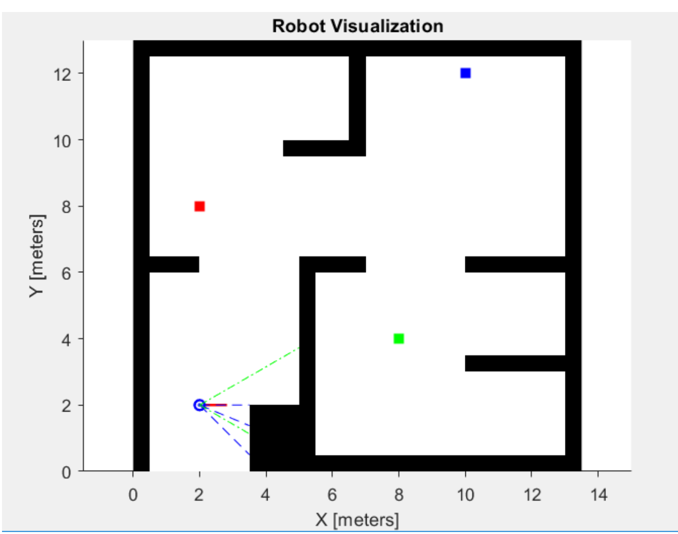


Fig. 6 The initial position of the mobile robot in second scenario.

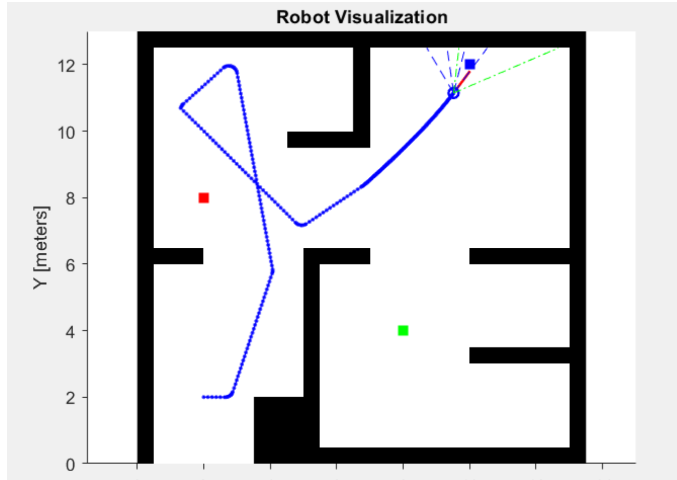


Fig. 7 The searching path of the mobile robot of the second scenario.

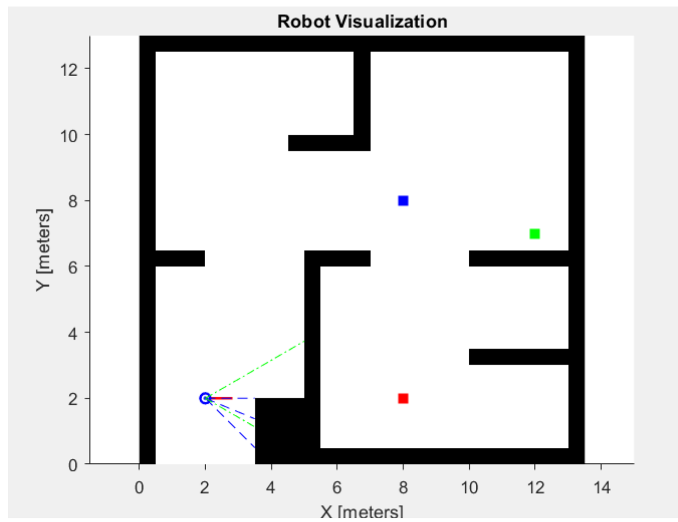


Fig. 8 The initial position of the mobile robot in third scenario.

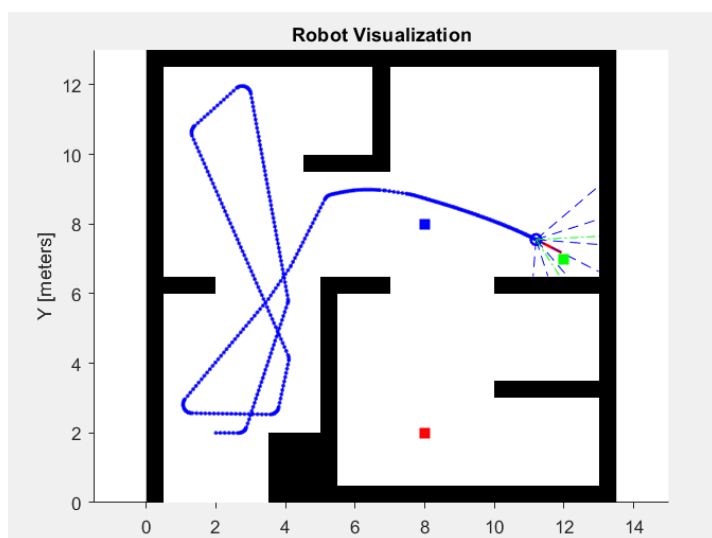


Fig. 9. The searching path of the mobile robot of the third scenario.

## V. Conclusion

A new algorithm for avoiding obstacles and finding an object depending on its color is proposed in this work. Two types of sensors are used to achieve this task: infrared sensors and a color detection sensor. The Mobile Robotics Simulation Toolbox in Matlab is used to test the proposed algorithm. Three different scenarios are introduced to investigate the effectiveness of the proposed algorithm. The simulation results show that the mobile robot succeeds to find any targeted object in an unknown environment without colliding with obstructing obstacles. In all conducted scenarios, the proposed algorithm has introduced a feasible solution to the problem of obstacle avoidance and finding the colored object. The generated path in all case studies is feasible and it is obstacles free. Although some wandering around during the motion have been observed, these paths are optimized as the mobile robot keeps trying to search for the location of the targeted colored object.

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