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Robotic Design to Detect and Avoid Collisions

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Abstract:- Robot becomes one of the most essential technologies which gain tremendous benefits in the life and makes the implementation of many normal tasks regarding (professional lives, social life, driverless vehicles, industrial working, and household tasks) as well as other dangerous tasks easier and with more accurately manner. In this project, the detecting of the collisions through several methods in order to reduce, minimize, or even to mitigate the collisions between the robots and the objects around it (perception of the environment, collision avoidance algorithms or by making a control process for the robot). Further, the studying of this paper was firstly by detecting and avoiding only one obstacle, detecting several obstacles in the next step, as well as to avoid many obstacles which locate beside each other and in complicated positions in the last step by applying the mathematical equation. Also, some previous related works make the understood of the process better by viewing the results in those related works. Moreover, the modelling of a system in this paper, which is differential drive system was shown with its details. The calculations for the model were also clarified (such as how to find the model's kinematics and other parameters.Finally, the results for the modelled system are illustrated for the three types of avoidance (for one obstacle, several obstacles and for the complex map obstacles) and based on the obtained results some recommendation is provided for this project which can be helpful for the future works such as modifying the control process or altering other parameters of the robot, depending on the area where the robot will work (on the land or underwater or other areas such as the air).

Keywords;- *Robotic Systems, Collision Detection, Collision Avoidance, Mathematical Modelling, Control Process, Obstacle.*

I. INTRODUCTION

Robotics is the technology area that works with robot design, development, operation as well as implementation. Due to their high degree of efficiency and reliability, robots are now broadly used in several industries (Mrujool et al., 2016). Also, robotics are known as artificial intelligence (AI); they are used in factories around the world for several tasks, including manufacturing, searching, rescuing missions as well as in the military (Mrujool et al., 2016). Besides, all required tasks from the Robot, including inspection, maintenance, or repair job, will provide many benefits, which are:

a) Better safety: Robots can enter unsafe conditions and carry out tasks that are highly hazardous to humans. With little to no harm, these tasks could be completed.
b) Improved accuracy: because that human labour cannot be reliably maintained over long periods to a certain degree of consistency and accuracy. Thus, the Robot can be used with minimal errors, if any.
c) Longer hours: The robots can plan the job to operate for long hours without the need for breaks in the routine maintenance tasks.
d) Flexibility: For several applications, robotic systems can be reused, re-tooled as well as reprogrammed.

Identifying collisions between the industrial environment and the Robot, particularly humans and other production systems, is one of the key issues in human-robot systems. Even so, in a very complex, unstructured well as partly unknown environments, the industrial robots should be capable of functioning, share the workspace with the human user, and avoid potential and unwanted collisions (Haddadin et al., 2017).

The planning of the motion for robotics is often carried out in its specification room (C-space), space where each part represents a particular configuration of a robot. A joint space of the robotic manipulators is an illustration of C-space since a collection of joint positions can be necessary to describe the location of robotic manipulators in the space completely. The dimensionality of the C-space refers to the number of independent variables that can uniquely describe a robot configuration (Das, 2020).

Robotics with obstacle avoidance is utilised to sense barriers and prevent a collision. This is a robot that is autonomous. Depending on their mission, the obstacle avoidance system design involves the integration of several sensors. The prime objective of this autonomous Robot is obstacle detection. The Robot gets the data from installed sensors on the Robot from the area surrounding it. Several sensing instruments, such as ultrasonic sensors, bump sensors, as well as infrared sensors, are utilised in obstacle detection. The ultrasonic sensor is most useful for detecting obstacles and is low-cost, and has a high range of capabilities.

When robots and humans have the same space, protection is critical because the proximity of the user to the Robot could lead to potential accidents. Guidelines, which provide safety concerns and specifications; be considered during human-robot contact (The HRI) (Sharkawy, 2019).

To compare the detection and response techniques on an objective and repeatable basis, a mechanical verification platform was developed, consisting of an adjustable 1-DOF mechanical impedance. It is used to attract attention to the significant differences between the measured solution regimes and illustrate their underlying disadvantages and shortcomings. True impact tests with a crash test dummy, a collision testbed, and a human user can demonstrate the advantages of the collision detection and response schemes offered.

The findings obtained suggest that such systems can be used a major role for the human operator in maintaining safety during human-robot physical contact. In addition, it would be Show how to detect and respond to collision support to avoid damage to the robotic system and, thus. In addition, it leads to an improvement in protection due to fault protection (Haddadin, 2008).

In any mobile robot, avoiding obstacles is a critical problem. Each mobile Robot, therefore, uses a technique to escape collisions and obstacles. Each approach has various characteristics of its own. The variations may be in the chips that regulate the Robot, the collision avoidance algorithms, or the sensors which detect obstacles in the nearby region. One of the most critical aspects researchers are focusing on is to provide accurate sensors. In robots, different sensor types can be used to prevent collisions, such as bump sensors, infrared sensors, laser range sensors, in addition to ultrasonic sensors (Nafea et al., 2012).

II. AIMS AND OBJECTIVES

This paper aims to design a robot that can identify and Prevent accidents with any obstacle when moving to monitor the concentration of LPG in the region, and this aim can be achieved by the following objectives:

a) To design a robot with a differential drive (DD) system to avoid obstacles.
b) To test the designed Robot in avoiding one obstacle.
c) To test the designed Robot in avoiding several obstacles.
d) To test the designed Robot in avoiding complex obstacle maps.

III. LITERATURE REVIEW

A. General overview about differential drive (DD) Robots

The mobile Robot is a platform with high mobility in its environment, which can be land, air, or underwater; it is not stable in one physical location. There is a possible use for mobile robots in several domestic and industrial applications. The processes of mobile robot' design and control are not considered as a simple task within this mobile robot operation is basically a time-variant, where the mobile robot operation parameters, climate as well as road conditions frequently differ. Consequently, the mobile Robot containing a controller has to be designed in order to make the system adaptive and robust, as well as enhancing the system on steady and dynamic state performances.

The differential drive (DD) robots with two-wheel is considered as one of the most used and simplest structures in the applications of mobile robotics; a simple design of the two-wheel differential drive mobile robots is shown in Figure 1.

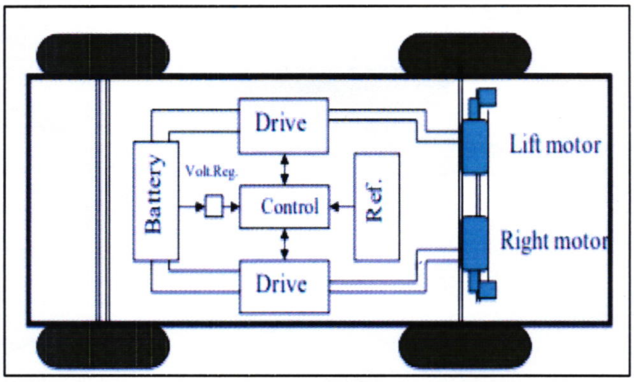


Figure 1: Top view for simple differential drive (DD) robots with two-wheel (Salem, 2013).

The design shown in Figure 4 includes a chassis with in-line electric motors as well as two fixed typically has the third fulcrum with one or two additional wheels, these wheels could rotate freely in any directions in the presence of one additional wheel, where it has little control over the robot kinematics, its effect could be ignored (Salem, 2013).

According to Snape et al. (2010), differential-drive robots are widespread to be used in several sectors. A basic drive mechanism, which comprises of two drive wheels installed on a central point, is used by these robots. In addition, each wheel in forward and reverse movements could be driven individually. Many mobile robots have differential-drive limits, such as vacuum cleaners and powered wheelchairs (Philippsen and Siegwart, 2003). Progressively, robots are being used as part of a decentralized set of various robots, not just in isolation. For the protection and environmental monitoring, search and rescue, groups of organized mobile robots can be used together Michael et al., (2008). In these situations, approaches to measuring collision-free paths for these robots regarding other robots and obstacles need to be developed. The Robot, however, can move easily. For several mobiles or functional service robots, the smoothness property is critical as it must consider the physical limits of robot sensors as well as other safety concerns. A example of the differential-drive robot kinematic model is shown in Figure 2.

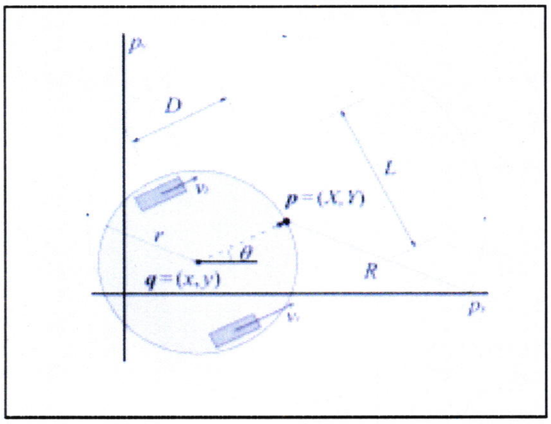


Figure 2: An example of the differential-drive Robot kinematic model (Snape et al., 2010).

B. Collisions detection and avoidance in Robotic Design

The issue of designing a mobile robot to move from one position to another is an old issue that involves main two questions, the first designed mobile Robot is about the path which should be selected to reach the required location, and the second question is about the fast and the close to the obstacles that the Robot can go without compromising safety (Ogren, 2003).

According to Luca, and Flacco, (2012), using friendly robots in everyday life as well as in the industry as multi-functional service assistants, contributing to the physical human-robot interaction, is now a fact because of the requirements of performing complex and physically challenging tasks. To combine human movements and Robot's high performance regarding the accuracy and speed, as the close cooperation between Robot and humans is necessary, the strategies of safety-oriented control are essential to make the coexistence of healthy human-robots viable. The key aspect of these robots, therefore, is protection; without that, coexistence as well as cooperation could not actually occur. In general, one of the most significant problems in the use of robotics is collision avoidance. As discussed in the study conducted by Flacco et al. (2012), the typical real-time method for collision avoidance involves three parts, which are shown in Figure 3.

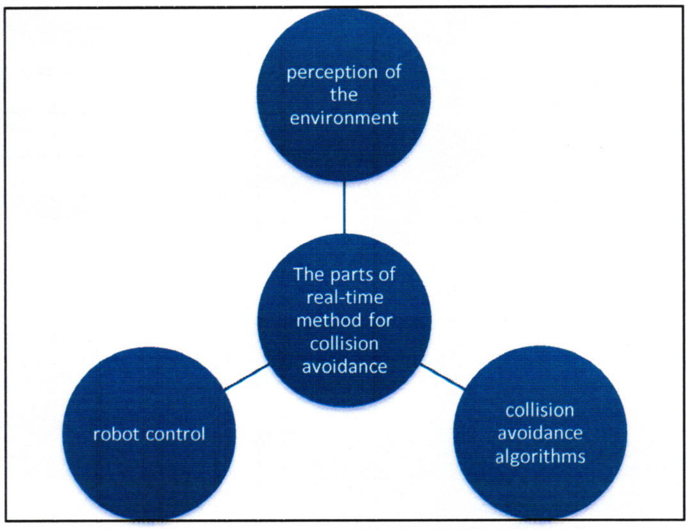


Figure 3: The parts of a real-time method for collision avoidance (Flacco et al., 2012).

The study conducted by Haddadin et al. (2017) gives more detailed architecture about the collision avoidance method where there are seven main phases, which are pre-collision, detection, isolation, identification, classification, reaction as well as post-collision. These seven phases of the collision and the expected outputs are shown in Figure 4.

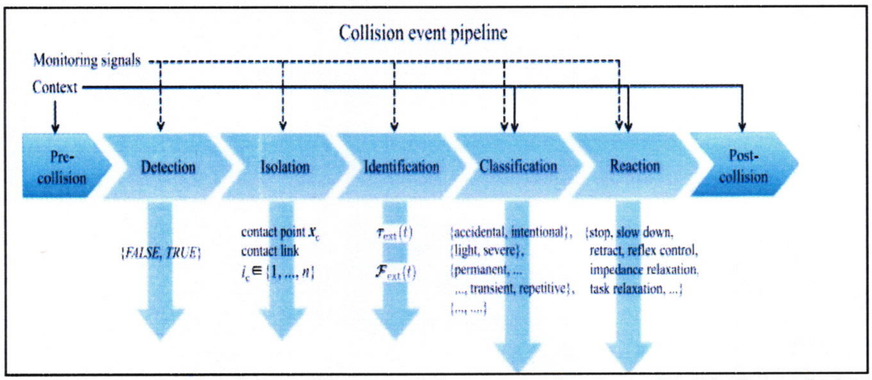


Figure 4: Seven phases of the collision and the expected outputs (Haddadin et al., 2017).

To collect details about the incident, different monitoring signals could be used. Some stages are (almost) immediate; others are not. In addition, the phases through the detection to identification are context-independent, while the other phases rely on both internal and external variables, such as the state of the human/environment, in addition to the on-going mission.

Several planning and control methods for obstacle avoidance have been developed in recent years. Among the potential solutions are compatible mechanical manipulator design as well as collision detection/reaction strategies depending on using effective sensors. Other methods are focused on the consistency of the Robot's degrees - of - freedom that can monitor the required trajectory while preventing barriers. Also, many algorithms for real-time planning depend on the so-called potential field technique (Sangiovanni et al., 2018).

According to Min et al. (2019), different methods have been developed for the identification of robot collisions. An intuitive method is to track the transient current in the Robot electric drives, searching for the shock changes in currents induced by the collisions. Another method is the tactile sensors mounted within robot skins. In addition to these two methods, there are several methods such as the so-called model-based method, which is the Kalman filter method or the state observer; the detection algorithms mainly depend on the assessment of monitoring signals, including motor currents, and the difference between actual, as well as forecast torques that should be below certain setting values, otherwise, collision alerts are developed.

The choosing of thresholds of the monitoring signals is the major practical issue in these approaches because modelling error, as well as sensor noise, influence the monitoring signal in the same as collision disruption. Consequently, the impact of modelling errors, as well as sensor noise on the monitoring signal, should be distinguished from a real collision by using an effective detection algorithm. It likely contributes to a trade-off among the false alarm rate and sensitivity, with the possibility of an overly conservative threshold for this purpose. To solve this problem, there are various proposed methods, such as the using of a dynamic threshold to describe the residual reliance on the condition of the Robot, including position, acceleration, and velocity depending on fuzzy logic rules (Luca et al., 2006).

Furthermore, the study conducted by Caldas et al. (2013) suggests an algorithm for adaptive detection depending on the dynamic threshold that is state-dependent. Some extended state observer, as well as sliding-mode observer methods, have been proposed recently to achieve more efficient detection performance.

C. Related works

Based on Fujita (2020), the planning for moving the Robot's system and the block diagram for the control system illustrated in Figure 5 considered the surrounding area in this study.

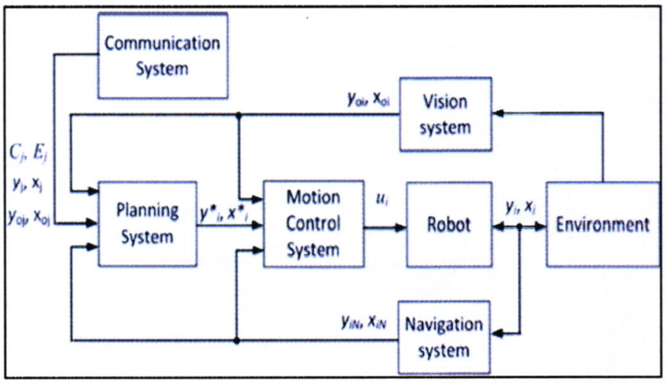


Figure 5: Block diagram for robot movement control (Fujita, 2020)

Ensuring and verifying the existence of a number of obstacles and humiliation in order to change the direction and verify the movement availability or use of accounts in order to obtain an optimal location is the primary goal of the control system. Based on the information and data collected completely in the system of vision, the estimate related to the condition of the surrounding area was classified. An integer number, which is Ci, was used to indicate the results of the obtained categories. If there is no obstacle to the Robot, the results will be, which is expressed in an integer number Ci = 0. While if there is an obstacle in the way of the Robot, but the distance between them is safe, the value of the correct number will be Ci = 1. The value of Ci is not limited to the number 1 and 0, as it may be 2 or 3 sometimes. Therefore, CI gives an estimate based on the geometry of the surrounding area (Ω).

In this study, the steps that were followed in this algorithm were as follows: The first step was the creation of an aggregated group, and this group had involved the work of robots, based on the detection of obstacles using a system specialized in vision in order to detect obstructions and the vertices. It has an area of Ω0, which is represented by white squares as shown in Figure 6.

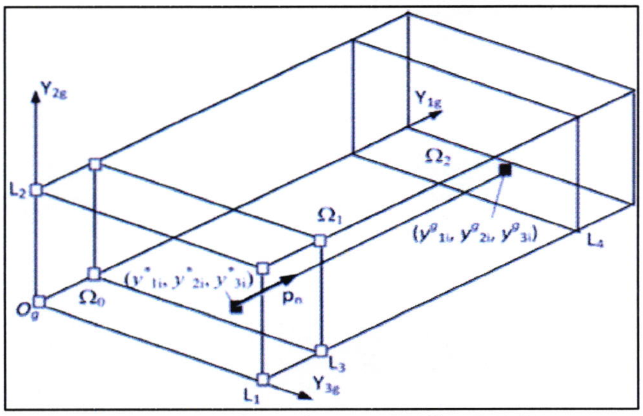


Figure 61: The Path Areas (Fujita, 2020)

As for the second step, the neighbors were calculated for the robots, which is referred to by the $i - th$, and that is through Delaunay triangulation was carried out. The results were obtained for the nearby objects and elements in the form of an image using magnetic resonance MRI. Each of the adjacent elements and the distances between robot $i - th$ and the area was calculated in the third step using the following equation (Fujita, 2020):

$rij = kij\,[y\,(1i - y1j)2 + (y2i - y2j)2 + (y3i - y3j)2].5$ Eq. 1

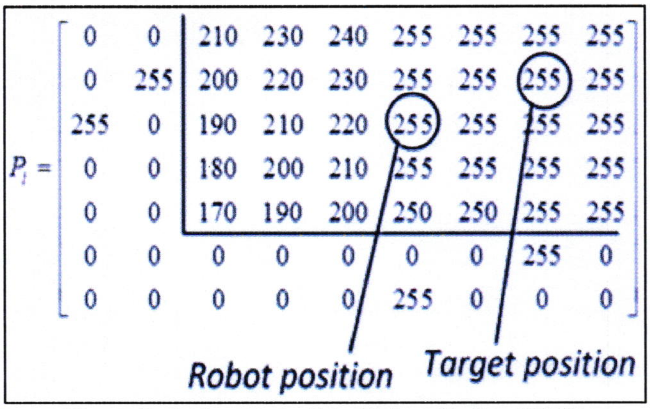
Where:

- rij : It expresses the distance measured between the object of $j - th$ and the Robot of $i - th$.
- kij : It is defined as the weight parameters as it is completely dependent on the value of Ci. Where kij will be approximately 1 if Ci is 0, otherwise its value will be 0.
- i = 1, ni and ni represents the amount of the nearby items to i-th robots, j = 1, NG,

Free variables are (yi1, yi2, yi3) were used in the fourth step in order to improve and optimize both the distance and the path and apply the next criteria:

$(min\ ij\ (rij)) \rightarrow max\ (y1i, y2i, y3i)$ Eq. 2

The below matrix has been collected, which indicates the location of the Robot and the goal position.



$$P_i = \begin{bmatrix} 0 & 0 & 210 & 230 & 240 & 255 & 255 & 255 & 255 \\ 0 & 255 & 200 & 220 & 230 & 255 & 255 & 255 & 255 \\ 255 & 0 & 190 & 210 & 220 & 255 & 255 & 255 & 255 \\ 0 & 0 & 180 & 200 & 210 & 255 & 255 & 255 & 255 \\ 0 & 0 & 170 & 190 & 200 & 250 & 250 & 255 & 255 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 255 & 0 \\ 0 & 0 & 0 & 0 & 0 & 255 & 0 & 0 & 0 \end{bmatrix}$$

Figure 7: the location of the Robot (Fujita, 2020).

Research results observed during the simulation were, which means that the Robot would differ from the substance and item obstacles.

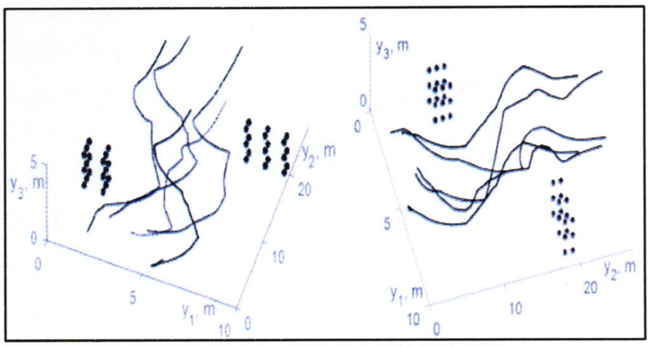


Figure 8: The robot Path (Fujita, 2020).

According to Zangina et al. (2020), a non-linear PID controller was used to track the path of the Robot that is moved by a differential motor. A number of methods have been used to get the robots to move along the specified and desired path between the differential drive systems, these methods are the KBBC and the PID control unit. The KBBC and PID control unit has been used to reduce the non-linearity of the robot movement on the specified path and to isolate its speed as well. Procedures for controlling robots are shown in Figure 9.

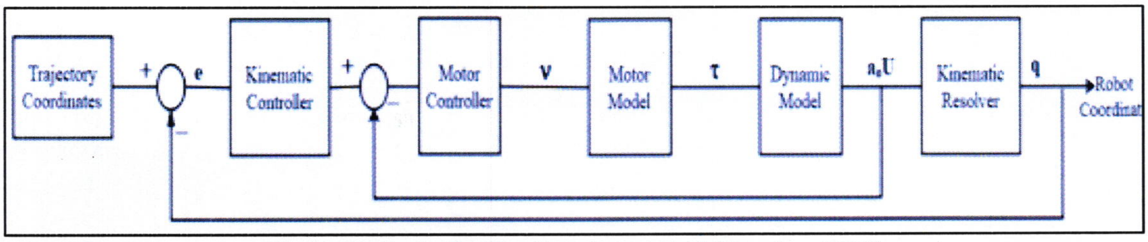


Figure 9: Block diagram for robot control (Zangina, 2020)

The principle of virtual work has been exploited in this research, during the modelling of the mechanical model, which is the essence of this study, and the equations that were used in order to control a number of parameters, such as torque, the goal of this is to ascertain the path followed by the Robot when carrying out the tasks required.

Regarding the Kinematics of the Robot, the angle and linear motion of a robot that uses two independent wheels are explained by the two-wheel-drive differential system. As for the angle of movement, it can be verified as follows:

$\theta i = -\theta r$ Eq. 3

Where:
θ: is the rotation angle in the two wheels.
r: is a depiction of the left and right wheels.

It was expected in this study that the Robot will move in two directions (2D), if the values of each of the x and y coordinates are information, the location of asthma will be accurately and completely determined, which will be known at the level of the Robot's movement.

The angle between the y-axis and the x-axis of the Robot and the radius of the wheel were represented using the following matrix, which represents the final result.

$$\dot{P} = \begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\varphi} \end{bmatrix} = \frac{r}{2} \begin{bmatrix} \cos(\varphi) & \cos(\varphi) \\ \sin(\varphi) & \sin(\varphi) \\ \alpha & -\alpha \end{bmatrix} [\dot{\theta}_r \quad \dot{\theta}_i]$$

According to Singh et al., (2020), a study of the T2FC type is a fuzzy control unit and contains five basic elements, which are Fuzzifier, fuzzy system inference engine, reducer type, based rule system. The simplest type of control device appears in Figure 10.