Volume 6, Issue 7, July – 2021 International Journal of Innovative Science and Research Technology

ISSN No:-2456-2165

# 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.

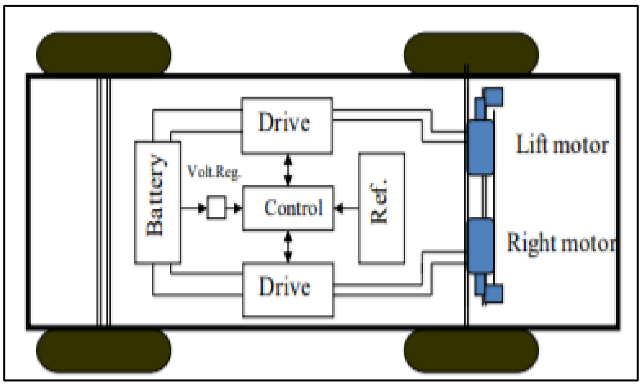


Figure 1: Top view for simple differential drive (DD) robots with two-wheel (Salem, 2013).

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.

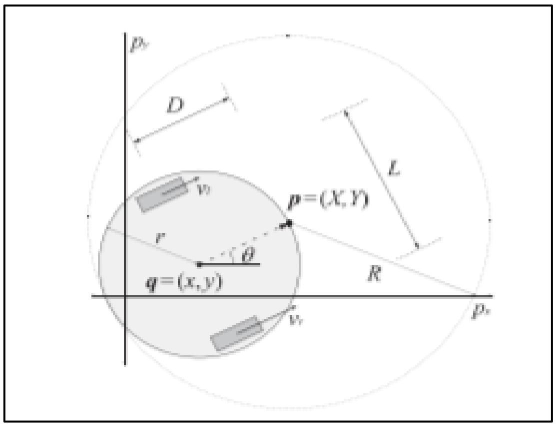


Figure 2: An example of the differential-drive Robot kinematic model (Snape et al., 2010).

### *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.

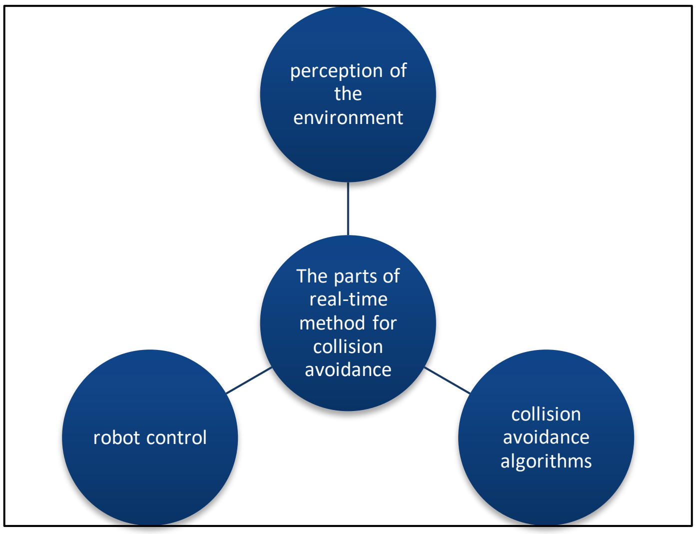


Figure 3: The parts of a real-time method for collision avoidance (Flacco et al., 2012).

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.

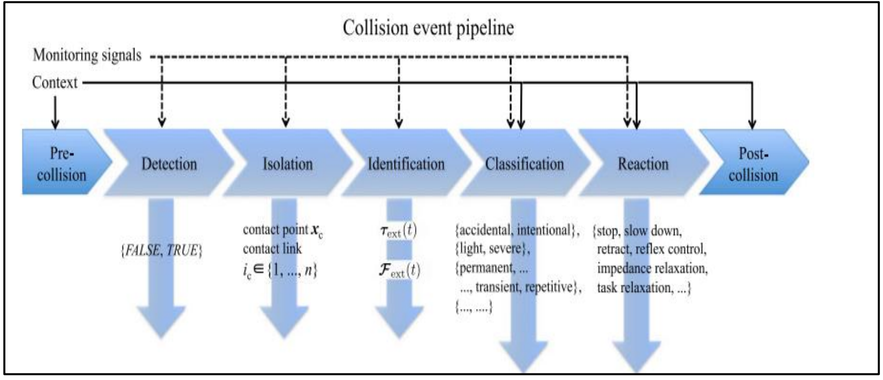


Figure 4: Seven phases of the collision and the expected outputs (Haddadin et al., 2017).

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.

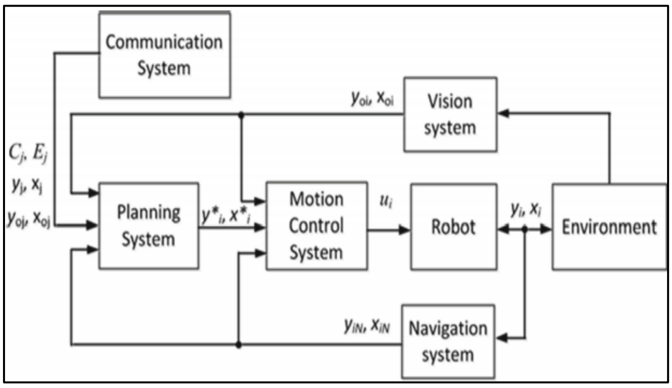


Figure 5: Block diagram for robot movement control (Fujita, 2020)

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.

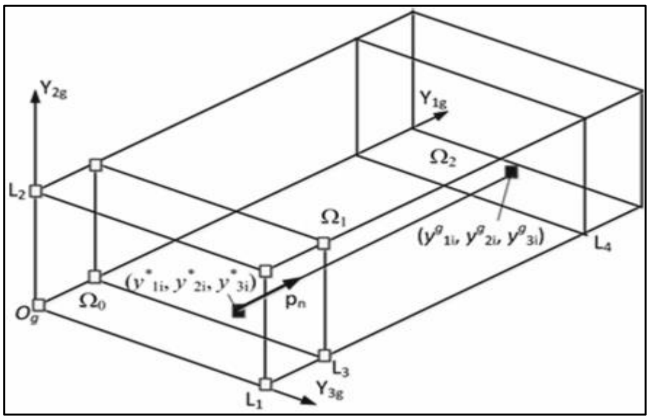


Figure 61: The Path Areas (Fujita, 2020)

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

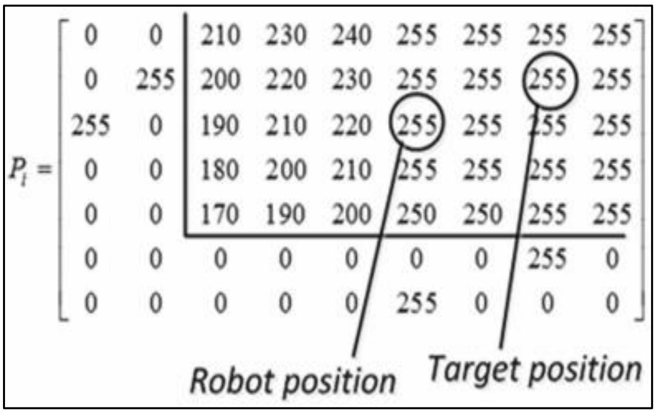
Where:

- $rij$ : 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:

$$(\min ij\ (rij)\ ) \rightarrow \max\ (y\,1i, y2i, y3i) \qquad \text{Eq. 2}$$

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.

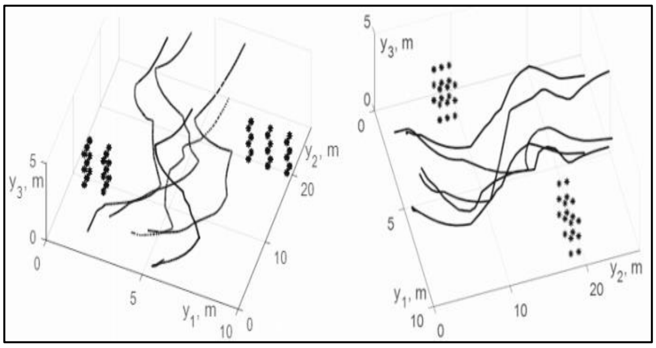


Figure 8: The robot Path (Fujita, 2020).

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.

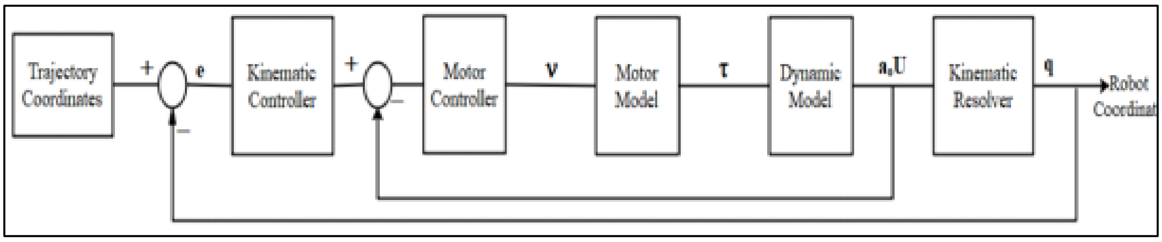


Figure 9: Block diagram for robot control (Zangina, 2020)

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.

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

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.

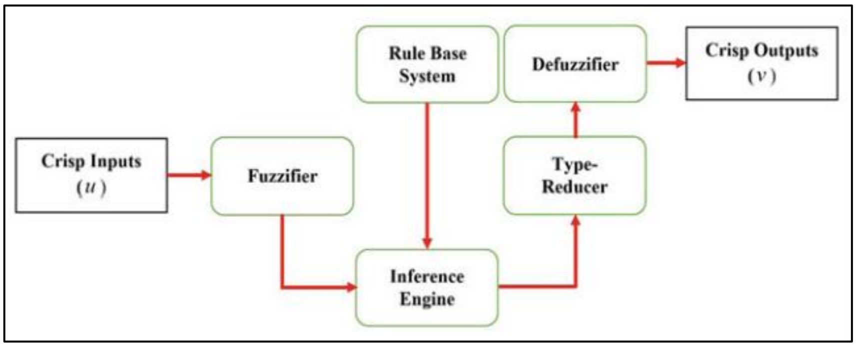


Figure 10: The simplest structure of the T2FC controller (Singh et al., 2020).

For T2FC, it contains a number of inputs, such as the distance of the item taken by the sensors that are installed in the Robot. On the other hand, it had a steering angle, which was the only way out. The simulation was done on MATLAB. A number of steps were followed in MATLAB, where the sensor signal was sent by V-REP to MATLAB as it was considered as the input of the T2FC control unit that was used in order to provide the required angle. The Robot was controlled by the fuzzy controller to know the actions of the Robot when encountering an obstacle, as shown in Figure 11.

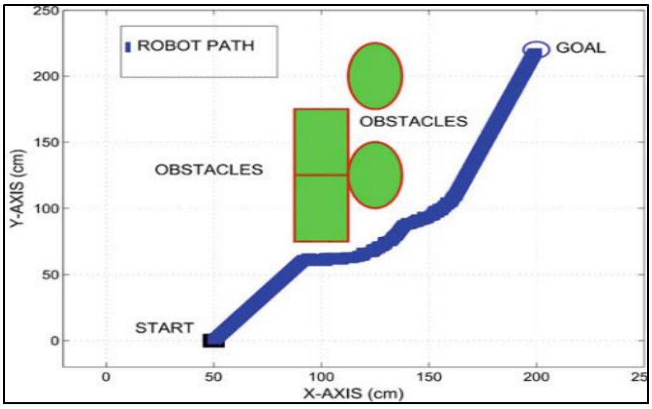


Figure 11: The actions of a robot using a normal fuzzy controller (Singh et al., 2020).

From the other side, the Robot that used the T2FC controller would act in a more specific manner, as shown in Figure 12.

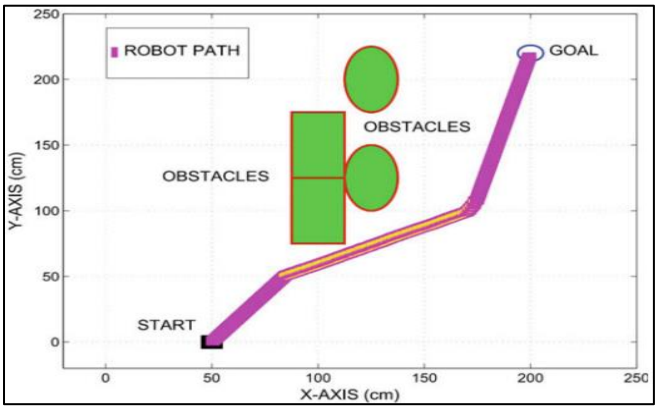


Figure 12: The Robot action through the T2FC controller (Singh et al., 2020).

According to Sangiovanni et al. (2018), a clear methodology was presented in order to avoid the collision in real-time, through machine learning, and it aims to coexist between robots and humans safely. The problem of avoiding the collision that occurs with robots is generally dealt with through deep reinforcement learning (DRL) techniques. An algorithm was used that was characterized as being completely free from Normalized Advantage Function (NAF) after defining robotic systems in continuous space. The Robot, which was designed to evaluate the proposal made in this project, which is expressed using the COMAUSMART3-S2 model, was considered. For automatic evaluation, training, and control, the automated system had to be connected through external tools. In this project, the operations that were performed regarding simulations on the virtual environment were reported in order to show the efficiency of the algorithm that was used. The Incentive role in the Planar Portion of the Environment is shown in Figure 13.

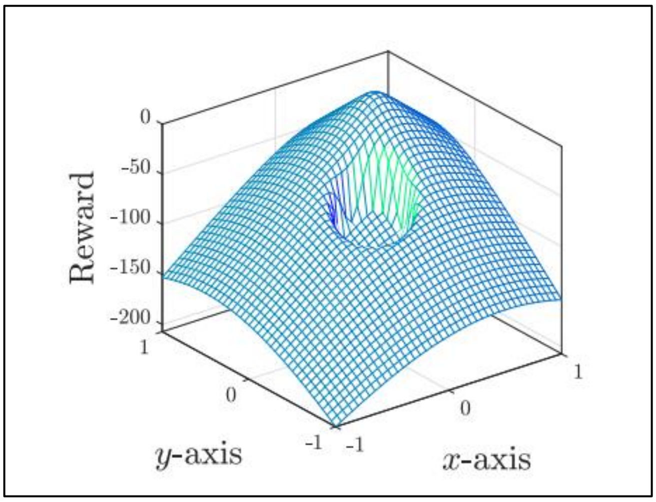


Figure 13: The Incentive role in the Planar Portion of the Environment (Sangiovanni et al. 2018).

Figure 14 displays the action of the compensation function measured through a robot ergonomics plain cross-section. The plane was parallel to the surface as well as it is at the same level as the goal as well as the direction of the barrier. The goal position is determined at (0.5, 0.5) as well, as the barrier is cantered at (0.1, 0). For convenience, the Robot has been believed to have been a traveling point on the graph, and that only the concepts RT, as well as RO, were regarded for a reward variable. As seen in Figure 13, the result variable becomes concave of amounts less than 0 as well as achieves the limit when another robot tipped becomes positioned at the target position. In addition, the value reduces as the Robot gets closer to the barrier. Also, the scenario of the training in the V-REP with virtual COMAU SMART3-S2, target, and obstacles is shown in Figure 14 with red circles.

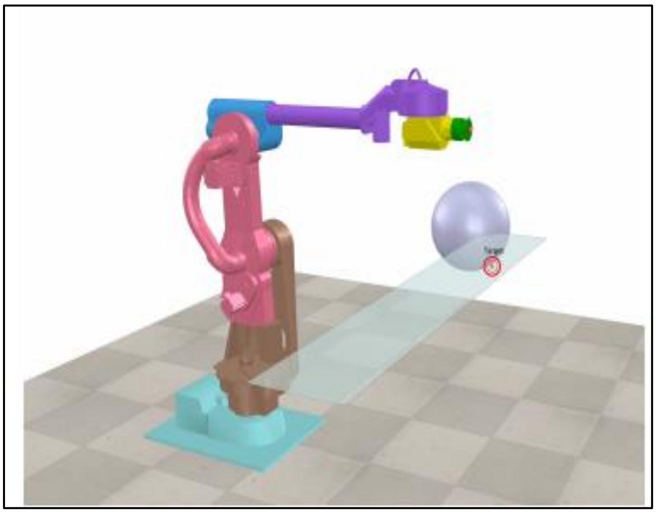


Figure 14: the scenario of the training in the V-REP with virtual COMAU SMART3-S2 (Sangiovanni et al. 2018).

The outcomes have been obtained through applying an algorithm that is known as collision avoidance NAF with only sex joints and reaches the point within the space in the end-effector, which has been illustrated in Figure 15.

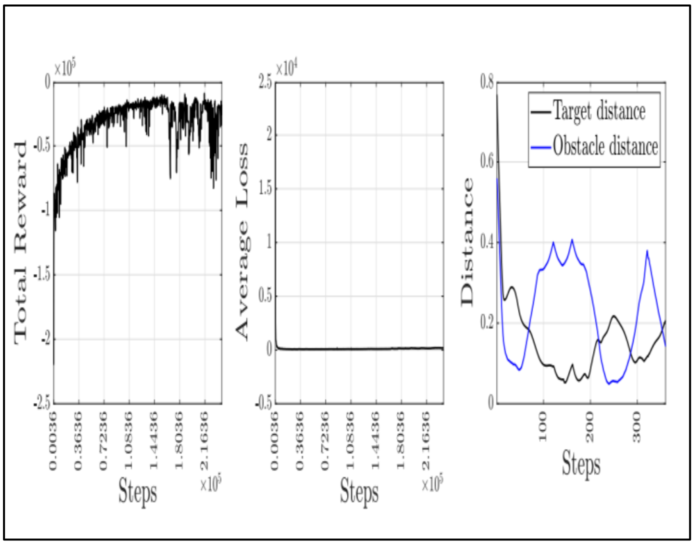


Figure 15: The outcomes which have been obtained through applying an algorithm (Sangiovanni et al. 2018).

The performance of these three methods regarding transfer learning is shown in Figure 16.

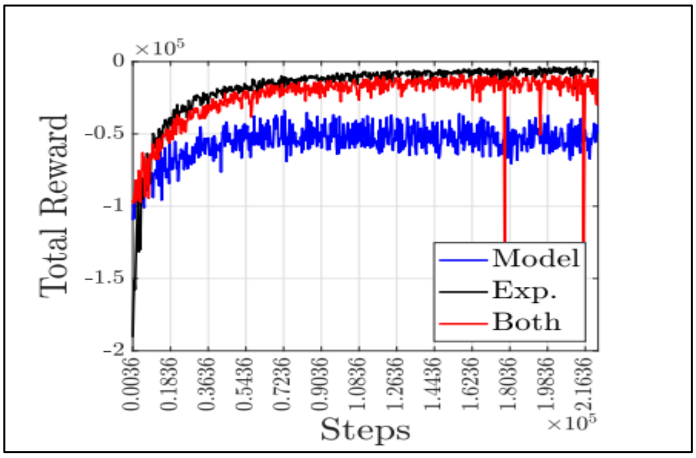


Figure 16: The performance of these three methods regarding transfer learning (Sangiovanni et al. 2018).

According to Kabanov, & Tokarev. (2020). this work proposes a Collision detection and protection algorithm for two robot manipulators working together. The algorithm depends on dividing the workspace manipulators into small discrete volumes, which are defined by the spatial coordinates of x, y, and z in the workspace and the logical variable that determines the volume conditions (free) or (occupied). The volumes at which both the manipulator joints as well as the linking lines are situated are denoted as being occupied. When calculating the control, a prediction is made of the future location of the manipulator's joints. If the new location of the manipulator contributes to the occupied area, the re-computation shall be made.

The geometrical properties consideration of the manipulators is an essential development in the current method. The variance of the workspace discretion under division through unit volumes may be extended with an exception for the geometry of the connections as well as manipulators' joints. The kinematic model describes the variety of joints with known coordinates and connections between them. Thus, the individual motors values, generators, junctions as well as other positive factors are not considered.

The inclusion of geometric figures representing the volume representation of these components would make it possible to consider the manipulator's collision under the conditions of the actual design. The manipulator coordinates ties are added to each of the figures. This approach helps in predicting the collision of two or more manipulators as well as eliminating critical states at the control design level. The block-scheme of the collision detection and prevention algorithm followed in this study is shown in Figure 17.

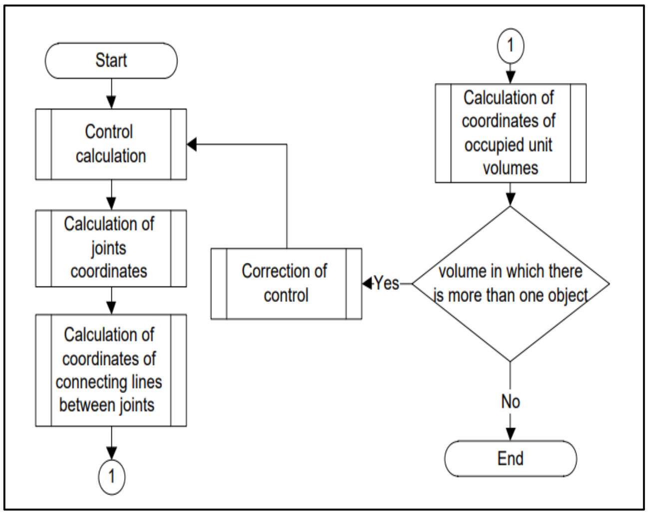


Figure 17: The block-scheme of the collision detection and prevention algorithm followed in this study (Kabanov, & Tokarev 2020).

Every manipulator comprises 2 ties as well as 3 joints. The joints are connected to each other by direct lines, and the coefficient of discretion (kd) equals 1.

## IV. METHODOLOGY

The differential drive (DD) system is used in this paper to design the robotic system as shown in the following figure.

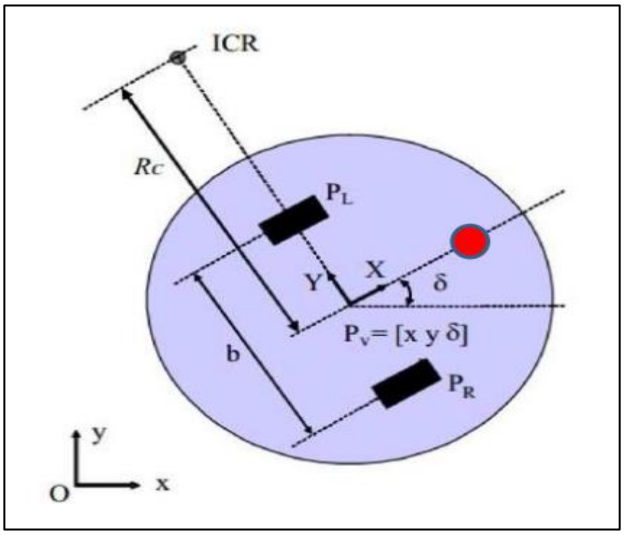


Figure 18: The differential drive (DD) system.

- The model's kinematics:

Firstly, $Xr$ and $Yr$ will be found as shown below:

$X_r = X + d\cos(\theta)$ Eq. 10

$Y_r = Y + d\sin(\theta)$ Eq. 11

Furthermore, the following equation will be used in order to find the velocity depending on the reference point:

$\dot{X}\mathrm{r} = \dot{X} - d\dot{\delta}\sin(\delta)$ Eq. 12

$$\dot{X}\mathrm{r} = \frac{V_{right}+V_{Left}}{2}\cos(\delta) - \mathrm{dsin}(\delta \frac{V_{right}-V_{Left}}{b})$$

$$= \mathrm{V_{Right}}\left(\frac{Cos\ \delta}{2} - \frac{\mathrm{dsin}(\delta)}{b}\right) + \mathrm{V_{left}}\left(\frac{Cos\ \delta}{2} + \frac{\mathrm{dsin}(\delta)}{b}\right)$$

$$\dot{Y}\mathrm{r} = \mathrm{V_{Right}}\left(\frac{sin\ \delta}{2} + \frac{\mathrm{dcos}(\delta)}{b}\right) + \mathrm{V_{left}}\left(\frac{sin\ \delta}{2} - \frac{\mathrm{dcos}(\delta)}{b}\right)$$ Eq. 13

After derivation, the substitution of Xr and Yr is shown below:

$$\begin{bmatrix} \dot{X} \\ \dot{Y} \\ \dot{\delta} \end{bmatrix} = \begin{bmatrix} \frac{V_{right}+V_{Left}}{2}\cos(\delta) \\ \frac{V_{right}+V_{Left}}{2}\sin(\delta) \\ \frac{V_{right}-V_{Left}}{b} \end{bmatrix}$$

Then, the Simulink MATLAB was used in order to build the system model, which is shown in Figure 19.

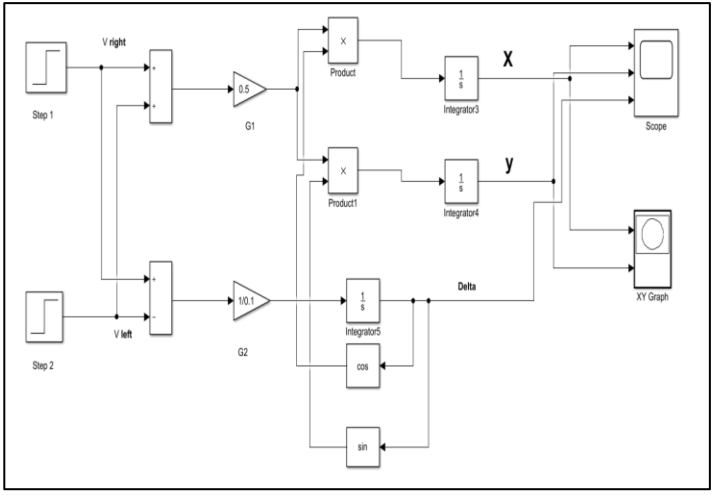


Figure 19: Kinematic model block diagram

## V. RESULTS AND DISCUSSION

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### A. Avoiding one obstacle

The Robot must move from point 0 and reach the required position at 6.7; the Robot must consider in its choice the avoiding of the impedance at the obstacle at point 3.3, which is in diameter of 1.4. Figure 20 shows the selected path by the Robot.

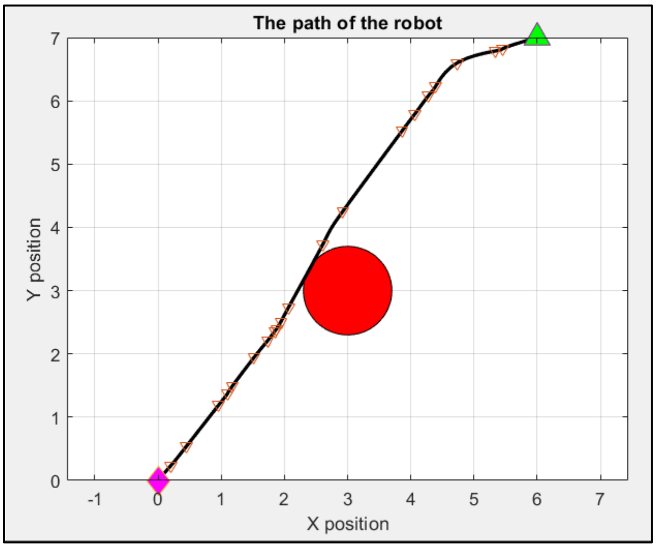

Figure 20: The selected path with one obstacle.

It is notable that the Robot selected the best path, which prevents the collision with the existed obstacle. The design of the model depends on one obstacle in order to improve the visualization of the robot actions.

### *B. Avoiding several obstacles*

The Robot must move from point 0 and reach the required position at 6; the Robot must select the path which avoids the impedance with the several existed obstacles. Figure 21 shows the selected path by the Robot.

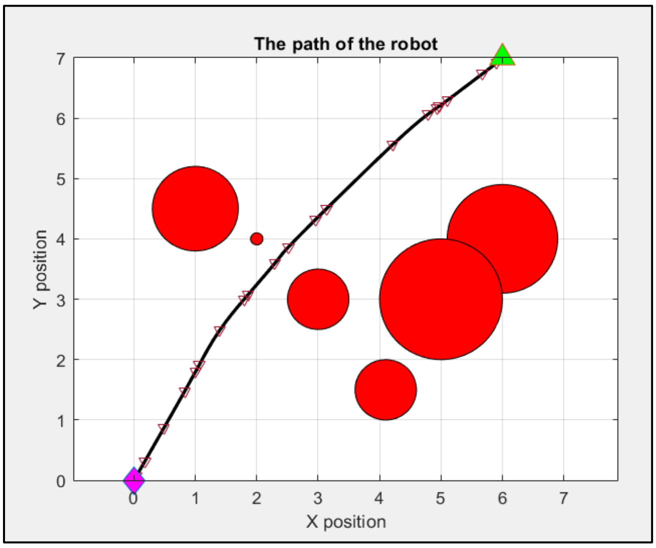

Figure 21: The selected path with several obstacles.

It is notable that the Robot selected the best path, which prevents the collision with the several existed obstacles. This path was reached after 600 trials in order to achieve the smallest path.

### *C. A complex obstacle map.*

The Robot needs to maintain its desired performance, which includes choosing the shortest route and avoiding all obstacles, even with the complex obstacle map; the selected path of the Robot with a complex map of obstacle case is shown in Figure 22.

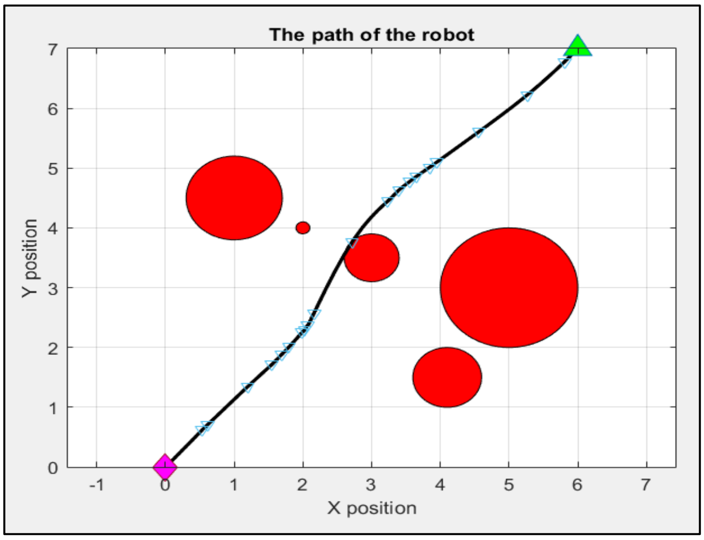

Figure 22: The selected path of the Robot with a complex map of obstacle case.

After analysing the obtained results, the model accuracy was shown; the following path regulation is conducted by minimizing the direction by using the particle swarm optimization criterion in order to reduce the path length. Mixing between the two approaches of artificial intelligence and kinematics is performed to explain the usefulness of control and machine learning. When the findings of the model are compared to the previous related studied models, it is obvious that the Robot takes a shorter distance than the other models.

## VI. CONCLUSION

The idea from this project is to detect the possible collisions that may occur between the robot and the surrounding material and objects during its movement from place to another. In this project some information has been collected from the previous studies which plays the major role of the gaudiness for implementing this project and which was stated that the moving of the robot body is the best prompt option and response from it in order to mitigate any collisions. This project was conduct to study multi scenarios. This first stage is having just one obstacle, the control process of this stage is much simpler than the rest scenarios. The second stage is to try avoiding several obstacles distributed randomly in the surrounding area, and finally, the last stage is to mitigate the collisions if the map of the position for the obstacles was in complex form.

It was concluded that by controlling the movement of the robot and calculating the distance between the robot and the nearest obstacle based on the mathematical equations. Also, it has been found that the usage of the differential drive system, which own two-wheel, is the most proper and suitable type for these kinds of controlling process since the design of its structures is simple in the applications of mobile robotics, and the accuracy of it is very well.

Finally, the most important outcome that has been obtained from this project is that the control process of the robot moving must be done for seven stages which are: the pre-collision, the detection, the isolation, the identification, the classification, the reaction, and the post collision. So, the control process and achieving the desired outcomes depend mainly on the previous seven steps.

For potential future work, the adverse environments of the obstacles should be addressed in the control system by raising the raising of ultrasonic sensors number and the angles between the Robot and sensors. Additional analysis should be performed about the distance between the obstacle and the Robot by reducing the overall distance and increasing the distance between the obstacle and the Robot. This may be achieved by using twice optimization of the particle swarm.

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