Intelligent Controller for Robot Manipulator

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ABSTRACT

This paper suggests an intelligent controller to control the manipulator movement in an environment of two and three – dimensional. The fuzzy logic controller of planning structure locally approach constructs of multi-unit. The aim is to transmit or guide the manipulator from the elected to a desired configuration. Modeling, scenarios and simulations are presented clearly in two dimensions and three dimensions together with their analysis which be done using MATLAB software. In addition, the results of the robot navigation in two-dimensional environments also compared with the results of the navigation in three-dimensional environments to clarify the strength of the suggested intelligent controller, where results (in rad) for the third link for both two and three- dimensional environments are minimum: 1. and $-7.452147499 \times 10^{-4}$ in the scenario 1 also minimum results in scenario 2 as the following: −٠.٠٠٦١ and −٠.٠٠١٨. Simulation results indicate this manipulator successfully reached the desired goal configuration.

Keywords: planning the path, fuzzy logic controller, robot manipulator.

INTRODUCTION

The arm of robotic is utilized to pick and place object at locations are set in a given hemispherical three dimensional space. The mechanism of pick and place finds it applications in the field of electronics industry, consumer goods industry, military and food industry [1].

Traditional control methods require near complete knowledge of a robot's nonlinear dynamics in order to generate effective control signals. Obtaining accurate model parameters consumes time, expense, and loses accuracy over time. Robot path planning is an important part of the development of autonomous systems [2-4].

The low cost, fast response, real-time ability is good and unnecessary knowledge the accurate sample of the model to control it and meet the real- time demands for planning the motion of the robot are benefits of fuzzy control [5, 6]. Fuzzy system illustrated in Figure (1) [7].

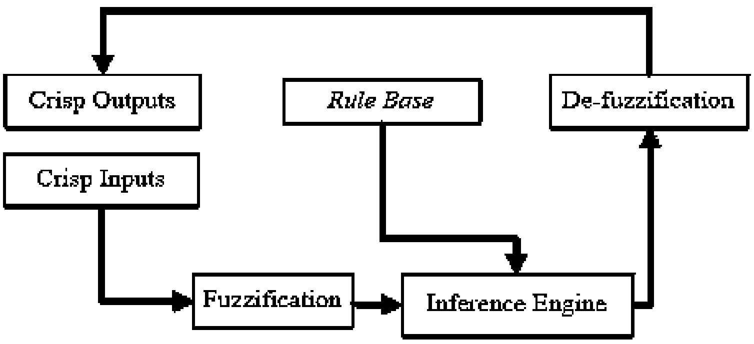

Figure (1): Fuzzy Inference System structure (FIS) [7].

Some previous researchers dealt with the subject of robot strategies for navigation system as follows: Tawfik M. A. et al [8] presented a three-dimensional continuous autonomous chaotic system, Basic properties of the presented system were analyzed by means of Lyapunov

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exponent spectrum, Poincar'e mapping, fractal dimension, power spectrum and chaotic behaviors. Furthermore the cited chaotic system was implemented in robotics field for coverage area purposes, where it's used to generate chaotic motion for mobile robot that's guarantee of scanning the whole connected workspace as an example of advantage of this system.

Hussein Z. D. et al [9] suggested a study for optimal performance of a robot to be used in human surgery (Laparoscope device). The optimal performance was obtained by using genetic algorithm method to choose the optimal path planning in the working area. The robot used was the Lab-Volt Servo Robot System.

Wei and Shimin [10] presented three-dimensional planning the path using NNT networks for a robot manipulator. They reported that it is complex to find a good path when the robot is in a complex dynamic change condition. Algorithms for the device to perform path planning and trajectory prediction were described.

Dubey et al [1] suggested evolutionary process to optimize robot manipulators task time. Tasks can be planned with relative to joints of robot / relative to end effector of robot.

Aljarboua [11] presented a distance transform based on geometric algorithm of planning the path with vision capability suitable for robots.

Ramírez and Rubiano [12] presented the forward kinematic model for industrial manipulator three degrees of freedom with a multiple applications.

Fani and Shahraki [13] suggested an individual FOPID controller is applied in order to control each link. Three evolutionary optimization algorithms included particle swarm optimization (PSO), genetic algorithm and estimation of distribution algorithm, are compared from optimal coefficients determination point of view.

Albert, Koh, Chen et al., [14] presented application and the formulation of a genetic algorithm based on strategy for the calculations of optimizing joint angles in a given search space for three armed planar manipulator structure that would contribute to a quality and a productive way of material processing and handling.

In this paper, the suggested approach effectiveness is validated through simulations. It meets the real-time demands for planning robot motion in environments of two – dimensional and three – dimensional.

Theory of the Fuzzy Inference System

Mamdani and Sugeno are the most widely used methods in fuzzy inference to determine the fuzzy intersection operation. The operators of minimum and product are the fuzzy rules. Every output of fuzzy unit can be calculated by utilizing the gravity center (COG) defuzzification method [15, 16], this method is used for the defuzzification:

$$\frac{\sum_{x}^{b} \quad _{A}(x).x}{\sum_{x=a}^{b} f_{A}(x)} \qquad \text{... (1)}$$

Where f_A is the consequent center membership function of rule (A). x means the area under the membership function.

Suggested Method

In this section, the suggested system has been described and illustrated. To make the design more comprehensive and expanded, the structure is applied into two environments of two – dimensional and three – dimensional.

The suggested fuzzy logic controller is to control the robot manipulator motion where this robot arm consists of three links. Each link produces $\Delta\theta_n$ depending on the input $\Delta\theta_{ng}$ and on the current value θ_n, Where $\Delta\theta_{ng}$ means error between the goal value and θ which represents the input2 to the first fuzzy unit and *n* the number of link, similar to units two and three of fuzzy logic controller.

Figure (2) shows the overall structure of navigation robot arm applied in two different cases environments as illustrated below where, in two dimensional environment and three dimensional environment respectively.

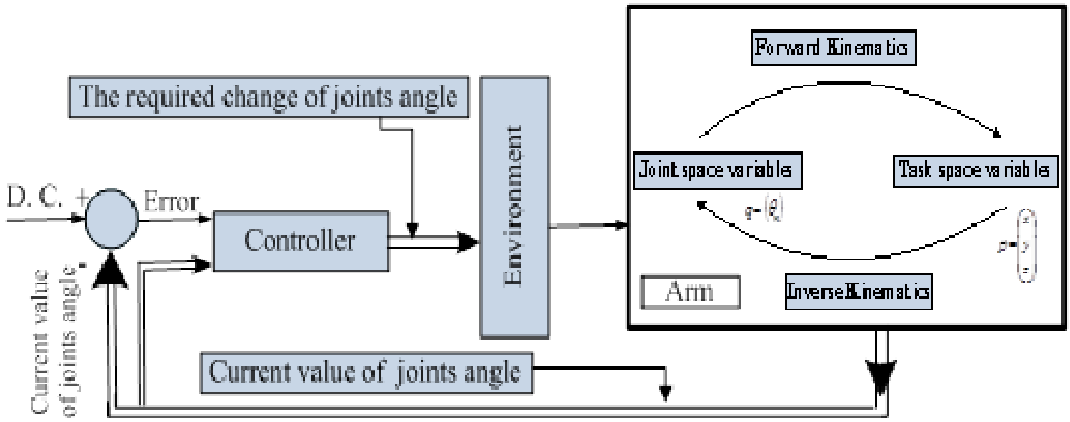


Figure (2): Overall structure

The varial ˙ ˊˊ ıts) of fuzzy system are angle parameters, where illustrated in Figure (3).

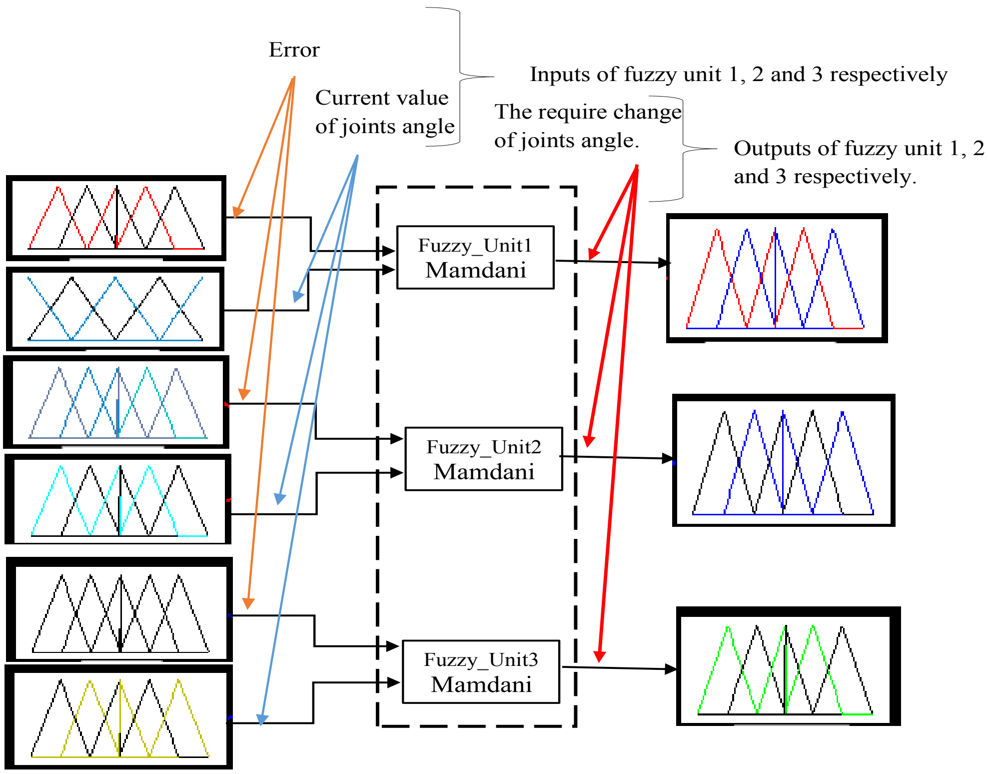


Figure (3): Fuzzy inference system for calculating the required change of joints angle for each link

The mathematical equations for the suggested method in equation (٢) and equation (٣):

... (٢)

Then the output of controller (the required change of joint angle) can be easily computed by the following:

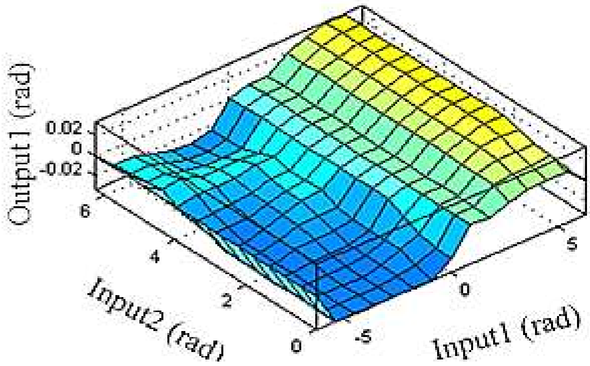
$(i \quad 1) \qquad (i)$ ... (٣)

Where, $D.C.$ means Desired Configuration also called $G.C.$ which means Goal Configuration.

By using Mamdani method and center of gravity in equation (1), For example rule 1: When (Error Negative Far i.e. negative value of membership function) and (Current value of joint1 angle is Left i.e. negative value of membership function) then the output (will be Negative Far i.e. negative value) also try and error used in each one.

As example below part of rules of first unit of fuzzy control in two – dimensional environment:

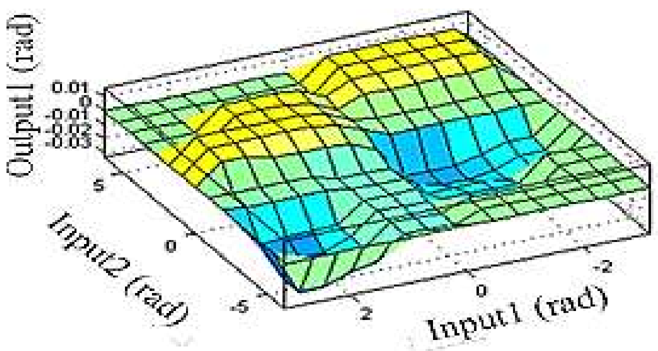
If Error is NFar and Current value of joint1 angle is Left then Output1 is NFar
If Error is NFar and Current value of joint1 angle is Right then Output1 is NAverage
If Error is NAverage and Current value of joint1 angle is Below then Output1 is NClose
If Error is NAverage and Current value of joint1 angle is Right Positive then Output1 is NFar
If Error is NClose and Current value of joint1 angle is Right Positive then Output1is NClose
If Error is NClose and Current value of joint1 angle is Below then Output1 is PClose
The surface viewer of this link is shown in Figure (4).



Figure(4): The surface viewer of first link

Also part of rules of second unit of fuzzy control in two – dimensional environment:

If Error is NAverage and Current value of joint2 angle is PFar then Output2 is NClose
If Error is NClose and Current value of joint2 angle is PAverage then Output2 is NFar
If Error is PClose and Current value of joint2 angle is NFar then Output2 is NClose
If Error is PClose and Current value of joint2 angle is NClose then Output2 is NClose
If Error is PClose and Current value of joint2 angle is PClose then Output2 is PClose
If Error is PAverage and Current value of joint2 angle is NClose then Output2 is PClose
The surface viewer of this link is shown in Figure (5).



Figure(5): The surface viewer of second link

Moreover, part of rules of third unit of fuzzy control in three – dimensional environment as example:

If Error is NFar and Current value of joint3 angle is PFar then Output3is NFar
If Error is NAverage and Current value of joint3 angle is NClose then Output3 is NMedium
If Error is NAverage and Current value of joint3 angle is PFar then Output3is NClose
If Error is NClose and is Current value of joint3 angle NAverage then Output3 is NFar
If Error is PClose and is Current value of joint3 angle NFar then Output3 is NClose
If Error is PClose and is Current value of joint3 angle NClose then Output3 is NClose

Where N is Negative for example NFar means Negative Far and so on. The surface viewer of this link is shown in Figure (6).

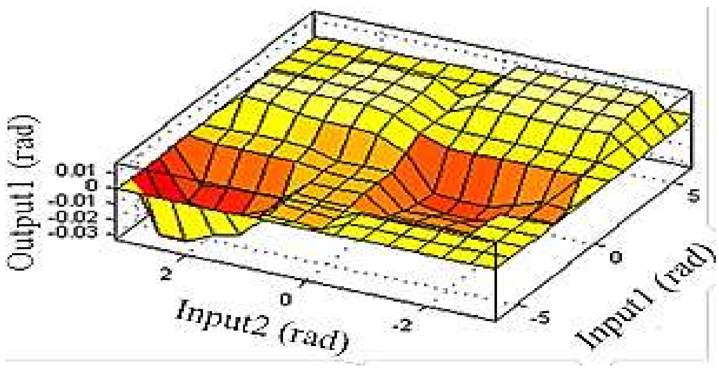
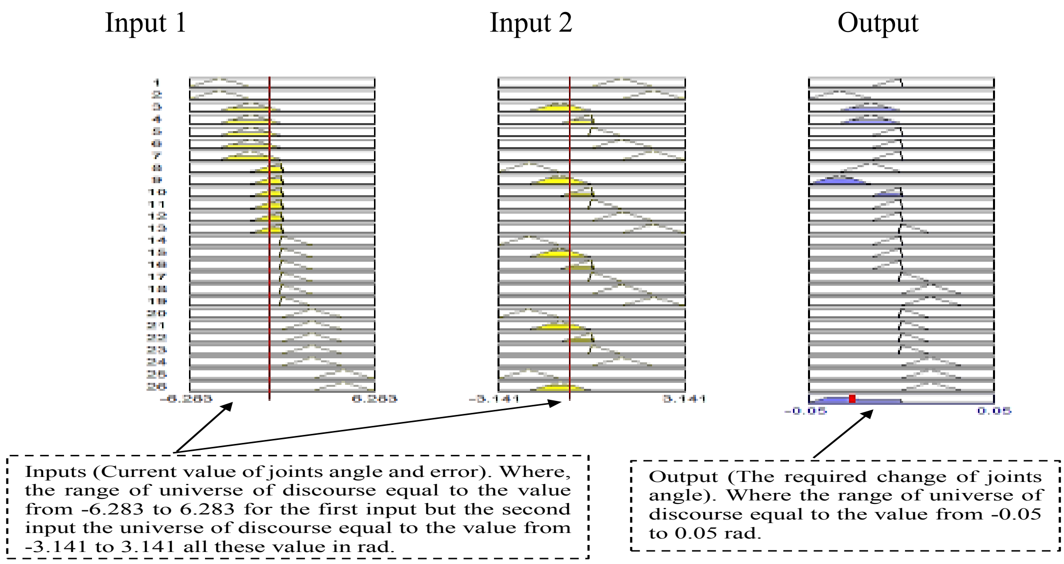


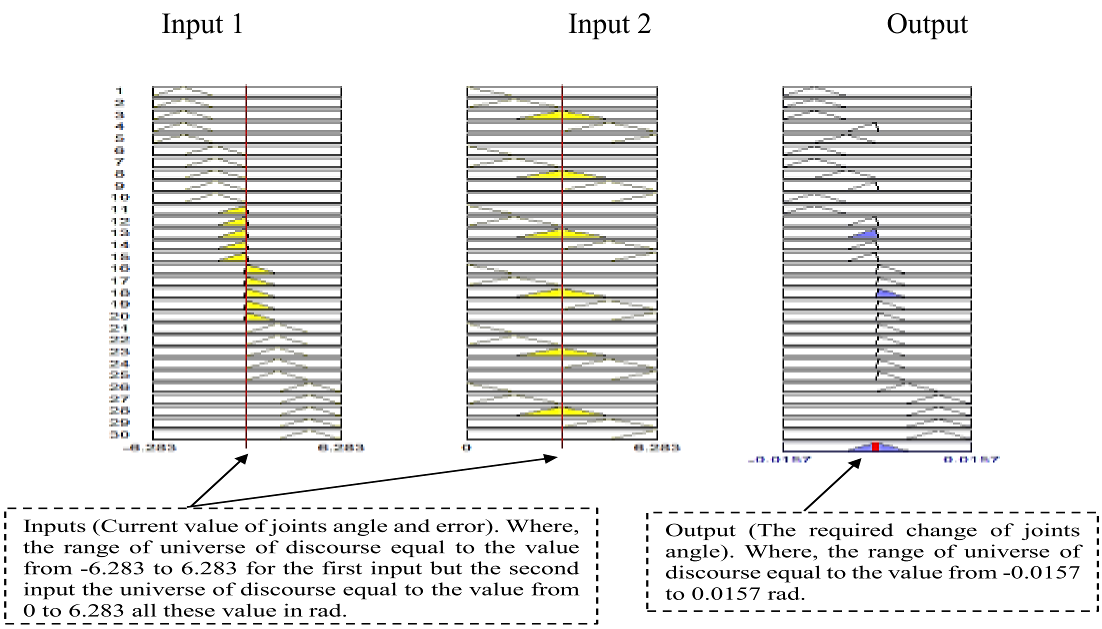
Figure (6): The surface viewer of third link

Moreover, below Figure (7) shows part of fuzzy rule table that suggested in this paper for robot navigation in two and three dimensional environments respectively.



(a)

Continued



(b)

Figure (7): Some fuzzy reasoning rule table: (a) for navigation in two-dimensional, (b) for navigation in three-dimensional

Simulations Results and Discussions

To test the overall system of Figure (2), Table (1) and Table (٤) below show the specifications of scenario 1 and scenario 2 of robot arm navigation in two and three dimensional environment respectively. Additionally, the results of the system structure of navigation in two and three dimensional are illustrated in Table (٣) and Table (٦) respectively.

Table 1: The specifications of scenario 1 of robot arm navigation in two and three dimensional environment

Scenario 1				
Environment	**No. of Links**	**Link length (m)**	**Start Configuration (Degree)**	**Desired Configuration (Degree)**
Navigation in	1	1	20	120
	2	1	40	90
	3	1	60	90
Navigation in	1	1	20	120
	2	1	40	90
	3	1	60	90

Table (2) and Table (5) clarify comparison between desired configuration and reached configuration for both scenario 1 and scenario2 respectively.

Table (2): Comparison between desired configuration and reached configuration

Environment		Desired Configuration (Degree)	Reached Configuration (Degree)
Navigation in		120	120.01323323
		90	90.07461632
		90	89.98883547
Navigation in	120	120.0013354	
	90	90.03550576	
	90	90.04269766	

Figure (8) shows the arm navigation in two – dimensional environment and Figure (9) the simulation results of scenario 1 where, S.C. Start Configuration and $D.C.$ Desired Configuration also called $G.C.$ which means Goal Configuration. L_1, L_2 and L_3 mean Link1, Link2 and Link3 respectively

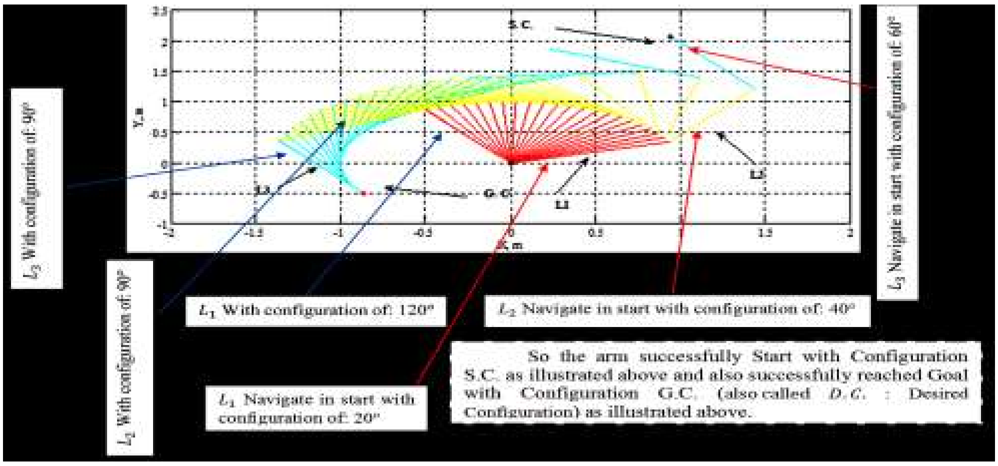


Figure (8): The arm navigation in two – dimensional environment scenario 1

Applying the same mechanism of Figure (8) to three – dimensional environment but the difficulty to understand and imagine the navigation in three – dimensional environment so that make (Axial, Side, Top view.

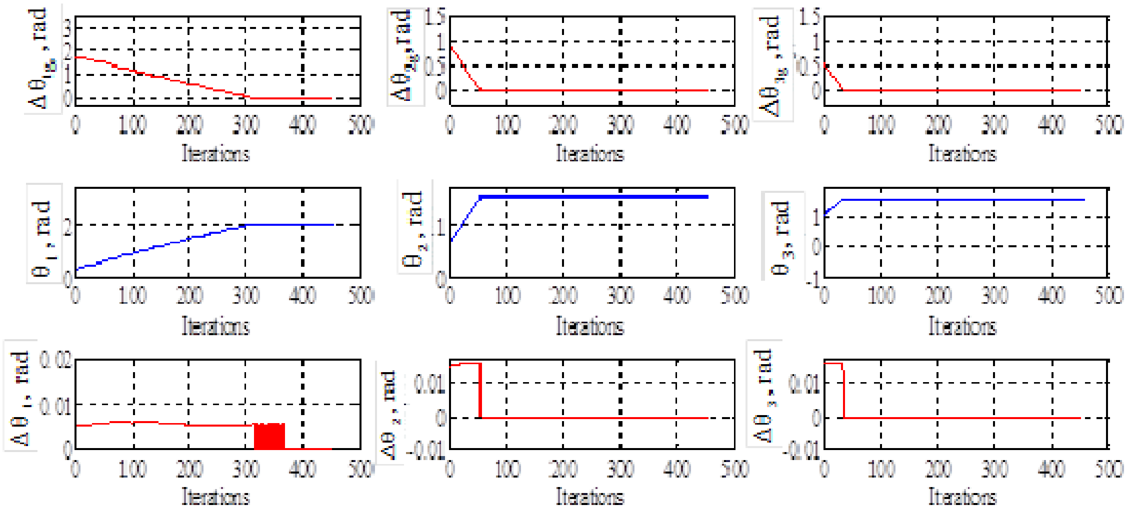


Figure (9): Scenario 1 simulation results

Figures (10), (11), (12) and (13) show the arm navigation in three – dimensional environment, moreover all viewer directions such as 3 D view, axial view, side view and top view respectively. Figure (14) the simulation results of scenario 1. L_1, L_2 and L_3 mean Link1, Link2 and Link3 respectively.

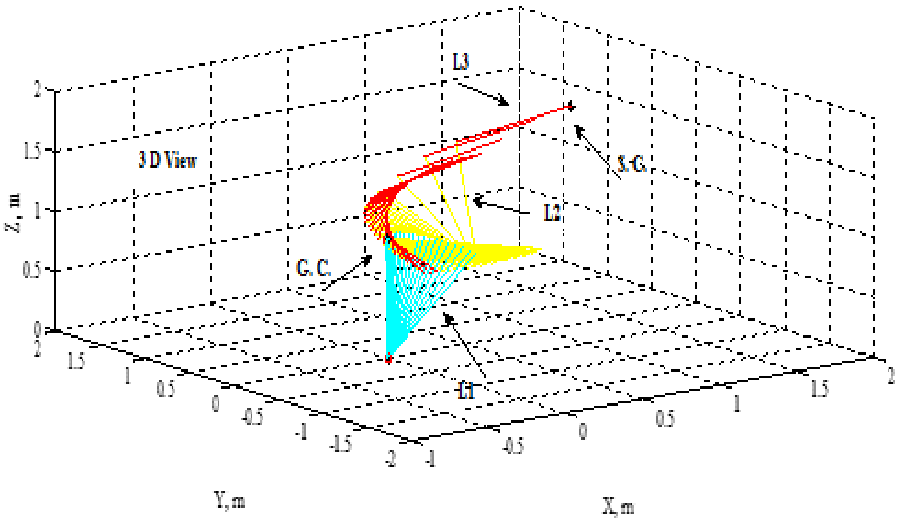


Figure (10): The arm navigation in three – dimensional environment scenario 1

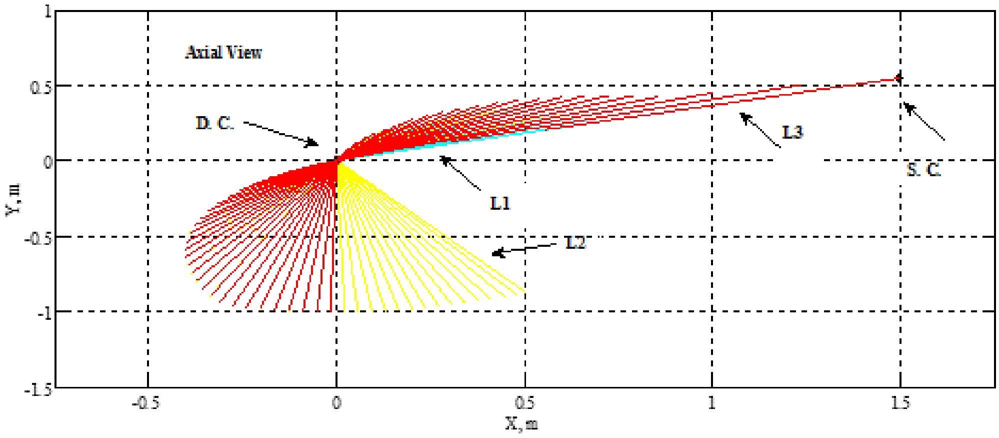


Figure (11): The arm navigation in three – dimensional environment: Axial view scenario 1

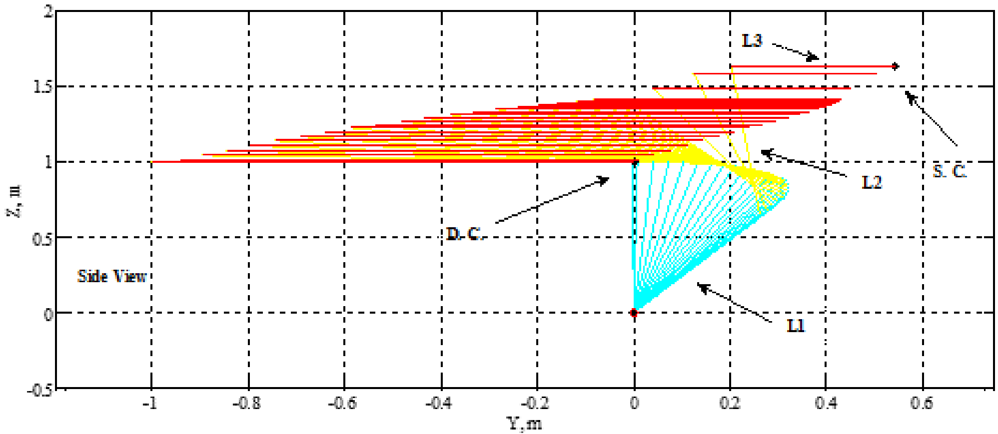


Figure (12): The arm navigation in three – dimensional environment: Side view scenario 1

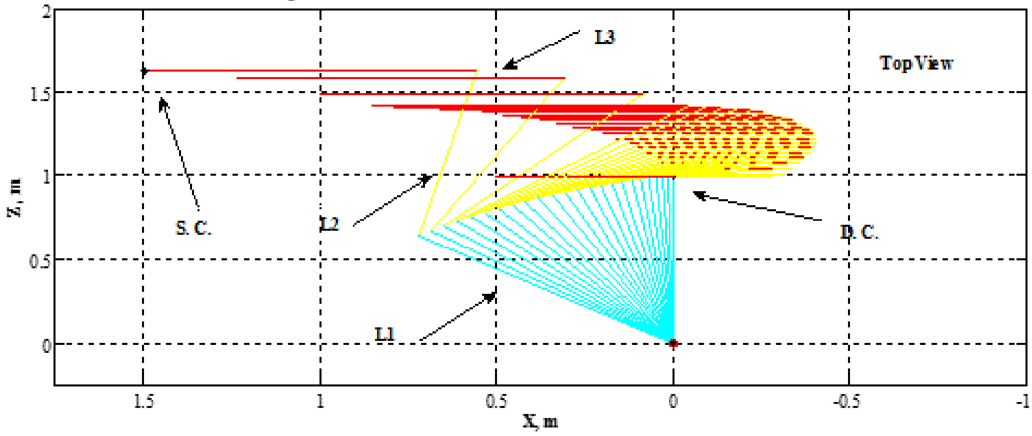


Figure (13): The arm navigation in three – dimensional environment: Top view scenario 1

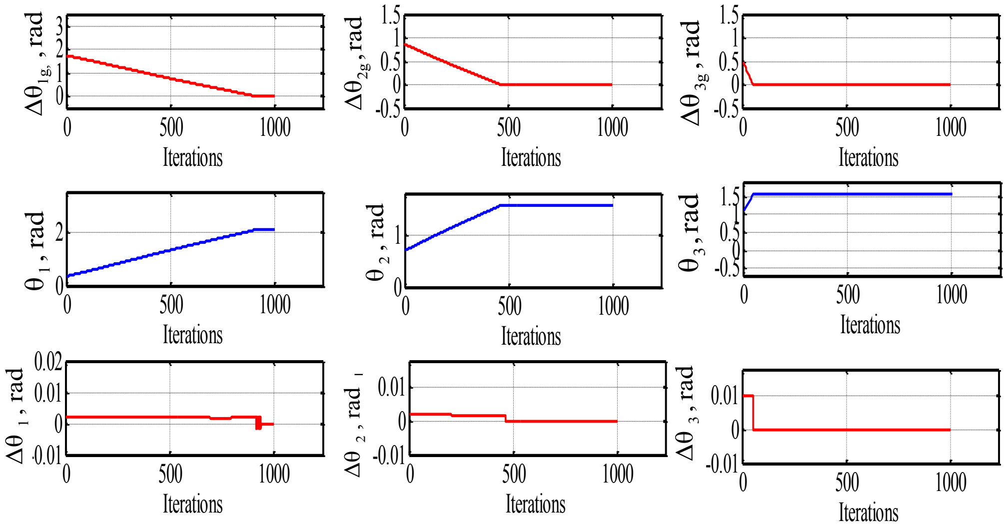


Figure (14): Simulation results of scenario 1

Table (3): The numerical results of scenario 1 of robot arm navigation in two and three-dimensional environment

Environment	Iterations	Error(Rad)	Error(Degree)
Navigation in	455		
Navigation in	1000		

More inclusive, we take another scenario by taking different values as clarified in Table (3) and the numerical results in Table (4) to test the overall system of Figure (2).

Table(4): The specifications of scenario 2 of robot arm navigation in two and three dimensional environment

Scenario 2				
Environment	No. of Links	Link length (m)	Start Configuration (Degree)	Desired Configuration (Degree)
Navigation in	1	1	25	155
	2	1	0	90
	3	1	10	90
Navigation in	1	1	25	155
	2	1	0	90
	3	1	10	90

Table (5): Comparison between desired configuration and reached configuration

Environment	Desired Configuration (Degree)	Reached Configuration (Degree)
Navigation in	155	154.7061956
	90	90.06725777
	90	90.34791521
Navigation in	155	154.9998675
	90	90.01432269
	90	90.103031

In another scenario take new start and desired configuration as shown in Figure (15) which shows the scenario 2 and Figure (16) shows the results of scenario 2.

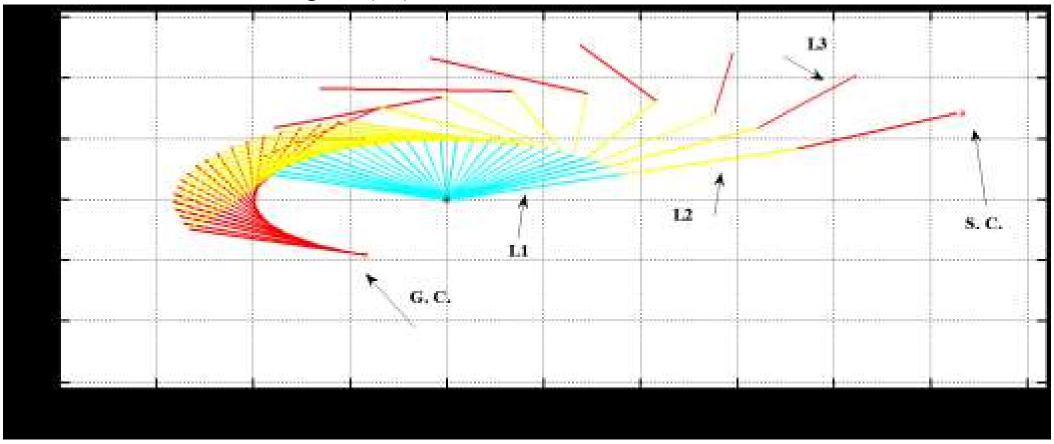


Figure (15): The arm navigation in two – dimensional environment scenario 2

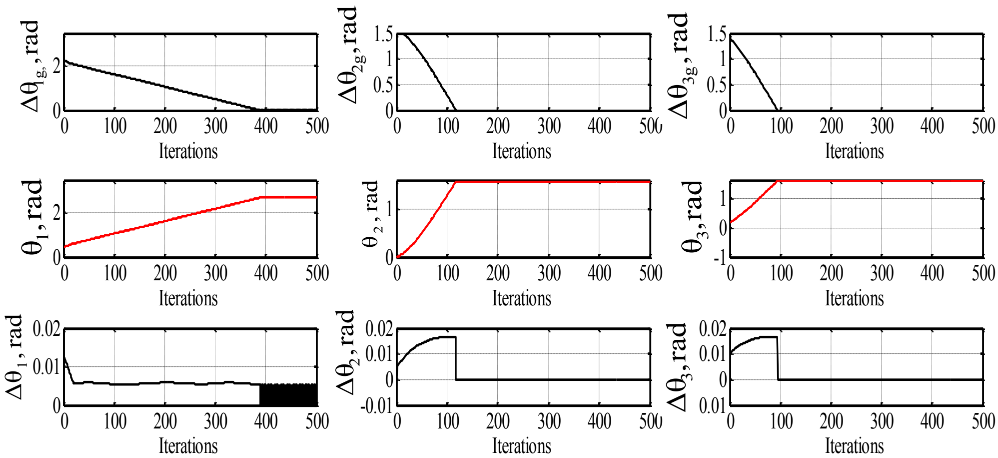


Figure (16): Simulation results of scenario 2

Furthermore robot arm navigates in three-dimensional as shown in Figure (17).

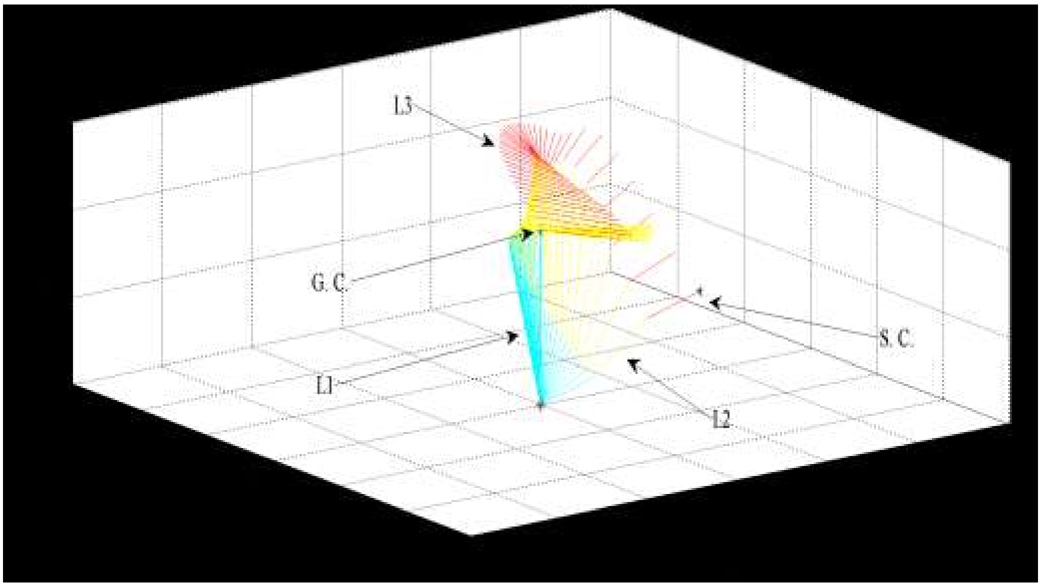


Figure (17): The arm navigation in three – dimensional environment scenario 2

Figures (18), (19) and (20) show the arm navigation in three – dimensional environment, Moreover all viewer direction such as Axial view, side view and top view respectively. Figure (21) the simulation results of scenario 2.

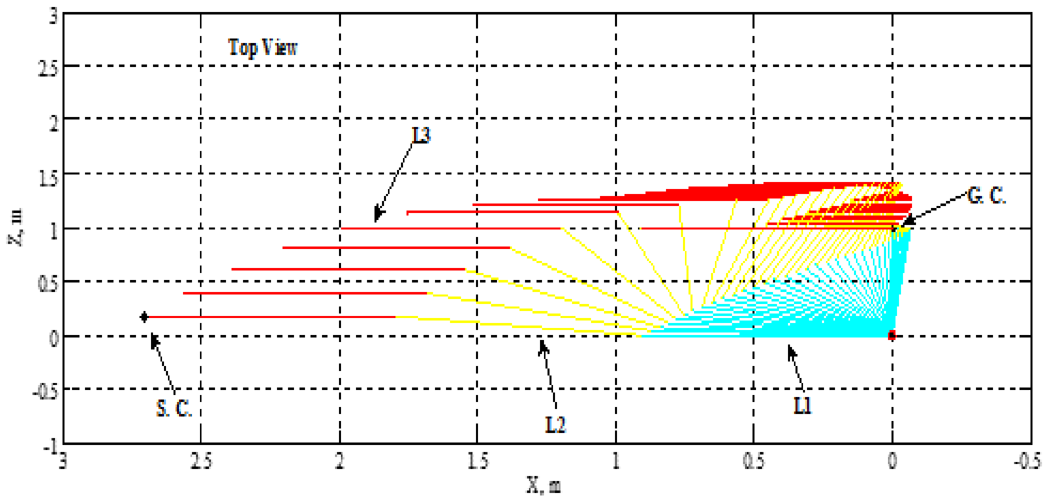


Figure (18): The arm navigation in three – dimensional environment: Top view scenario 2

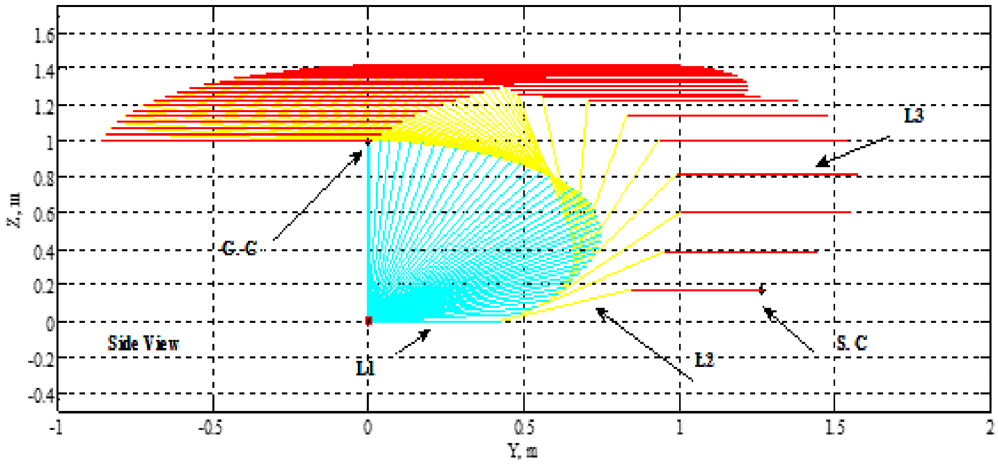


Figure (19): The arm navigation in three – dimensional environment: Side view scenario 2

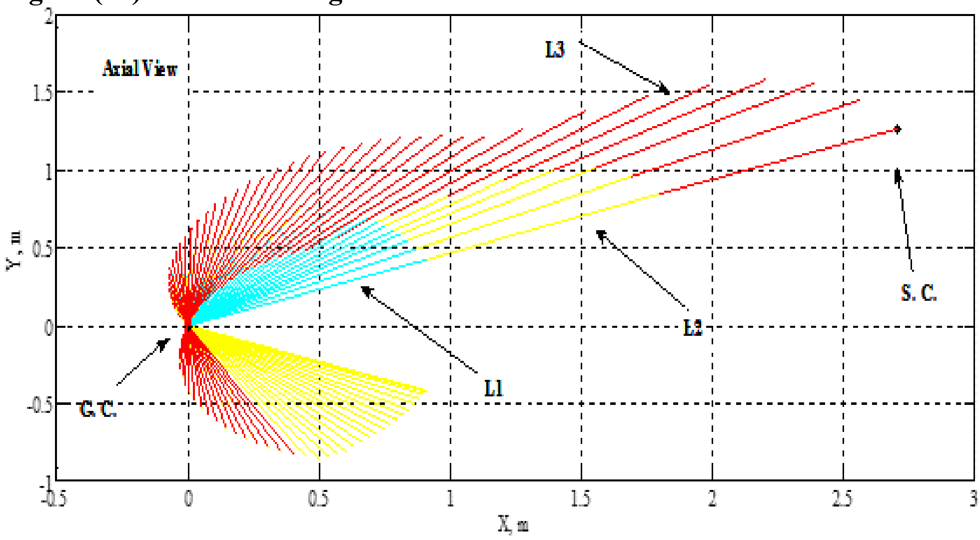
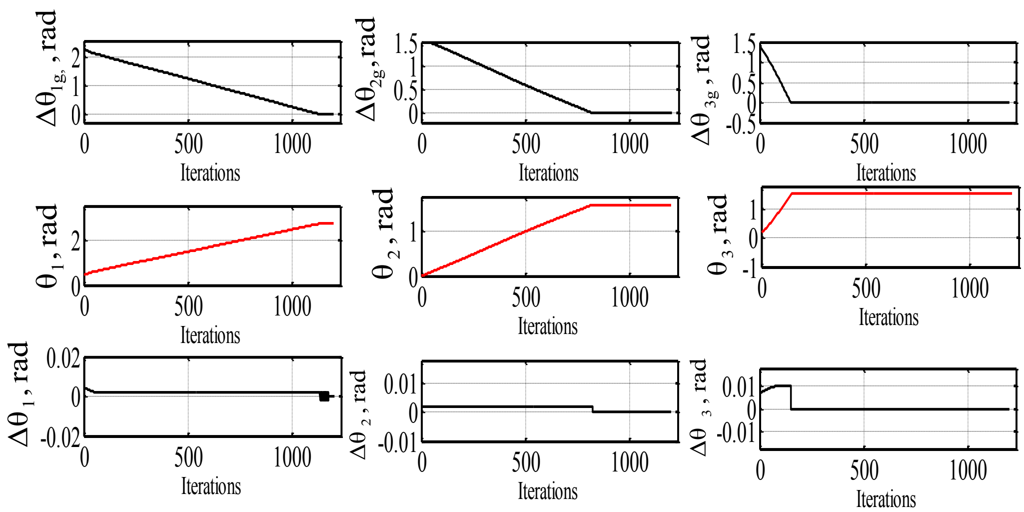


Figure (20): The arm navigation in three – dimensional environment: Axial view scenario 2



Figure(21): Simulation results of scenario 2

Where:

The error value, where n

Joint angle, where n

The required change of joint angle, where

Table (6): The numerical results of scenario 2 of robot arm navigation in two and three-dimensional environment

Scenario 2			
Environment	**Iterations**	**Error (Rad)**	**Error (Degree)**
Navigation in	505	٠.٠٠٥١	
		−٠.٠٠١٢	
		−٠.٠٠٦١	
Navigation in	1200		١.٣٢٤٦
			−٠.٠١٤٣
		−٠.٠٠١٨	−٠.١٠٣٠

From tables of simulation results for both two- dimensional and three- dimensional environment the robot arm reached successfully to desired configuration with (٠.٠1١2 °) minimum error value in navigation in two-dimensional environment after minimum iterations of program (455 and 505) However, three-dimensional navigation is more complex to explain, although it may enable more accurate.

CONCLUSIONS

This paper includes two essential parts. In the first one, navigate the robot arm in two-dimensional environment and the second one, navigate the robot arm in three dimensional environment. To prove and evaluate the performance of the arm, two scenarios for both environment applied so the results show that the problem solved for these structures by using intelligent controller. This algorithm is useful and applicable when dealing with intelligent controller. In this work, robot arm has been successfully reached to the desired configuration when the navigation in two and three-dimensional environments. Moreover a comparison has been made between them. Where, navigation in these environments exhibits good results where the results of reaching the goal (٠.٠1١2 °) after minimum iterations of program was minimum values in navigation in two-dimensional environment and good performance, while the navigation in three-dimensional the program iterations was larger than in two-dimensional environment (455 and 505 in two-dimensional, 1000 and 1200 in three- dimensional) but also the error remain acceptable with minimum value (−٠.٠4269766 °). However, 3D navigation is more difficult to interpret, although it may enable greater precision.

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