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Reduction of Large Scale Linear Dynamic MIMO Systems Using Adaptive Network Based Fuzzy Inference System

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ABSTRACT

Large Scale Multiple Input Multiple Output (MIMO) technology is a promising technology in wireless communications, and it is already at the heart of many wireless standards. MIMO technologies provide significant performance improvements in terms of data transfer rate and reduction the interference. However, MIMO techniques face large-scale linear dynamic problems such as system stability and it will be possible to overcome this problem by tuning the proportional integral derivative (PID) in continuous systems. The aim of this paper is to design an efficient model for MIMO based on Adaptive Neural Inference System (ANFIS) controller and compare it with a traditional PID controller. and evaluated by objective function as integral time absolute error (ITAE). ANFIS is used to train fuzzy logic systems according to the hybrid learning algorithm. The training involves the fuzzy logic parameters through simulating the validation data to represent a model to know the correctness and effectiveness of the system. It is optimizes the system performance in real time, however, to avoid potential problems such as easy local optimality. In the proposed approach stability is guaranteed as the initial steady-state scheme. ITAE is combined with ANFIS to minimize the steady-state transient time responses between the high-order initial pattern and unit amplitude response. The proposed ANFIS self-tuning controller is evaluated by comparing with the conventional PID. MATLAB simulink is used to illustrate the results and demonstrate the possibility of adopting ANFIS controller. The simulation results showed that the performance of ANFIS controller is better than the PID controller in terms of settling time, undershoot and overshoot time.

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1. Introduction

Wireless communication is considered one of the most advanced technologies of our time, and this coincides with the development of new products and services on an almost daily basis. Improving the wireless communication environment is extremely important due to the increasing use of Bluetooth, mobile phones, and internet services [1], [2]. These developments have created significant challenges for communications engineers, as the demand for wireless communications has increased dramatically. In fact, the challenges faced by wireless network designers arise from the difficult physical nature and complexities of the underlying network dynamics [3], [4]. One of the technical problems in wireless communications is multipath fading, multipath fading in wireless communication systems has a significant impact on signal quality, range reduction and data rates. These effects are particularly severe in urban environments, where there are many obstacles. Obstacles cause the signal to be subject to multiple diffractions and reflections. Thus multipath fading is seen as a weakness of wireless communications [5]-[7].

However, an opportunity can now be provided to improve the capabilities and reliability of these systems Multipath fading can be represented by small-scale fading that results in random and rapid changes in the strength of signal at the receiving antennas [8].

Multiple Input Multiple Output (MIMO) technology is a wireless communications solution that provides an opportunity to overcome traffic capacity limitations in accessing a high-speed wireless broadband network. It provides increased capacity and high reliability without the need for additional power or bandwidth [9]. By using multiple antennas at both the sending and receiving ends, MIMO technology improves the performance and efficiency of systems through enable improved throughput, signal quality and overall system performance [10]. Wireless communications. The popularity of MIMO technology has increased due to its high performance and enhanced capabilities which has already become an important part of modern wireless networks in communications standards such as IEEE 802.11, WiMAX [11].

To achieve extraordinary gains in energy and spectrum efficiency in wireless communication systems, Massive or LS-MIMO technology is used, which is one of the promising technologies that contribute to addressing the burden resulting from the massive growth in wireless traffic. In Massive MIMO technology, hundreds of antennas communicate with many of users at the same time, which increases energy efficiency and bandwidth [12]-[14].

The main difference between LS-MIMO and MIMO systems is bandwidth efficiency, power efficiency, multiplexing gain and diversity gain. With global mobile traffic rapidly expanding day by day, these massive MIMOs have gained great importance in technology This is due to the need to complete simulations within a sufficient period of time in addition to providing memory capacity, and these requirements must be obtained with very reliable results [15]-[17].

While LS-MIMO technology is capable of improving almost all aspects of a wireless communication system, it faces challenges as the multi antenna design makes the systems more complex than single antenna. One of the major challenges facing LS-MIMO is the significant increase in the computational complexity of the code detectors on the uplink receiver side due to the large number of antennas [18], [19]. It is noted that the complexity of point-to-point channels is more important on the receiver side than on the sender side, that is, the complexity grows significantly with increased antennas numbers on the sender side. In MIMO systems, besides the receiver side, the sender side must be attention as the propagation signal must be delivered to a number of users simultaneously [20], [21]. Complexity in the structure of dynamic scenarios is an important priority especially in the field of wireless communications, Specifically, LS-MIMO technology [22].

In real time, the difficulty lies in using a complex mathematical model because it involves many mathematical formulas and many variables, this is due to the need to complete simulations within a sufficient period of time in addition to providing memory capacity, and these requirements must be obtained with very reliable results [23], [24]. As is well known, adaptive control is an important and useful approach when dealing with uncertainty in the system due to its ability to provide online estimates of unknown system parameters using measurement [25], [26]. Therefore, researchers paid continuous attention to developing methods to control and synthesize variables to achieve higher accuracy and stability.

The control strategy is presented by Patrascu et al. in [27] using traditional control algorithm with evolutionary optimization technique. The proposed strategy was applied to a nonlinear MIMO system and several implementations of the genetic algorithm were tested. The results showed that the best performance was obtained with tuning traditional control loops via genetic algorithm. Taieb et al. In [28] Introduced a new development for designing a MIMO Fuzzy Optimal Model Predictive Control (FOMPC) using the Adaptive Particle Swarm Optimization (APSO), the proposed control aim is to have good performance by guaranteeing a minimal control. It is done by determining the optimal weights of the objective function. The proposed algorithm enhance the convergence and accuracy of the controller optimization, which is much easier for implementation in real time. An adaptive tuning of Proportional-Integrate-Derivative (PID) controller is proposed by Slama et al. in [29] to developed (MIMO) non-linear systems. In this controller, the author integrating neural networks with PID. The experimental results conducted on a multi-input/output nonlinear system showed that by using such controller, the system outputs can track the desired references with greater efficiency and less time. Zhong et al. In [30] Introduced a new tuning method for both PID and active disturbance rejection control (ADRC) for MIMO that coupled with the nonlinear systems. The results showed that ADRC with PID controls can effectively deal with the uncertain nonlinear coupled MIMO separation problem. Sulttan et al. in [20], the authors enhanced the step response of MIMO using the Gray Wolf Optimization (GWO) Statistical method to tune the PID controller and evaluated by objective function as integral time absolute error (ITAE). The results showed that improvement can be achieved, according to the proposed method. The result of response demonstrated that the the control optimization strategy obtained a fast and stable response, a powerful index, a Minor overshoot, reduction of Steady error. Alkhasraji et al. in [31] minimized wide-scale nonlinearity of MIMO system by Using modular order reduction technology with PID controller, Ant Colony Optimization algorithm and (ITAE) fitness. The simulation results showed good performance of the system and the controller performance was presented regarding dynamic response in terms of settling time, rise time, and over/undershoot. Rospawan et al. in [32] Proposed a new adaptive predictive PID controller using large-scale, recursive, iterative learning schemes for MIMO digital control systems.

To satisfy users of communication systems, it is necessary to provide highly efficient networks that rely on the latest technologies. The development of any modern technology used is measured based on the level of performance and efficiency. For example, the (LS-MIMO) technology provides data to many users at the same time and works to increase and enhance spectral efficiency. It is part of the fifth generation networks in the wireless communications system [33], [34].

The presence of technologies within systems is considered essential and important in all fields, and to test the quality and efficiency of these technologies, the simulation process can be used. Studies have proven the possibility of using computer simulations to conduct tests for various systems, including communications systems, specifically a technology that relies on several inputs to the system and several outputs to the system. Work is underway to develop a simulation model to identify the behavior and performance in addition to the dynamic response of that technology. This can be verified by relying on the results of simulation tests for the proposed cases, which It includes an open-loop system as a test case for a prototype, after which feedback is added and a model of a closed-loop system is represented, which is a second test case through which the difference between the two systems can be known through their results. To improve the system’s performance, two other cases are tested, including adding a traditional controller and adding an expert controller represented by ANFIS. When conducting the proposed tests, the simulation results showed the possibility of improving performance by relying on traditional and expert control systems, with a clear advantage for the expert controller over the traditional controller. This study came as a result of the need for an efficient and adaptable optimization technique for improve response of large scale linear dynamic MIMO systems in term of reliability and stability, by applying adaptive network based intelligent ANFIS controller and comparing the performance with traditional PID controller through performance evaluation that includes response analysis. The contribution of the present work is to study and analyze the behavior of linear MIMO systems for different cases by representing that system with a simulation model based on ANFIS to know the dynamic response and adopting appropriate performance measurement criteria. The system response can be determined from the simulation results and the performance measurement criteria include a rise time as well as the rates of overshoot and undershoot to verify the efficacy of the system.

2. Method

2.1. Proportional Integral and Derivative (PID) Controller

PID controller is one of the most common algorithms for controller design [35]. It is is one of the most stable and accurate controllers and is used in many industrial applications to regulate many process variables [36], [37]. This type of controller has been successfully used in many types of systems, such as robotics, automation systems, wireless networks, etc., due to its ability to effectively optimize system parameters with minimal user effort [38]. The algorithm of PID controller provides a control procedure for a process designed according to the requirements [39]. In a PID, the frame is controlled and errors are reduced. A PID controller is a commonly used control feedback loop mechanism, the controller adjusts the parameters to ensure control performance towards zero error e(t) between the desired setpoint output and the system variables [40], [41].

This controller operates in a closed loop system and through this closed-loop, the sensor signal will be compared to the set point that was initially chosen. The difference signal is then sent to the PID controller for plant control [42]. The PID controller includes a combination of controllers represented by proportional, derivative and integral controllers. as shown in Fig. 1, [42], [43].

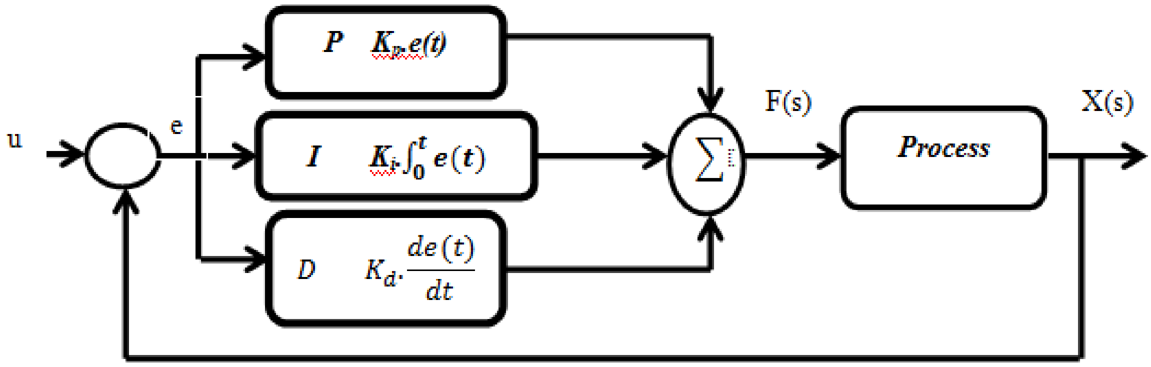


Fig. 1. Feedback loop in PID controller

It can be noticed from Fig. 1. that the controller consists of three separate stages, and the output of this controller represents the sum of these stages. The function of each controller is explained below: [45]-[46].

- Proportional control (P): Adjusts the process output according to the current error value between the setpoint and process variable. The larger the error, the larger the correction applied.
- Integrated Control (I): adjusted the output according to the accumulated error over time. It contributes to eliminating the steady state error and improving the stability of the control system.
- Derivative control (D): Adjusts the output according to the rate of change of the error. It helps to reduce oscillations and improves the stability of the control system.

The transfer function of the PID controller is given by the equation (1) [47]

$$PID(S) = K_P + \frac{K_I}{S} + K_D S = \frac{K_D S^2 + K_P S + K_I}{S} \quad (1)$$

Where

PID(S): Transfer function

K_P: Proportional gain

K_I: Integral gain

K_D: Derivative gain

The required value of input represented by (R) and the actual output is represented by (Y). The difference between required inputs and actual outputs is represented by the variable (e), which is called error tracking. This error e(t) is sent to the PID controller, and the controller calculates the derivative and integral of this error. The signal u(t) just passed the controller now equals the relative gain (KP) times the error magnitude plus the integral gain (KI) times the error integral plus the gain derivative (KD) times the error derivative as illustrated in equation (2).

$$u(t) = K_P e(t) + K_I \int e(t)dt + K_D \frac{d}{dt} e(t) \tag{2}$$

Where

$\mathrm{u(t)}$: PID control variable

$\mathrm{e(t)}$: value of error

$\mathrm{de(t)}$: change in error value

dt: change in time

The signal (u) is transmit to the plant and gives a new output signal (Y). This signal (Y) is feedback to the sensor to find the new error. The controller calculates the derivative and integral of the new error signal [48].

The result of system disturbances due to changing operating conditions, which transforms the state of the system from a stable system to an unstable system. System instability is treated by returning it to the stable state in a short time, that is, quickly in response to exceeding the transient state of the system through the use of control systems, including traditional ones such as PID. Properties of controllers P, I and D [48], [49]:

- The proportional (KP) controller minimize rise time but does not completely eliminate the steady-state error.
- Integrated control (KI) eliminates the error of steady state, but the transient response gets worse.
- Derivative (KD) increases the stability system by reducing overshoot, the transient improves the response of the system.

2.2. ANN and Fuzzy Inference System (ANFIS)

Most soft computing tools widely use artificial neural networks, fuzzy logic, and genetic algorithms to design intelligent control algorithms thatcan mimic human behavior. In control and decision-making applications, fuzzy logic is used. While artificial neural networks are used to simulate many problems and can perform as efficiently as fuzzy logic in many cases, genetic algorithms can be used as optimization tools. Fuzzy logic has the advantage of handling fuzzy knowledge and approximate logic but lacks effective learning ability. Neural networks have positive learning and adaptive properties. Combining these tools provides an opportunity to maximize the advantages and avoid the disadvantages [50], [51].

ANFIS is a system that combines artificial neural network (ANN) and the Fuzzy Inference System (FIS). Incorporation into the ANFIS model can be significantly improved its ability to grab nonlinear structure, progression and adaptation, and rapid learning ability. The main goal of using ANFIS is that the feature advances the learning capabilities of both ANN and fuzzy inference systems [52]. The idea of combining the two techniques is to use the learning capability of neural networks to automate and implement the fuzzy systems which uses higher-level thinking ability similar to that of humans. The synthetic ANN fault detection method alone cannot provide heuristic knowledge for the fault detection process due to the black box approach. On the other hand, fuzzy logic is a tool that can easily implemented and use heuristic logic, but is difficult to ensure accurate solution [53]. The ANFIS algorithm is accordingly divided into two main phases: the training phase and the testing phase. In the training phase, training in the ANFIS model is done using numbers selected from the input and output data set. These data sets can be obtained from various sources for operational applications. Training data is used to improve machines and make them learn the parameters of neural network and fuzzy rules in the training algorithm, the back propagation algorithm is used to adjust the parameters of neural network. When the ANFIS model has been trained, it is ready to predict the output variables for the new input data during the testing phase. Accordingly, the outputs taken from the ANFIS model are tested, whether the model outputs and the data set outputs are consistent with each other, to ensure the accuracy of the mode [54], [55].

2.2.1. ANFIS Architecture

The ANFIS combines two algorithms, fuzzy logic algorithm and artificial neural network algorithm with five-layer structure. The first two layers provide the inputs fuzzification and evalution, the third and fourth layers represent the valuation of the fuzzy rule, and finally defuzzification in ANN structure is represented in fifth layer [35].

By defining the parameter values, the ANFIS system learns in order to reduce the error between the estimated and actual outputsproduction. The ANFIS algorithm is a hybrid program consisting of a combination of least squares model and backpropagation learning algorithm [56]. ANFAS five layers are shown in Fig. 2.

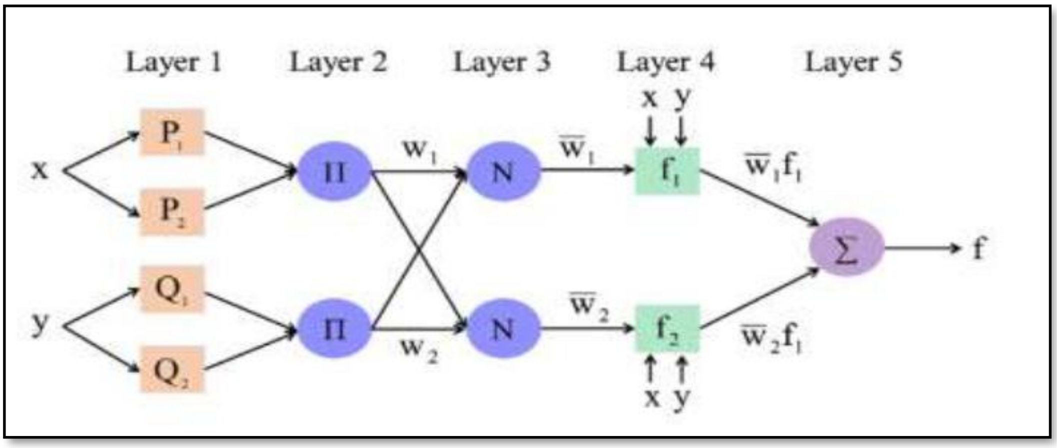


Fig. 2. ANFIS model's architecture [56]

Each layer of ANFIS serves a specific purpose in the modeling process [57], [58]:

1. Layer one (Fuzzification): in this layer input data is connected to fuzzy sets using membership functions (clear numeric inputs are converted to linguistic terms).
2. Layer two (Rule Evaluation): in layer two, each node calculates the firing strength of each rule using the prod or min operator
3. Layer three – Rule Conjunction: Allows to calculate the ratio of the firing strength of each rule to the sum of the firing strength of all rules.
4. Layer 4 – Normalization: In this layer, the firing strengths are normalized, to guarantee that the rules activations sum equals one.
5. Layer 5 – Defuzzification: weighted rule activations are Combinesinto a single node to produce the model output for all incoming signals, which is represented clear numerical value.

ANFIS has a high generalization ability as it can take explicit inputs and represent them in the form of membership functions and fuzzy rules, as well as generate explicit outputs from the fuzzy rules for inference purposes. This opens up applications that involve explicit inputs and outputs. It is a tool with exceptional potential in many other complex nonlinear control problems [59].

2.2.2. ANFIS Implementation

The ANFIS model includes rules and nodes. Rules allow the relationship between inputs and outputs to be represented where nodes are used as membership functions (MF). Assume the FIS contain two inputs 'x' and 'y' and one output 'f', the output result is always clear as the input variables are represented by linguistic values such as high, medium and low [60]. A first order sugeno fuzzy has following rules, where IF-THEN rules are incorporated into the implementation of the ANFIS network [60], [61]:

$$\text{Rule 1: IF x is P1 and y is Q1; then } f1 = p1x + q1y + r1 \tag{3}$$

$$\text{Rule 2: IF x is P2 and y is Q2; then } f2 = p2x + q2y + r2 \tag{4}$$

Where:

Pi , Qi are the membership functions of the inputs [x] and [y].

fi : weighted average of the outputs for each rule.

pi, qi, ri: the outlet function's parameters for $(i = 1, 2)$.

The functions of each layer in ANFIS architecture are listed below [56], [62]:

1. First Layer: In the first layer, each node is adaptive to a single parametric activation function. The output is the membership score for the given inputs that satisfy the membership function.

This layer convert input variables into fuzzy MFs as node output

Generalized bell functions describe the MFs of Pi and Qi as follows:

$$\mu_{Ni} = \frac{1}{1 + [(x - c_i)/a_i]^{2b_i}} \tag{5}$$

Where $\mathbf{a_i}$, $\mathbf{b_i}$, $\mathbf{c_i}$: the parameter set

2. Second layer: The degree of activation of the rule is calculated. The membership functions in this layer are multiplied:

$$w_i = \mu_{Ai}(x)\mu_{Bi}(x)(i = 1,2) \tag{6}$$

Where:

μAi: Degree of membership x in the set **Ai**

μBi: Degree of membership y in the set **Bi**.

3. Third Layer: As in equation (5), the (i th) node calculates the activity degree for (i) rule into the sum of the activation degrees of base (i$\mathbf{\overline{w}_i}$) the normalized membership degree of rule (i).

$$\overline{w}_i = \frac{w_i}{(w_1 + w_2)}(i = 1,2) \tag{7}$$

4. Fourth Layer: Calculate the output of any node:

$$\overline{w}_i f_i = \overline{w}_i(q_i x + r_i y + s_i) \tag{8}$$

Where q, r, and s: are irregular (changeable) parameters

5. Fifth Layer: in this layer, node produces the final network output as the sum of all incoming signals.

$$\sum \overline{w}_i f_i = \frac{w_i f_i}{w_i} \tag{9}$$

Quick adjusting and training parameters of the network are done in two steps. In the first step, defined premise parameters, and then propagated the information to (4th) layer in the network. The significant parameters in the fourth layer are determined using a least squares estimator. Specified parameters in the next step are fixed or passed back during error propagation.

3. Simulation Model and Results

In this section there are two parts, first part simulation model and second part include simulation result. It had three states include simulation model and result with PIDC, simulation model and result with ANFIS, simulation modeland result with PIDC and ANFIS.

3.1. Simulation Model of the MIMO System

A model of the system is also built and represented mathematically to know the behavior of the system in the case of a closed loop system with units to control it, and tests are conducted and the effect of adding the traditional controller. Simulation model had three states include modeling with PIDC, modeling with ANFIS, modeling with PIDC and ANFIS.

3.1.1. Simulation Model of the MIMO System with PIDC

In this test by using the closed loop system with a controller using the PID simulink model that show in Fig. 3.

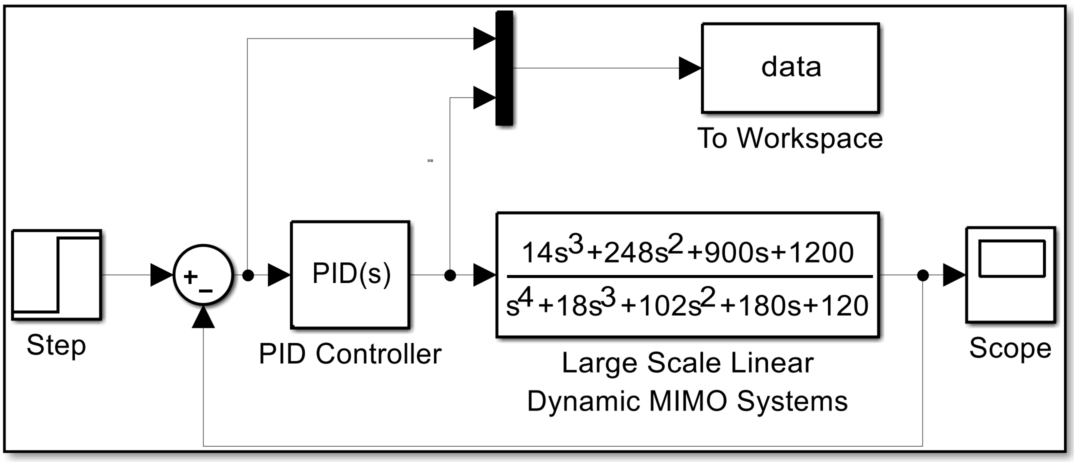


Fig. 3. Modeling with PIDC

3.1.2. Simulation Model of the MIMO System with ANFIS

In this test by using the closed loop system with a controller using the ANFIS simulink model that show in Fig. 4.

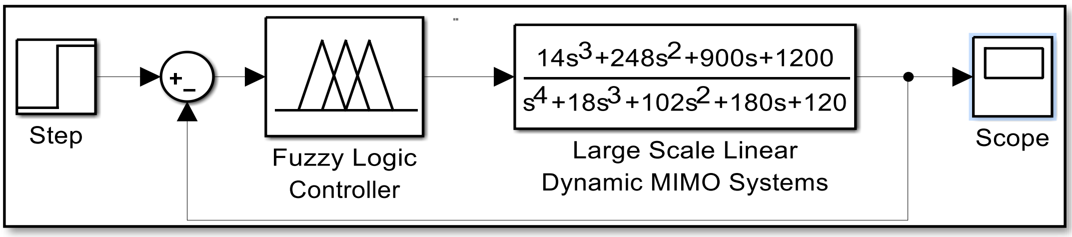


Fig. 4. Modeling with ANFIS

3.1.3. Simulation Model of the MIMO System with PIDC and ANFIS

In this test by using the closed loop system with a controller using the withPIDCand ANFIS simulink model that show in Fig. 5.

3.2. Simulation Result of the MIMO System

In this section there are three states include simulation result with PIDC, simulation result with ANFIS, simulation result with PIDC and ANFIS.

3.2.1. Simulation Result of the MIMO System with PIDC

In this test by using the simulink model in Fig. 3. the simulation result includes the simulation response of PIDC for MIMO system as show in Fig. 6. and the details of the simulation for MIMO system with PID controller as show in Table 1.

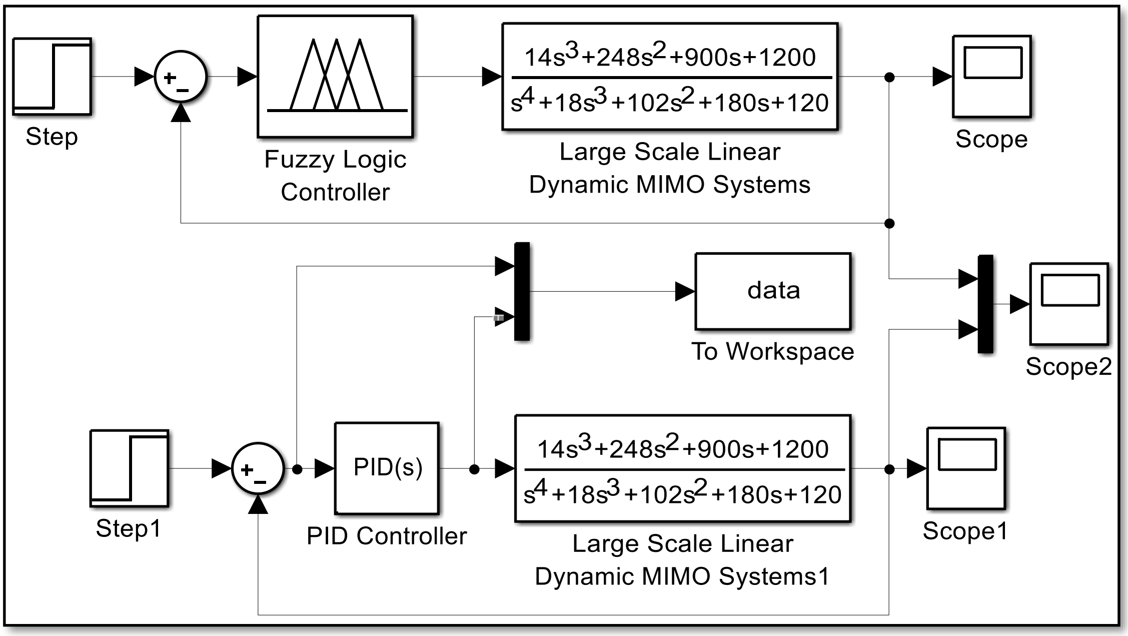


Fig. 5. Modeling with PIDC and ANFIS

Table 1. The details of the simulation for MIMO systemwith PID controller

Controller Types	Rise Time (sec)	Overshoot (%)	Undershoot (%)
PID Controller	771.584msec	6.989%	1.886%

3.2.2. Simulation Result of the MIMO System with ANFIS

In this test by using the simulink model that show in Fig. 4.the simulation result includes the simulation response of ANFIS for MIMO system as show in Fig. 7. and the details of the simulation for MIMO system with ANFIS controller as show in Table 2.

Table 2. The details of the simulation for MIMO system with ANFIS controller

Controller Types	Rise Time (sec)	Overshoot (%)	Undershoot (%)
ANFIS	766.156msec	2.604%	1.999%

3.2.3. Simulation Result of the MIMO System with PIDC and ANFIS

In this test by using the simulink model that show in Fig. 5. The simulation result includes the simulation response of PIDC and ANFIS for MIMO system as show in Fig. 8. and the details of the simulation for MIMO system with PID and ANFIS controller as show in Table 3.

Table 3. The details of the simulation for MIMO system with PID and ANFIS controller (Comparison between the proposed methods)

Controller types	Rise Time(sec)	Overshoot (%)	Undershoot (%)
ANFIS	766.156msec	2.604%	1.999%
PID Controller	771.584msec	6.989%	1.886%

The simulation results can be discussed through figures and tables, as the improvement in response can be observed through the difference between the rise time and the upper and lower transients. The difference can also be observed in the time and period of the transient and stable state.

3.3. Design ANFIS Based MIMO System

In this work, ANFIS technology is used to design the parameters of the traditional controller to regulate the work of the MIMO system. comparative by tests are using closed loop system without a controller, closed loop system PID controller, and ANFIS Simulink model.

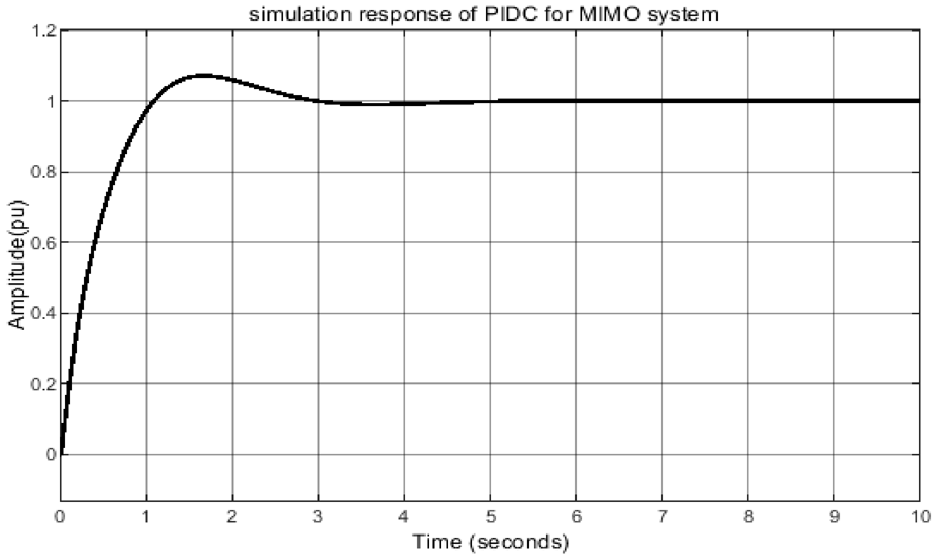


Fig. 6. The simulation results of PID control

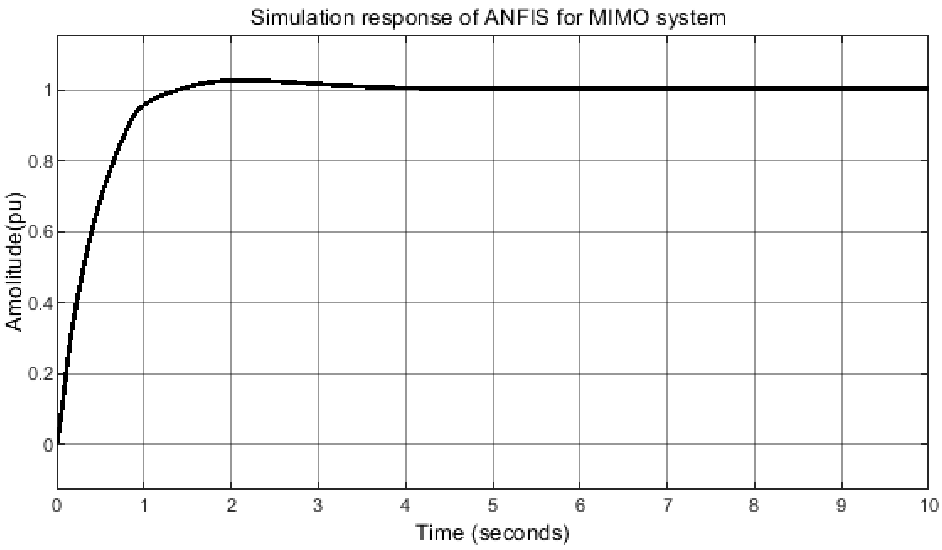


Fig. 7. The simulation results of ANFIS

In this simulation, the MIMO model is built and represented mathematically to identify the working principle of the system for a suitable design using (ANFIS) the parameters of the traditional controller. A system is reviewed by identifying the values of the system parameters and testing the initial system to determine the behavior during its operation in an open loop system, then knowing the behavior of the system in the closed loop, and then knowing the improvement in the performance of the system behavior using the proposed control methods to find out what is best and develop the appropriate design. There are five system cases in which tests are conducted for the proposed system. In this study, the working principle of the MIMO is identified, a model representing the system is simulated, and the appropriate conventional controller is designed using (ANFIS). In Fig. 1, show the open loop and in Fig. 2, show the closed loop without controller and MIMO using PID simulink model show in Fig. 3. Also, in Fig. 5, show MIMO using ANFIS simulink model.

Also, in Fig. 9, Fig. 10, Fig. 11, Fig. 12, Fig. 13, Fig. 14, Fig. 15, Fig. 16, Fig. 17. In Fig. 9 ANFIS designer (Neuro-Fuzzy) for training data. Fig. 10. illustrated ANFIS model's structure. In Fig. 11. ANFIS designer (Neuro-Fuzzy) for training error at Epochs 30. In Fig. 12. ANFIS designer (Neuro-Fuzzy) for training error at Epochs 100. In Fig. 13. ANFIS Rule Viewer. In Fig. 14. ANFIS Surface Viewer. And ANFIS designer (Neuro-Fuzzy) for training data of FIS output at Epochs 100 illustrated in Fig. 15. Command window at start training of ANFIS info in Fig. 16. Workspace and command window for ANFIS edit datain Fig. 17.

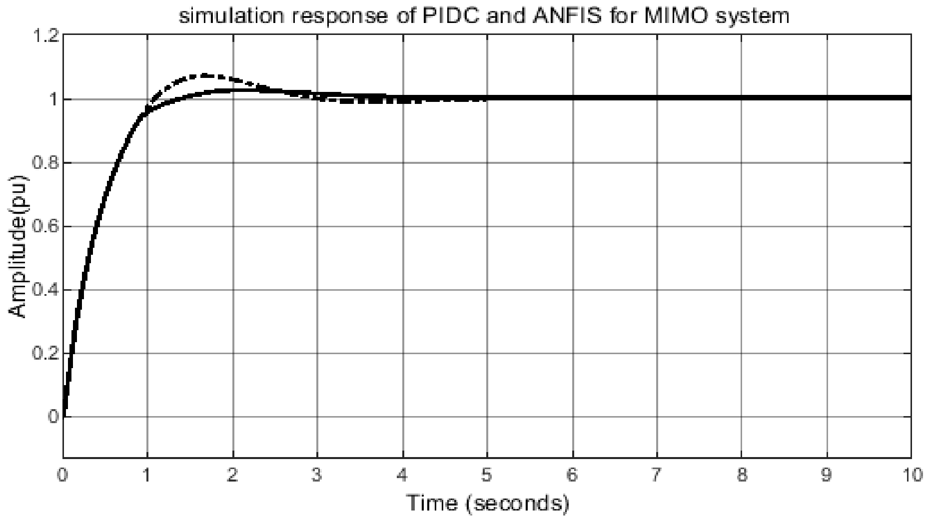


Fig. 8. The simulation results of pid control and ANFIS

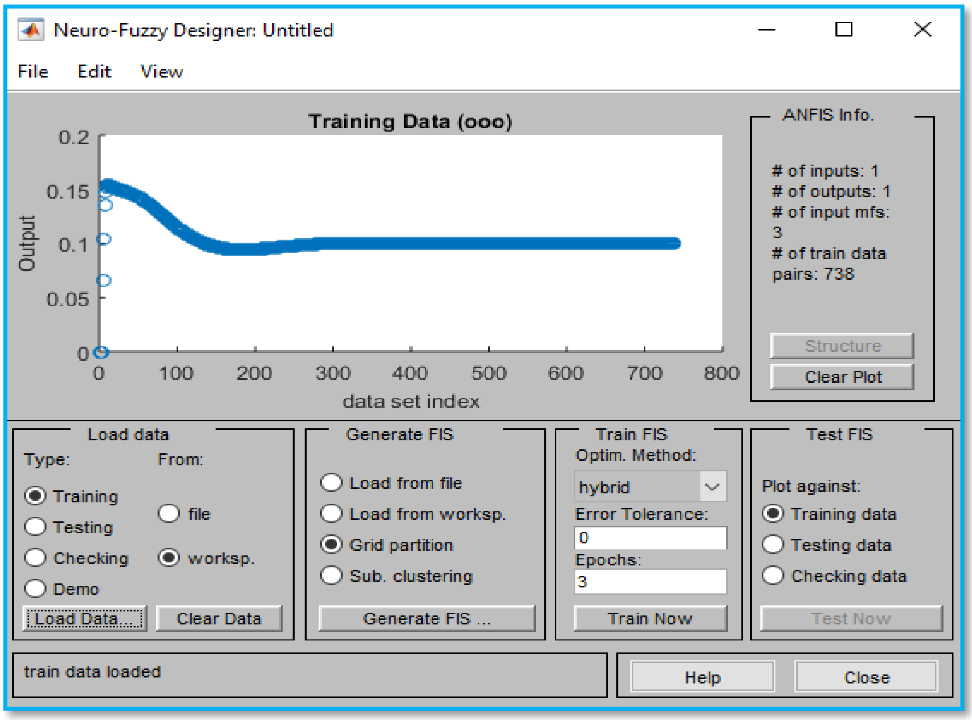


Fig. 9. ANFIS designer (Neuro-Fuzzy)

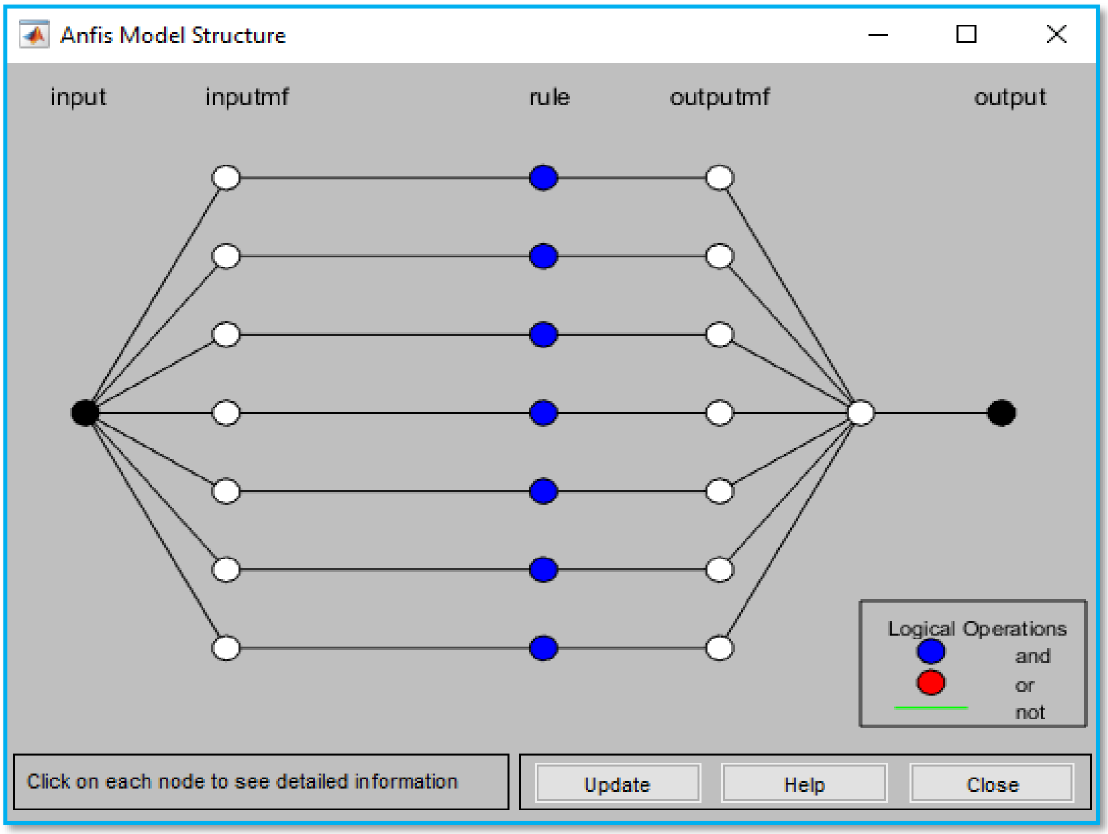


Fig. 10. ANFIS model's structure

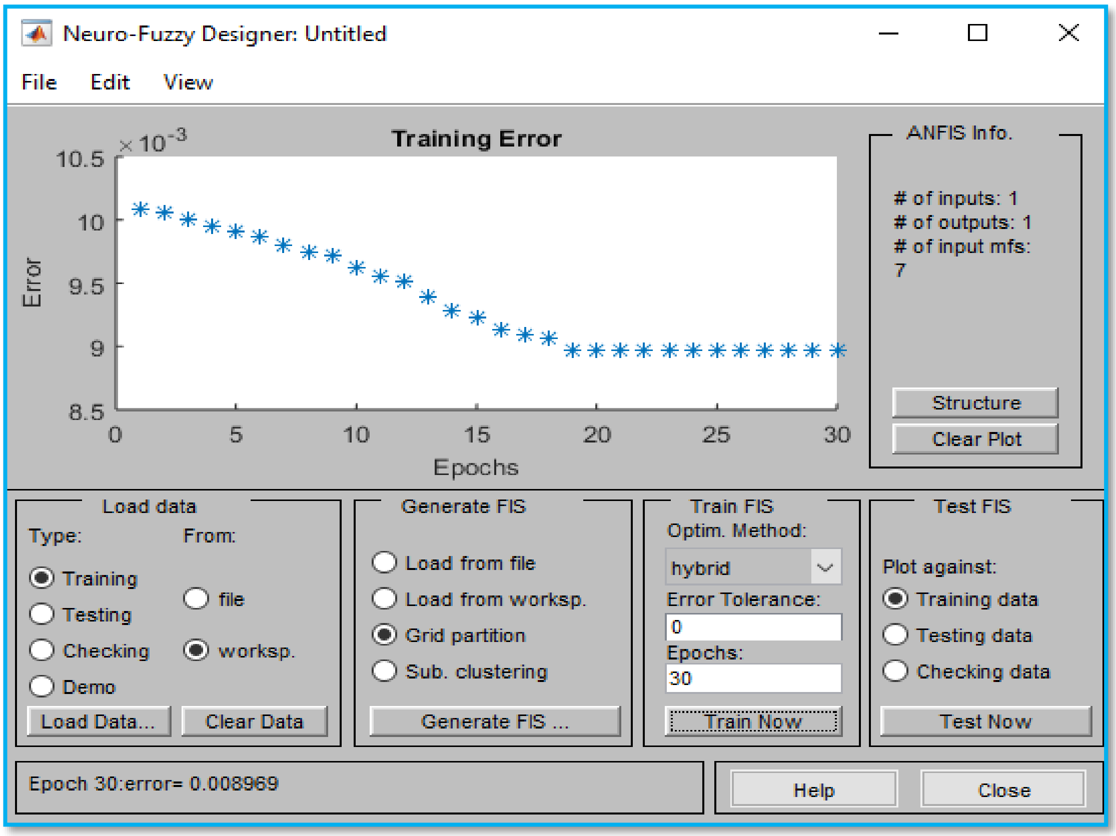


Fig. 11. ANFIS designer (Neuro-Fuzzy) for training error at Epochs 30

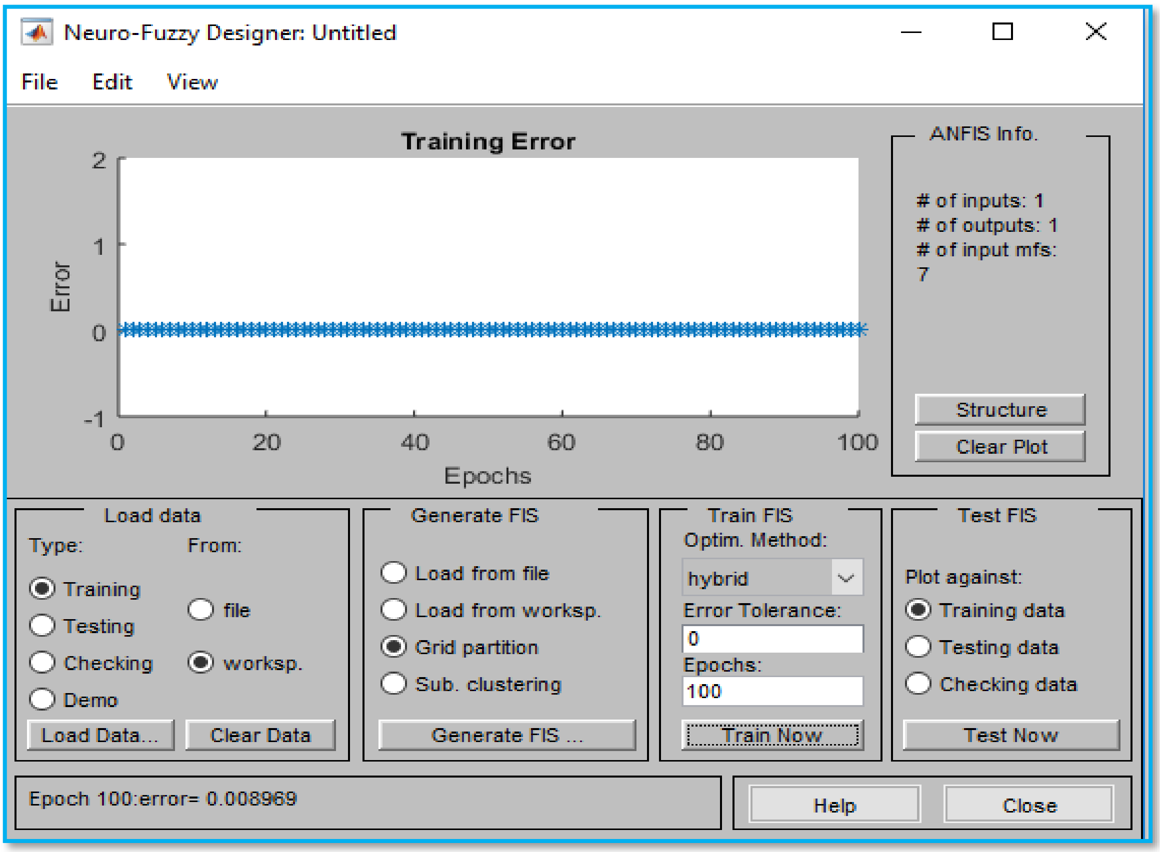


Fig. 12. ANFIS designer (Neuro-Fuzzy) for training error at Epochs 100

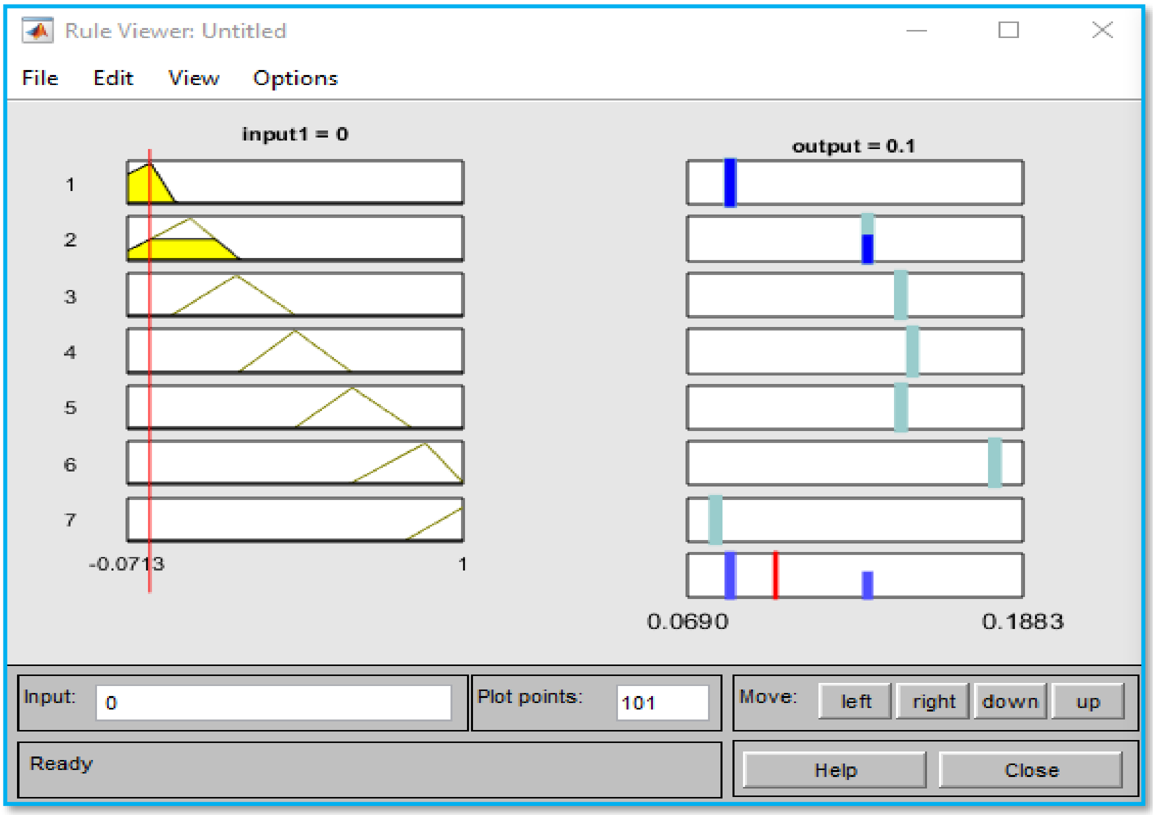


Fig. 13. ANFIS rule viewer

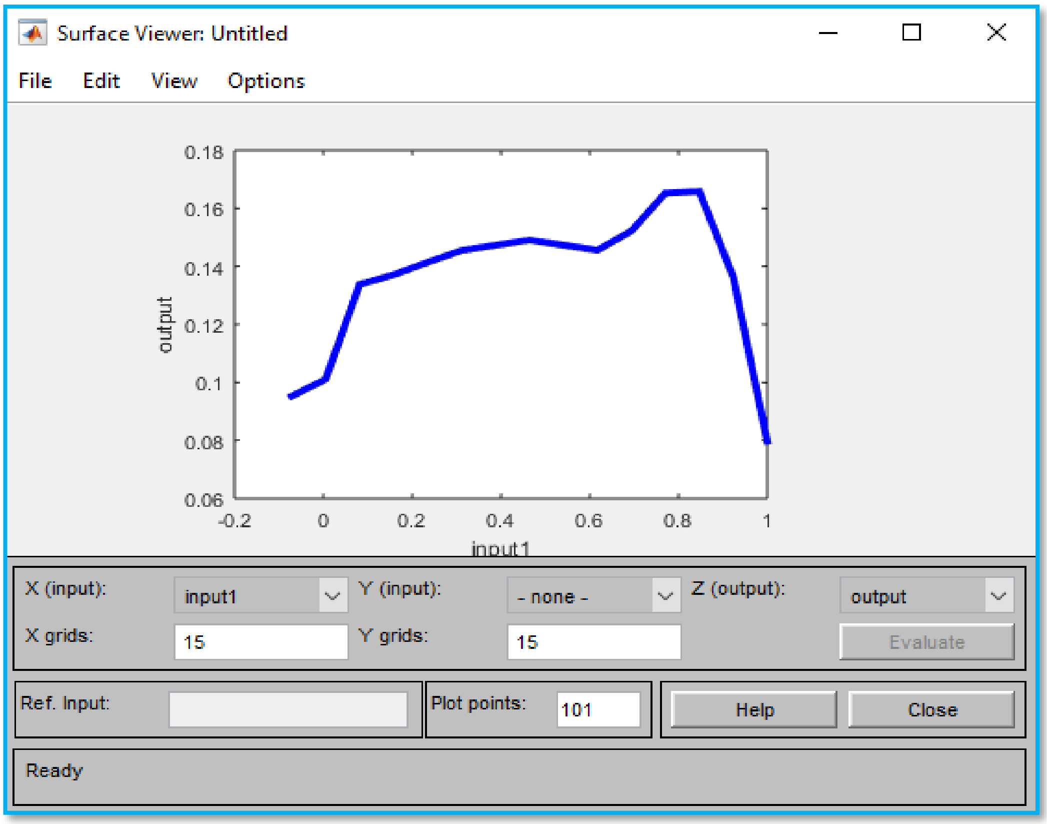


Fig. 14. ANFIS Surf

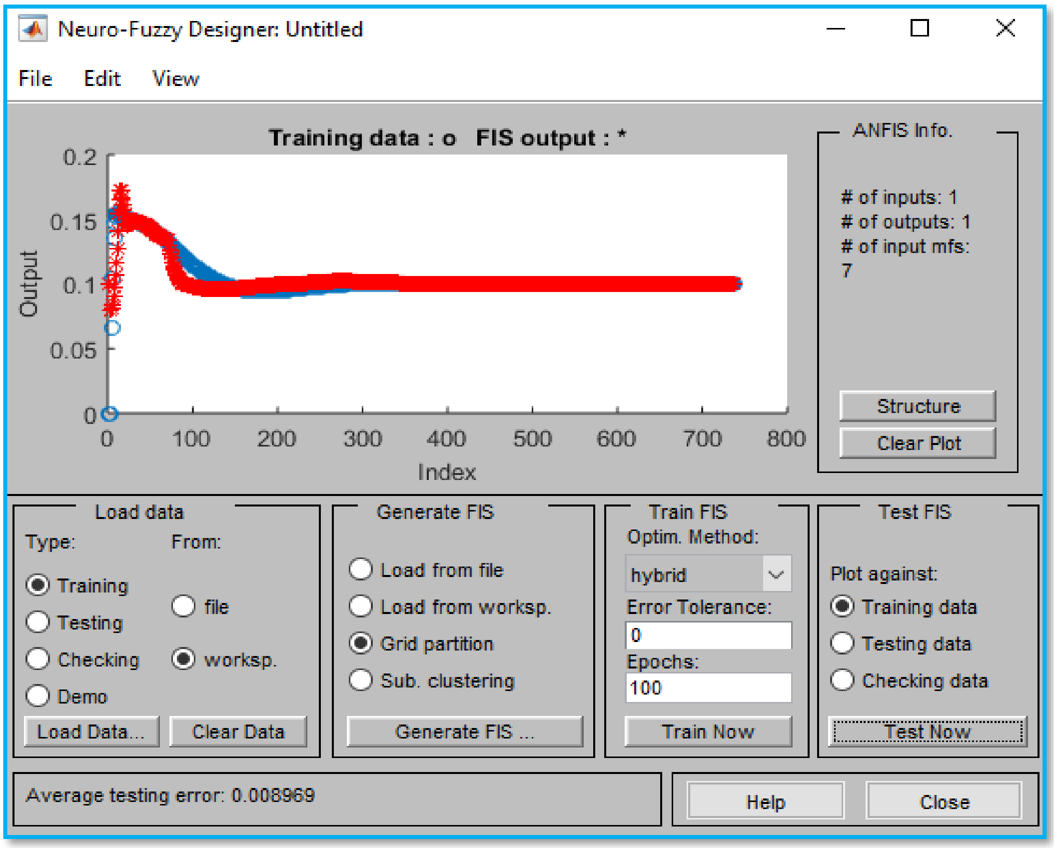


Fig. 15. ANFIS designer (Neuro-Fuzzy) for training data of FIS output at Epochs 100

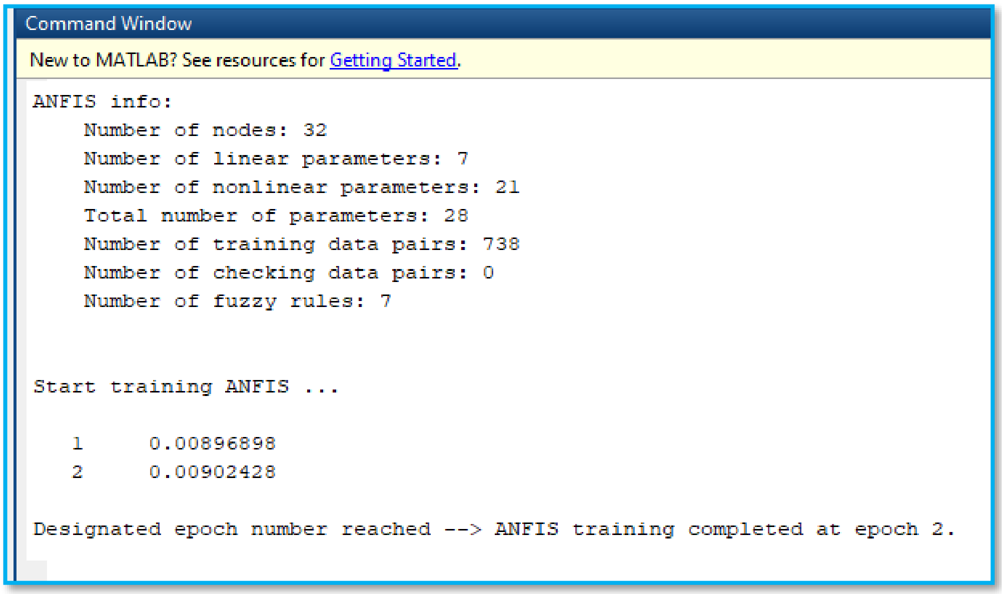
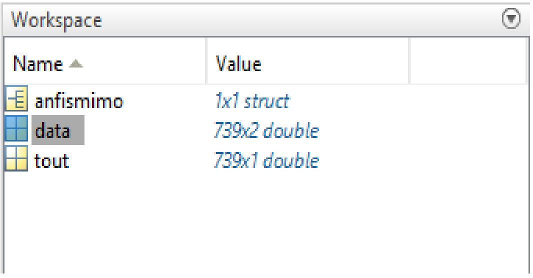
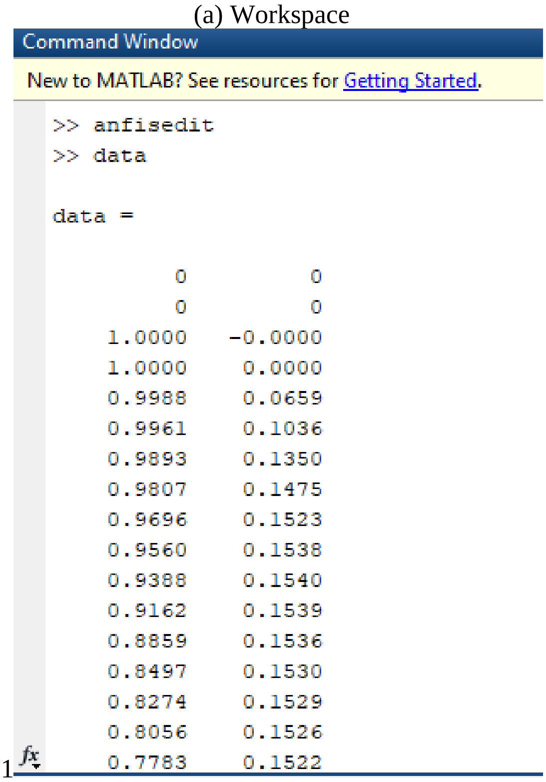


Fig. 16. Command window at start training of ANFIS info



(a) Workspace



(b) ANFISedit data

Fig. 17. Workspace and command window for ANFISedit data

4. Conclusion

The amazing advantages of MIMO systems compared to other networks such as the single input single output (SISO) and its rapid development that continues with the development of generations of wireless networks led to thinking about an effective and intelligent control method to adjust the parameters of these network .Since ANFIS has unique capabilities compared to other conventional controllers, and there are no previous studies on the use of this controller with large scale linear dynamic MIMO systems systems, it has been adopted as a method for tuning parameters to improve its performance.In the current simulation, the possibility of improving performance has been verified and how to handle the presence of an error in the system as a result of a transient state or any disturbances as a result of changing states or behavior of the system to reach a stable state and the result of the examination using the proposed performance measure. Performance measures vary depending on the use of the error and the attempt to reduce it, including (MSE, IAE, ISE, or ITAE), in addition to using the simulation process to examine. Implementing and operating the system and choosing the best one by comparing the traditional PID controller and the ANFIS. It is proposed to review an open and closed loop system with and without traditional, expert and intelligent controllers. The simulation results showed that the performance of ANFIS was better than the PID controller in terms of settling time, undershoot and overshoot time. Where in ANFIS the settling time reached (766.156 ms), overshoot (2.604%), and undershoot (1.999%) compared to the PID controller which settling time was (771.584msec), Overshoot (6.989%), and Undershoot (1.886%). In the context of future research topics, we suggest to use a genetic algorithm to optimize the ANFIS and the output parameters in MIMO systems. These results confirm the system stability and quick response MIMO SYSTEMS based on ANFIS compared to those based on PID.

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