Kufa Journal of Engineering
Vol. 16, No. 1, January 2025, P.P. 80-103
Article history: Received 21 April 2024, last revised 6 June 2024, accepted 18 June 2024

ARTIFICIAL NEURAL NETWORK (ANN) BASED PROPORTIONAL INTEGRAL DERIVATIVE (PID) FOR ARM REHABILITATION DEVICE

Salam Waley Shneen [1]*, Rajaa khalaf Gaber [2], Rasha Saad Salih[3], Suaad Makki Jiaad [4]

[1] Energy and Renewable Energies Technology Center, University of Technology – Iraq.
Email: salam.w.shneen@uotechnology.edu.iq

[2] Electro-mechanical Engineering Department, University of Technology – Iraq.
Email: 50049@uotechnology.edu.iq

[3] Electro-mechanical Engineering Department, University of Technology – Iraq.
Email: 50164@uotechnology.edu.iq

[4] Electro-mechanical Engineering Department, University of Technology – Iraq.
Email: 50181@uotechnology.edu.iq

https://doi.org/10.30572/2018/KJE/160106

ABSTRACT

The current work was developed under the title of Artificial Neural Network (ANN) Proportional Integral Derivative (PID) for the arm rehabilitation device and included building and designing the simulation model and simulation results for the arm rehabilitation device. A set of tests were proposed to include firstly testing a system that represents the state of the open arm rehabilitation device and secondly It represents the closed arm rehabilitation device, third represents the closed-loop arm rehabilitation device with PID control device, fourth represents the arm rehabilitation device using ANN, and finally the closed-loop arm rehabilitation device can be used with a comparison between PIDC and ANN. To conduct all the proposed test cases, a program can be used MATLAB, which can help simulate a device that represents an attempt to regain movement in the arm, which is called rehabilitation. It can be noted that the target group is some people who suffer from stroke. By representing the system in the proposed simulation model, its effectiveness can be verified. It is possible to conduct tests aimed at improving performance by working on developing the model by adopting the appropriate design for the characteristics that match the required operational behavior of the system with all conditions that suit different situations. The test cases demonstrated through the simulation results the possibility of identifying the system behavior for the proposed cases. The difference between the system behavior for all these cases was also identified. In addition to the possibility of improving the performance of the movement recovery device to rehabilitate the injured arm through the system's performance in the presence of an expert neural network controller, it is better than the traditional controller.

KEYWORDS

Arm Rehabilitation Device; open loop; close loop; ANN; PIDC.

1. INTRODUCTION

Dealing with nonlinear systems needs to building a model based on mathematical representation, and to verify the quality of performance (Triwiyanto, et al., 2023; Zadehbagheri, Mahmoud, et al., 2023; Dakheel, Hashmia S, et al., 2023). It is verified by conducting simulations using MATLAB / SIMULINK to build a model that is designed through simulation experiments for different working conditions that simulate real time, taking into account the fluctuations and disturbances associated with its work (Hassan, Ibrahim A., et al. ,2024; Abood, Layla H., et al., 2022; Raheem, A. K. K. A., et al., 2012). Simulations were conducted to achieve the work. In the required form, starting from "developing a mathematical model and representing it with differential equations, up to" representing the system with a transfer function, then conducting multiple tests (Umam, Faikul, et al., 2023; Mossa, Mahmoud A., et al., 2022; Shneen, Salam Waley, et al., 2016). It first included the system for the open loop and the last for the closed loop, then added the proposed control systems. The quality and accuracy of the work was verified with the speed required for the system response and error reduction to the discrepancy in the percentage of performance by making a comparison between the proposed methods (Nalibayev, Nurgali, et al., 2024; Baghli, Fatima Zahra, et al., 2023; Shneen, Salam Waley, et al. , 2023). The simulation proved the possibility of improving the performance -By using the traditional and advanced optimization method, but the best performance is superior to the optimization the traditional in terms of the level of upper and lower overtaking, response speed, stability, and ascent time to control the torque for a better performance of the servo system to the control to obtain an adaptive state of the system (Shamseldin, Mohamed A., et al., 2023; Chotikunnan, Phichitphon, et al., 2023; Eissa, Suad Ali, et al., 2023). Control of industrial systems (IS)is essential to manage and generate the required kinetic energy as various operating conditions change and system disturbances change during the system's operation, such as a change in the load (Saputra, Dodi, et al., 2023; Penta, Samyuktha, et al. , 2023; Shneen, Salam Waley, et al. , 2016). Industrial systems usually consist of system parts, including controllers and systems that generate motion and maintain system stability. Implementing control strategies is essential to protect the system's stability, reliability, and operating efficiency (Adetokun, et al., 2022; Kumar, G. Syam, et al., 2024; Shneen, Salam Waley, et al., 2021). In this research, a leveling control theory based on nonlinear control is developed to control and regulate the behavior of the system, regardless of variations of load conditions. The effectiveness of the recommended proposal has been implemented using MATLAB simulation, indicating that it is possible to provide stability in system behavior, reduce ripple content, and provide good performance. Therefore, the method is effective compared to the classical PI approach. The proposed control has a fast tracking speed, which is a very fast response time compared to the traditional approach, which takes to reach the reference value. To obtain accuracy in the performance of the robot's work in some industrial applications, this requires control systems designed with the robot's work system to perform its function in the correct position and the required force in addition to the required position. One of the industrial applications is the Arm Rehabilitation Device and to make the work conform to its correct and identical shape and position, this requires a closed feeding system with feedback and an appropriate control system. Therefore, this requires building an appropriate model that simulates the real model and by taking all expected cases, a mathematical model is built it is represented by differential equations through which it is possible to obtain the transfer function that represents the required model. To improve the functioning of the system, two control methods were proposed through which the performance of the system can be improved. The results proved the possibility of improving the performance of the linear system using the traditional method, and also proved the possibility of improving the performance of the nonlinear system using the second method for the perfect applicant (Jayasekara, Ninura, et al., 2024; Chotikunnan, Phichitphon, et al., 2024; Abdullah, Fatin Nabeel, et al., 2022; Kabir, Ryan, et al., 2022). The use of robots in industrial applications is considered one of the most important modern applications, and as a result of the progress and development in control systems, it has entered the field of organizing the work of robots. Industrial systems and traditional, expert, and smart control units are linked in various applications, including the wheel movement system for electric cars, the movement of an electric train car, the movement of an electric elevator car, robots, printers, and others. Traditional controllers work to address the disturbances occurring in the linear system and improve its performance by reducing the error to the minimum possible extent and returning the unstable system during the transient state to a stable system with a relatively acceptable response (Wa'il, A. H., et al., 2013; Chavoshian, Mahdi, et al., 2020; Mutlag, Ashraf Abdualateef, et al., 2024; Chotikunnan, Phichitphon, et al., 2023; Josiah, Princewill N., et al., 2023). In nonlinear systems, the required response may not be obtained from using traditional units, so this requires the use of systems that are more adaptive and give a better response, which are expert control systems such as ANN and FLC. Expert and intelligent control systems are adopted to improve the performance of industrial systems, which work to control The parameters of the traditional controller are adapted to work according to changing operating conditions and operate with high efficiency, quality and accuracy. Computer simulation is used to know the behavior of the system with changing operating conditions after building the model through mathematical representation of the system. The effectiveness of the system can be verified through simulation results, and a suitable model can be designed by comparing operating cases and selecting and determining the best model according to the proposed measurement criteria (Abdullah, Zainab B., et al., 2023; Najm, Vian N., et al., 2023; Abood, Layla H., et al., 2021; Attiya, Adnan Jabbar, et al., 2016; Mohamed, Mohamed Jasim, et al., 2023).

2. RELATED WORK

ANN has been used in a number of research to model the link between joint and muscle activation. Mohd Hafiz Jali et.al studied the clear prediction of the joint torque estimate model for the arm rehabilitation with the ANN technique. The biceps muscle acts as the agonist in this study, whereas the triceps muscle acts as the antagonist. The biceps and triceps are the muscles used in this movement; however only the biceps are considered accurately representing the link between elbow joint torque and EMG inputs. As a result, the arm rehabilitation devices' motor torque control can be achieved using this model. Still, despite in this study, the relationship between muscle function and electrical performance to achieve contraction and relaxation of the arm using muscles was taken into consideration. The range of motion is from an arm's flexion position to its full extension. The ANN model with two nodes at the input layer produces an average regression of 1.000 and an MSE of 1.7638e-11 at epoch 1000, according to the results. It is clear from the performance result that this neural network model is capable of the fact that the R Even though MSE yields nearly flawless results, there is always room for improvement in terms of stop epochs and training time elapsed. M. H. Jali et.al. in this work the Biceps Brachii muscles provide an EMG signal that is used to quantify the torque at the elbow joint with train a two-layer feed-forward network to estimate the torque value from the EMG input. The biceps muscle acts as the agonist in this study, whereas the triceps muscle acts as the antagonist. The biceps and triceps are the muscles used in this exercise; however only the biceps are considered in this study in order to better comprehend the range of motion is from the arm's flexion position to its ultimate extension. According to the experimental findings, the ANN model with two input nodes performs better in terms, two metrics that are critical for accurately representing the EMG-torque relationship in arm rehabilitation device control. Outcome, Model 2 performs better than ANN Model 1 in terms of MSE and R. Model 2 has an extremely low MSE value and achieves excellent R results. But compared to Model 1, Model 2's stop epochs and time elapsed are worse (Jali, M. H., et al., 2014). Francisco Medina et al. suggested an interpolation technique were integrated into the simulation program used to test the device. Four volunteers who demonstrated the predicted performance in accordance with the suggested evaluation scenarios were used to successfully evaluate. This work detailed the electrical instrumentation, mechanical design, and control of an AOD that, in the future, can help with the UL's rehabilitation through the use of a FES device that is activated by an ANN signal classifier. The user does not require any external mechanical support to carry this device. This feature provided a fresh approach to long-term arm rehabilitation (Medina, Francisco, et al., 2023). Yurong Li et al. they suggested a modeling approach based on neural networks and manage the FES system's execution for upper limb neuron rehabilitation. Genetic algorithms based on the experimental data. Lastly, the model's simulation results are shown to demonstrate the established model's efficacy. This paper achieves good results by controlling the FES system through iterative learning. Tests confirm that the system is capable of tracking control along the intended path (Zhu, Feifei, et al., 2022). Ikbal Eski and Ahmet Kırnap, investigated two sections in this work. First, individuals with upper limb loss of function were selected, and sensors were used to measure the angular displacement parameters at the wrist, elbow, and shoulder. In the second section, three control structures were chosen to follow the trajectories of the elbow, wrist, and shoulder angles. The findings of simulations and experiments indicate that the ANN-based PIDC structure is the most effective controller for tracking specified trajectories. In this article, the angle trajectories of the elbow, wrist, and shoulder joints are controlled using two different control approaches. PIDC and ANNPID control systems are examples of these controllers. Additionally, subdivisions are used to explain these controllers. This research presents the creation of a control structure based on data collected from nine patients with varying joint limitations and physical characteristics (age and gender). The autonomous passive upper limb therapy robot has a proposed controller. The majority of research on rehabilitation focuses on lower limbs and active rehabilitation equipment. The NNPID control system has the lowest steady-state error and is the best at adapting, based on simulation and experimental results. The neural network is incorporated into the PID control system and is selected due to its capacity for learning and generalization. The steady-state error has been significantly reduced by this newly designed control system. Therefore, the upper limb passive therapeutic exercise equipment will be controlled by these control structures. In the future, an upper limb rehabilitation robot prototype will be created using the suggested controller, and patient testing of the apparatus will follow ethical clearance. Other investigations on this topic indicate that the autonomous passive therapeutic exercise gadget with proposed controller has various advantages (Eski, İkbal, et al., 2018).

3. ARM REHABILITATION

For stroke patients, robotic systems offer safe, intense, and task-oriented rehabilitation at comparatively modest prices. Robot-based therapies have distinct advantages over traditional therapies, including precisely controlled force-feedback and an objective, quantifiable measure of subjective performance. Robotic device therapy can also monitor a number of other characteristics, such as reflexes, level of voluntary control, spasticity, and functional movements. The increased accuracy and decreased variation of robot-assisted training evaluation translate into a reduction in the size requirements for the targeted subjects, which is another benefit (Arantes, Ana., 2021). One potential solution to the rehabilitation challenges is a robot-based device. When it comes to repeated activities, robots are more reliable and consistent than humans. Various kinds of devices for the rehabilitation of upper limbs have been developed. Generally speaking, there are two types of devices: those that only have touch with the patient's leg at the furthest point. While the device's structure is thought to be simple controlling. The robot minimizes aberrant posture or movement by directly controlling each individual joint. However, compared to an end-effecter-based device, the construction is thought to be more intricate and costly (Su, Yun-Hsuan., 2020).

4. SYSTEM MODEL DESCRIPTION

In this study, the researchers aim to conduct a simulation of a humanoid system in the field of medical application. Through simulation, the behavior of the system can be identified in operational conditions similar to real time. In the current simulation, work is being done to present a mathematical model of the proposed system, and the construction and design of a two degrees of freedom (2-DOF) upper limb type system is presented. The simulation includes identifying the movement positions of the upper limbs at different angles with appropriate mechanical design and the movement of those limbs with the help of the electric motor. Work is also underway to verify the possibility of using the proposed system in the process of rehabilitating the upper limbs within a therapeutic program by conducting physical therapy exercises for patients. To build and design any model, there are standards and requirements according to its functions in the proposed system. It is also necessary to point out the system parameters and their imaginary importance in the process of creating a developed model, which include:

The initial state of the upper limbs and the appropriate angle at that state for all joints before the start of movement is at zero angle for all joints, the shoulder joint and between the upper body, the ulna, and the elbow joint, which is between the ulna and the arm, in addition to the hand joint, which is between the arm and the hand. There are also other joints between the fingers of the hand, as many as those. The fingers enable the hand to bend or extend, as is the case with the rest of the joints. They work and help in the process of extending and bending the upper limbs in question. Work is underway to determine the appropriate movements required for rehabilitation by determining the appropriate torque and angle required for the electric motor to perform the required movement. To provide the required movements, work requires developing an appropriate mechanical design. People's arms differ according to the size of the person, so lengths can be chosen that suit some people. This is one of the design parameters, which shows the length of the ulna and the length of the arm, which is the first design parameter. Work must be done to develop a plan that shows the locations of the movements for which it is proposed to conduct simulation tests by placing areas representing the joints of the limbs and the angles at which they move. The first step is when the limbs are close to the body, that is, at a zero degree angle. The force and angle at which the limbs move can be encoded according to the steps proposed for the subject of the current study. It must be represented mathematically by relationships linking the functions of the system's parts and the effects of the surrounding working conditions. The force in any movement of any joint and at any angle can be represented by the symbol F. The direction of movement is according to the axes. When it is in a direction within the x-axis, it is written as FX. While when moving towards the Y-axis, it is symbolized by FY. Movement from any point, the force can be moving from a point such as C towards the X-axis, then it is symbolized by CX. Whereas when the movement is towards the y-axis, it is symbolized as CY. Thus, the forces can be encoded according to the point and direction within the known and basic axes of the vectors.

The parameters that affect the calculations of the mathematical system and the analysis of the system's behavior can be written and include force, direction, and various movements. They also include weight, mass, Earth's gravity, the material from which the limbs are made, aluminum serum, load, length, and thickness. To represent the system mathematically, an image of the system diagram must be created to identify its parts and their functions. Thus, the system parameters can be known and the relationship between them can be made to build the mathematical relationships of the system. Necessary requirements for building and designing the system include the system diagram, including the angles of joint movement and direction, and the motor that manages the force and appropriate movement.Where, gravity is (g), mass is (m), weight is (w), force is (F) include Fx in x direction and Fy in y direction.

First state at free body diagram (FBD), the sum of the forces in the horizontal axis is equal to zero (+⟶) and the arrow represents the direction and the plus sign represents the sum. Therefore, the sum of the vertical forces is written with an arrow up and a plus sign (+↑), while the horizontal is written with an arrow to the right with a plus sign as in equations one and two:

$$\longrightarrow + \sum F_x = 0 \tag{1}$$

From equation one, the force at point C in the direction of the x-axis can be equal to zero, as in equation two:

$$\text{Equ.}(1) \Longrightarrow \ C_x = 0 \tag{2}$$

$$+\uparrow \sum Fy = 0 \tag{3}$$

$$\text{Equ.}(3) \Longrightarrow \ C_y - W_{load} - W_{ll} = 0 \tag{4}$$

$$W_{load}\,(\max) = 10 \cdot g \tag{5}$$

$$W_{ll} = m_{ll} \cdot g \tag{6}$$

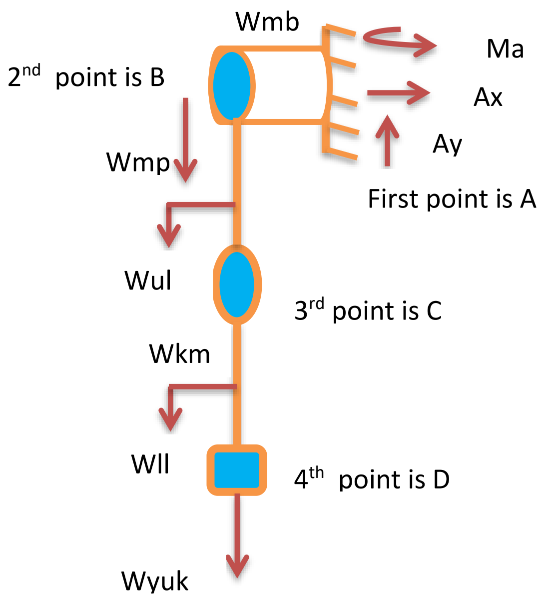


Fig. 1. the schematic diagram for Arm Rehabilitation Device (two degrees of freedom (2-DOF) upper limb type system) at 0°

5. SYSTEM MODELS AND CONTROL ALGORITHMS

Representing the system mathematically requires specifying the system parameters, their functions, and the relationship between them to provide the required movements according to a proposed work algorithm that suits their work in rehabilitating the upper limbs. One of the types of electric motors, such as a direct current motor, can be relied upon to provide the mechanical force necessary to move the upper limbs in the required direction and at the appropriate angle with the force. Which gives the proposed movements. Control systems can be relied upon to improve performance and to verify the effectiveness of the system, simulation tests are conducted for the prototype, with appropriate development being carried out to build and design an effective model. The motor can be represented as in the figure below, writing the mathematical equations for the electric motor for the electrical and mechanical parts, the Laplace transform , and then calculating transfer function:

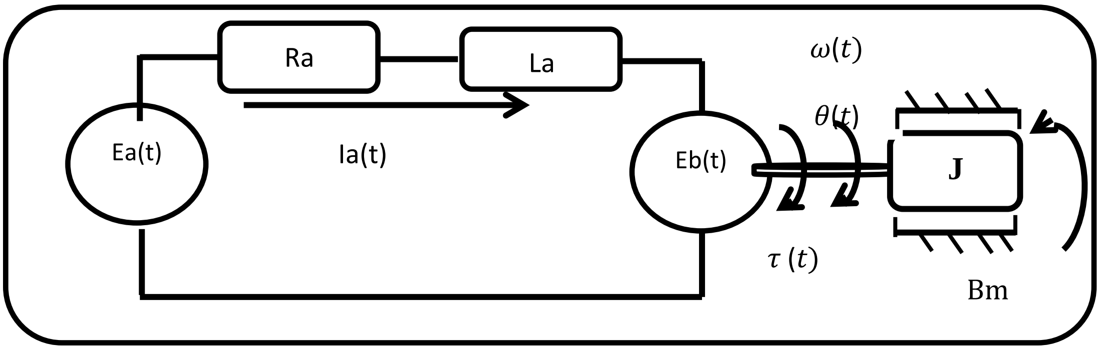


Fig.2 . modeling for DC motor

Where; armature voltage is $ea(t)$; armature current is $ia\ (t)$, armature inductor is La , back EMF is $eb\ (t)$, , the back EMF constant is Kb,angular velocity is $\omega(t)$, armature resistor is Ra, angular position is $\theta(t)$, viscous friction is bm and torque is τ.

The mathematical equation for a closed loop can be written on the input side to represent electrical quantities and include Ohm's and Kirchhoff's laws for current, voltage, resistance, and coil, as in the following equation:

$$\mathrm{EA(T) = IA(T) * RA + \frac{DI_A}{DT} * LA + EB(T)} \qquad (6)$$

The relationship between current, torque, speed, and voltage can also be written in the following two equations:

$$\mathrm{TM\ =\ IA\ \cdot\ KT}$$

$$\mathrm{IA\ = TM\ /\ KT} \qquad (7)$$

$$\mathrm{EB\ =\ KB\ \cdot\ \Omega M} \qquad (8)$$

After substituting the two equations (7&8) into the equation (6)and performing the Laplace transform, the transformation function can be written in the following equation (AKDOĞAN, Erhan., 2019):

$$\frac{\mathrm{\theta m}}{\mathrm{ea}} = \frac{\mathrm{Kt}}{\mathrm{JLas^3 + (JRa + bLa)s^2 + (bRa + KtKb)s}} \qquad (9)$$

$$\mathrm{T.F} = \frac{0.1052\mathrm{s} + 0.02344}{\mathrm{s}^2 + 0.1124\mathrm{s} + 0.002552} \qquad (10)$$

6. OPEN LOOP AND CLOSED LOOP WITH CONTROLLER

Systems are classified into an open-loop system that does not contain feedback, and there is a closed-loop system that contains feedback, in addition to the possibility of improving performance by relying on traditional, expert, and smart control units.

6.1. Artificial Neural Networks (ANN)

Units, or artificial neurons, are components of artificial neural networks. The ANN is needed to uncover the dataset's hidden patterns. Typically, an ANN consists of input layers, hidden layers and output layers. After receiving data from the outside world, the input layer's neural network learns more and more about the data, which ultimately leads to the output layer's output (Dakheel, Hashmia S., et al., 2022; Karis, Mohd Safirin, et al., 2023).

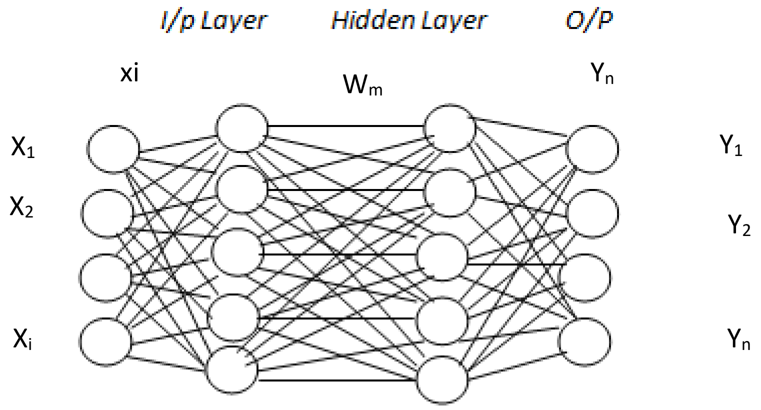


Fig.4. I/p Layer, Hidden Layer and O/P Layer of neural network.

ANN is based on the idea of neurons in terms of function and structure (human neurons) and is also called neural networks. Its layers can be known from the input side. The first layer of the network is the input layer and is linked to external sources, and from the second side it is linked to the second layer, which works to transfer data and is called the hidden layer. It consists of a group of cells. The neuron performs the function of processing information for the layer. It then works to calculate the weighted total and then transmits it to the neurons in the layer below. Because these connections are weighted, the effects of inputs from the previous layer are essentially maximized by giving each input a unique weight, which is then adjusted during training to improve model performance (Jali, M. H., et al., 2015; Jaber, Manal Hadi, et al., 2023; Jassim, Arkan A., et al., 2023).

Neural network, expert systems are considered important systems in many fields, including humanoid applications, i.e. robots, including industrial and medical applications, etc. In medical applications such as upper limb rehabilitation, expert systems such as neural networks are designed to learn in building systems that change with time, i.e. non-linear systems. Such as changing the movements of the upper limbs in terms of weight, i.e. load and torque, with changes in direction, axis, and angles, and how to control them to achieve the desired movement. Therefore, they are trained to treat patients in the limb rehabilitation process by following the appropriate paths required in the proposed experiments, based on the estimation process of the expert systems. So that the systems are The expert is represented by the neural networks MLP (A multilayer perceptron in a neural network) and its effectiveness is through controlling the sensory cells responsible for the movements of the upper limbs.

6.2. PID controller

The capacity to provide precise and ideal control has 3 terms P, I, and D influence on the sets of PID controller. The ideas behind the generation and application of these phrases are depicted in the block diagram on the right. It displays a PID controller, which uses proportional, integral, and derivative terms to provide a correction after continually, PID controllers are among the widely utilized control applications due to its implicit nature and high potency. In the world of engineering, PID controllers have been around for a while, and its three controller gain parameters are typically fixed. However, the PID controller's horrible handling of parameter fluctuations and outside disturbances contributes to system uncertainty (Shuraiji, Ahlam Luaibi, et al., 2022; Gazdar, Achraf, et al., 2020; Ding, Shihong, et al., 2019; Shneen, Salam Waley, et al., 2023).

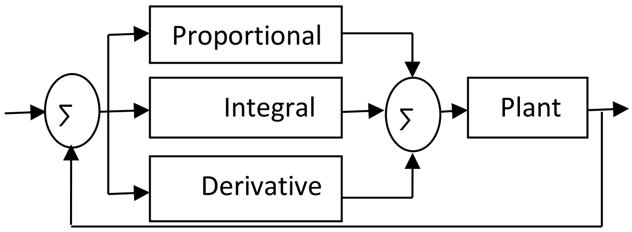


Fig.5. Closed loop with PID Controller and plant system.

7. SIMULATION MODEL AND SIMULATION RESULTS OF ARM EHABILITATION DEVICE

Rehabilitation algorithm: Building and managing the system depends on algorithms that operate according to a strategy that can control the system by controlling variables that represent the system's parameters, including force, location, and direction according to the required angle of movement. Rehabilitation algorithm: Building and managing the system relies on algorithms that operate according to a strategy that can control the system by controlling variables that represent the system's parameters, including force, location, and direction according to the required angle of movement. When it is wanted to create a rehabilitation model, the focus is on several things, the most important of which is that it be safe and stable because it deals with people, that is, with sick people, through precision and control of the environment in which the work takes place for the purpose of verifying the effectiveness of the proposed rehabilitation system according to the results of simulating the appropriate model by working on developing and designing a system that achieves the appropriate movements for all cases.

The simulation model of Arm Rehabilitation Device is implemented by using MATLAB / SIMULINK. In this section, there are five simulation models for Arm Rehabilitation Device by open loop, close loop, close loop with PIDC, closed loop with ANN and close loop with comparative between PIDC and ANN:

7.1. Open Loop of Arm Rehabilitation Device

In this section, the simulation model of Open Loop of Arm Rehabilitation Device that shows in Figure 6. The figure shows an open-loop system with no feedback, that is, without monitoring the output state.

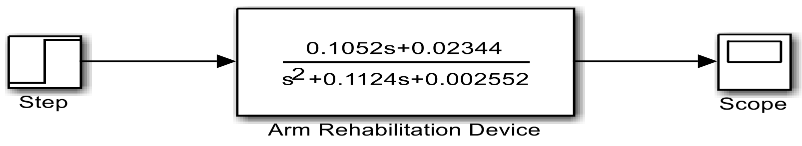


Fig.6.Simulation Model of Open Loop of Arm Rehabilitation Device.

The simulation result of Open Loop of Arm Rehabilitation Device as shown in figure. 7, the shape appears the response of the system as a worst response compare with the system response at the other states.

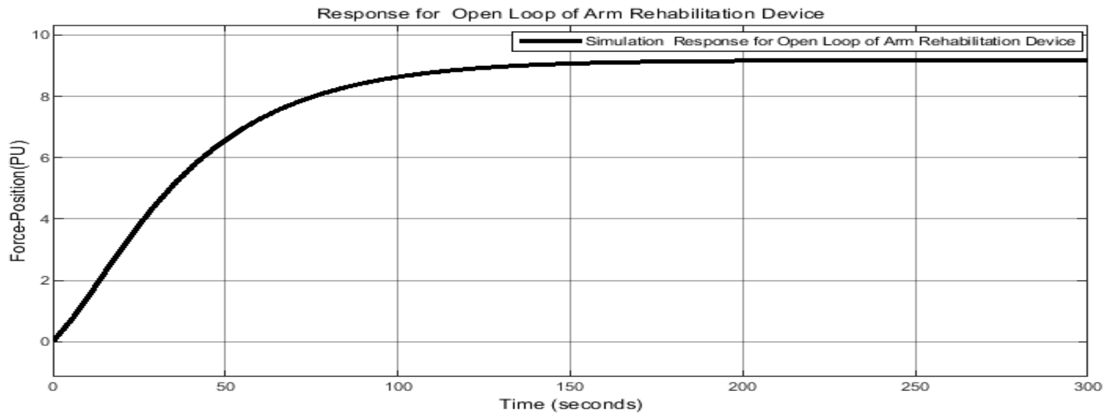


Fig.7.Simulation Result of Open Loop of Arm Rehabilitation Device.

7.2. Close Loop of Arm Rehabilitation Device

In this section, the simulation model of Close Loop of Arm Rehabilitation Device as show in Fig. 8.

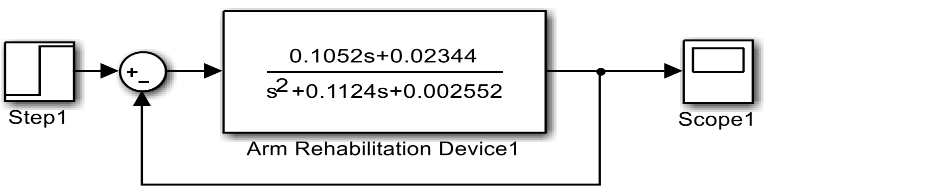


Fig.8. Simulation Model of Close Loop of Arm Rehabilitation Device.

The simulation result of closed Loop of Arm Rehabilitation Device as shown in figure. 9. A closed loop system takes into consideration the current output of the system and use to keep the process on a desired set point, Rise time (tr) = 10 , overshoot = 0.94, steady state (tss)=40.

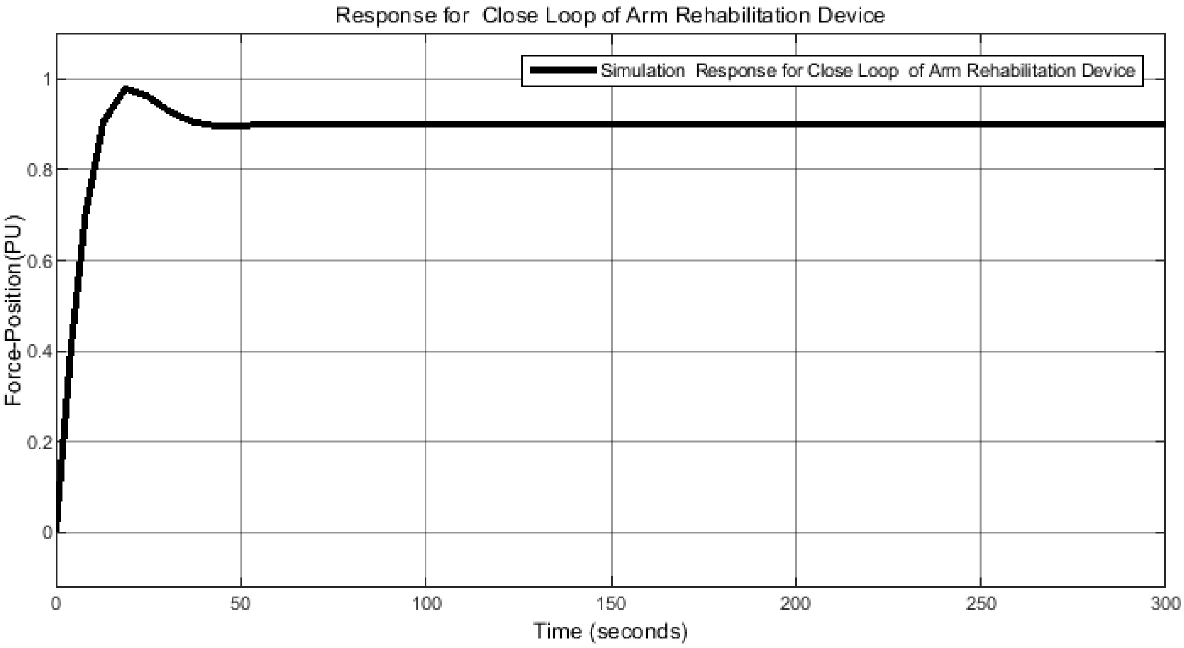


Fig.9.Simulation Result of Close Loop of Arm Rehabilitation Device.

7.3. Close Loop of Arm Rehabilitation Device with PID Controller

In this section, the simulation model of Close Loop of Arm Rehabilitation Device with PIDC as show in Fig. 10. The traditional controller can be distinguished by being capable of this type of improvement and raising the level of performance by understanding cases of variation in work behavior and operation to achieve better results. It is made up of three main components: a sensor, a controller, and an actuator. The PID controller in the control system is tuned using Auto-tuning method in Matlab.

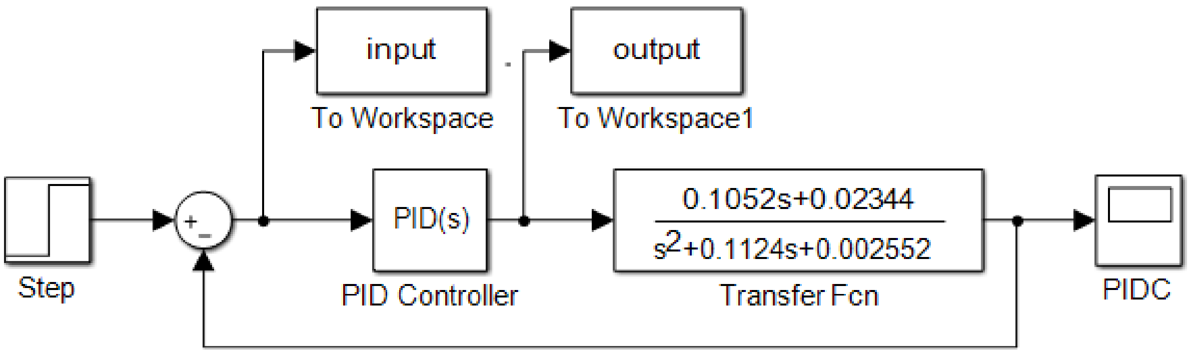
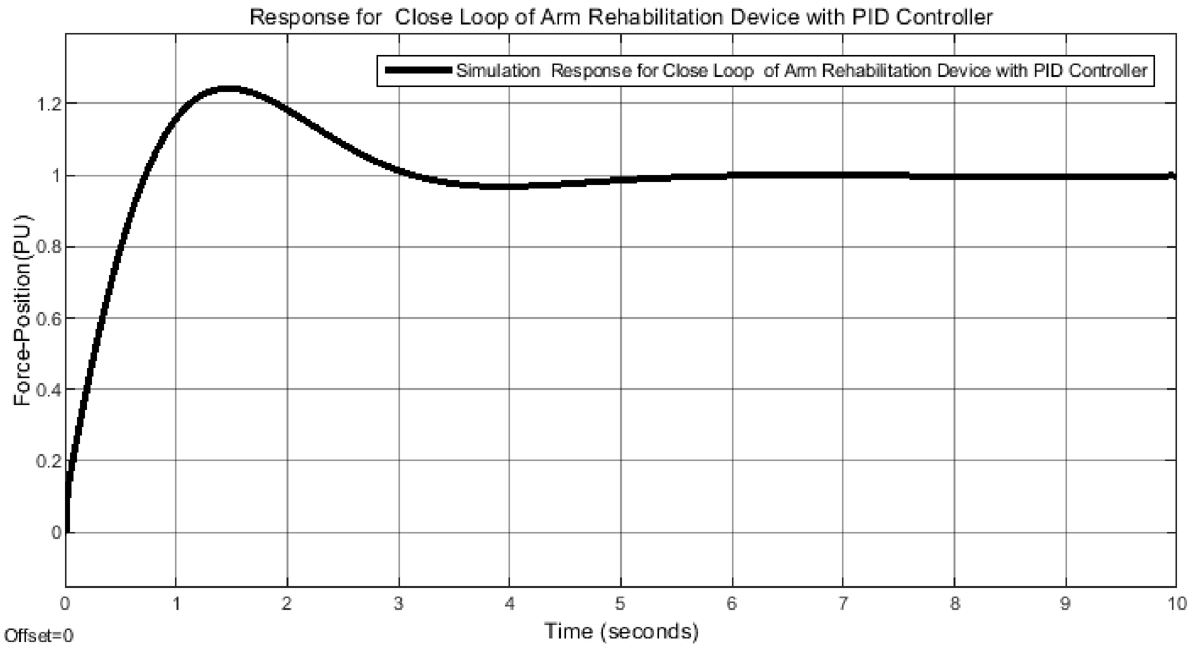


Fig.10.Simulation Model of Close Loop of Arm Rehabilitation Device with PID Controller.

The simulation result of closed Loop of Arm Rehabilitation Device with PIDC as shown in figure. 11. Rise time (tr) = 0.2, overshoot = 1.23, undershoot value =0.95 and steady state error=5.2.



section

Fig.11.Simulation Result of Close Loop of Arm Rehabilitation Device with PID Controller.

7.4. Close Loop of Arm Rehabilitation Device with ANN

In this, the simulation model of Close Loop of Arm Rehabilitation Device with ANN as show in Fig. 12.

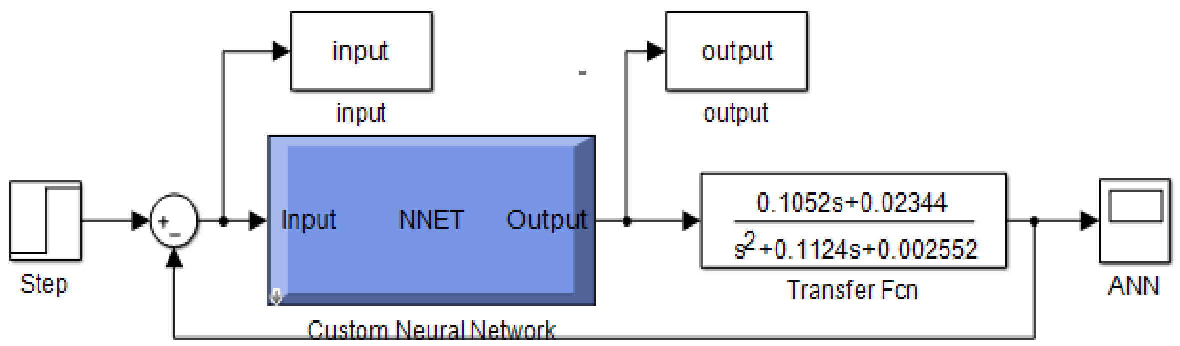


Fig.12.Simulation Model of Close Loop of Arm Rehabilitation Device with ANN

The simulation result of closed Loop of Arm Rehabilitation Device with ANN as shown in Fig.13. Rise time (tr) = 0.1, overshoot=1.12 and steady state (tss)=5.

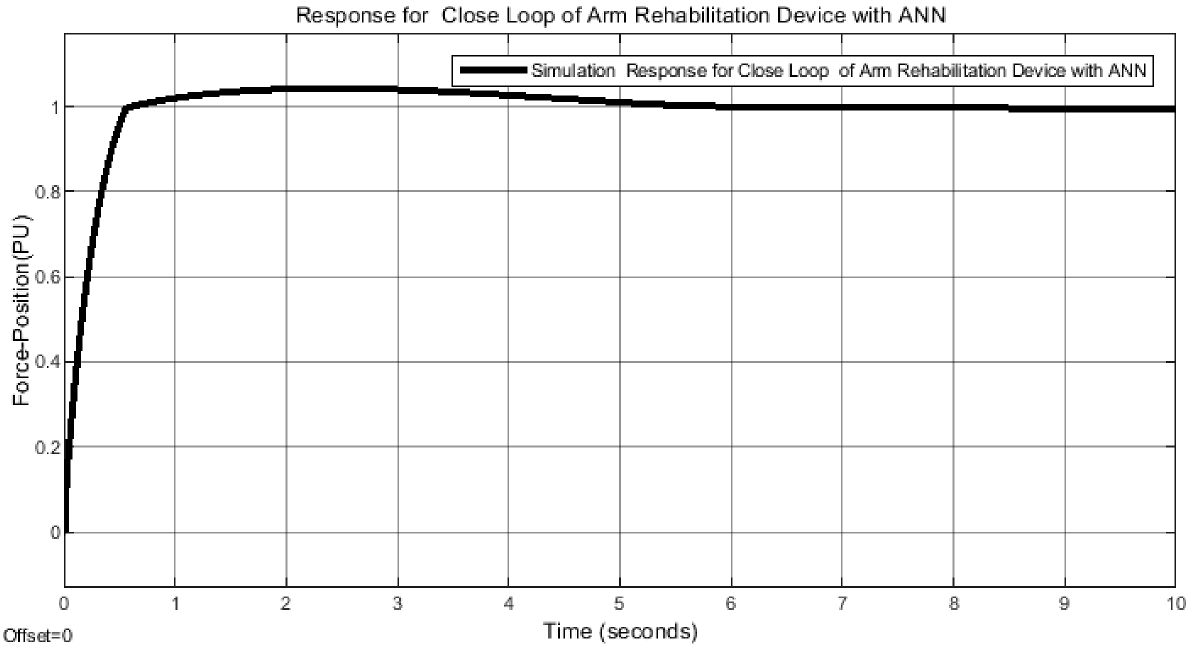


Fig. 13. Simulation Result of Close Loop of Arm Rehabilitation Device with ANN.

7.5. Close Loop of Arm Rehabilitation Device with comparative between PIDC and ANN

In this section, the simulation model of Close Loop of Arm Rehabilitation Device with PIDC and ANN as show in Fig. 14.

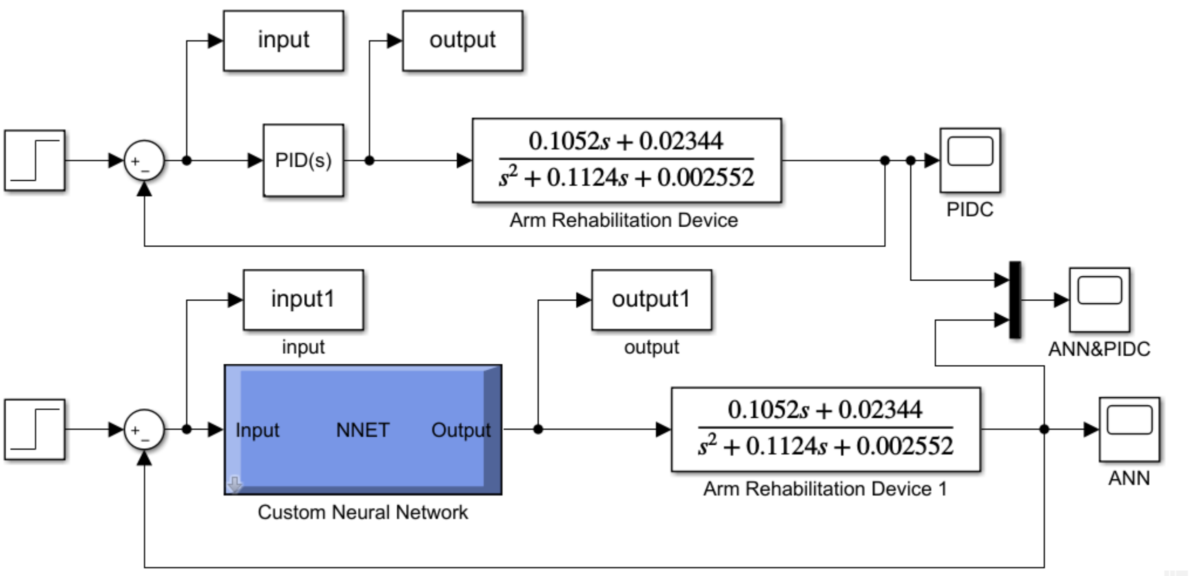


Fig.14.Simulation Model of Close Loop of Arm Rehabilitation Device with comparative between PIDC and ANN.

The simulation result of closed Loop of Arm Rehabilitation Device with PIDC and ANN as shown in Fig. 15. The shape appears the best response of the system compare with the response of system with the methods used in the simulation; this could be close to optimal values for Arm Rehabilitation Device. Simulation Result of Close Loop of Arm Rehabilitation with comparative between PIDC and ANN. Data of artificial neural network, the neural network training in this paper can be shown in Figure 16 to Figure 19. It is possible to represent and display how to train a neural network in the sections from Fig. 16 to Fig. 19, and titles can be placed that represent the performance status of the network stages(ANN training, best training performance, mean squared error, ANN-Gradient, Mu & Validation Checks and the ANN-Target Training.

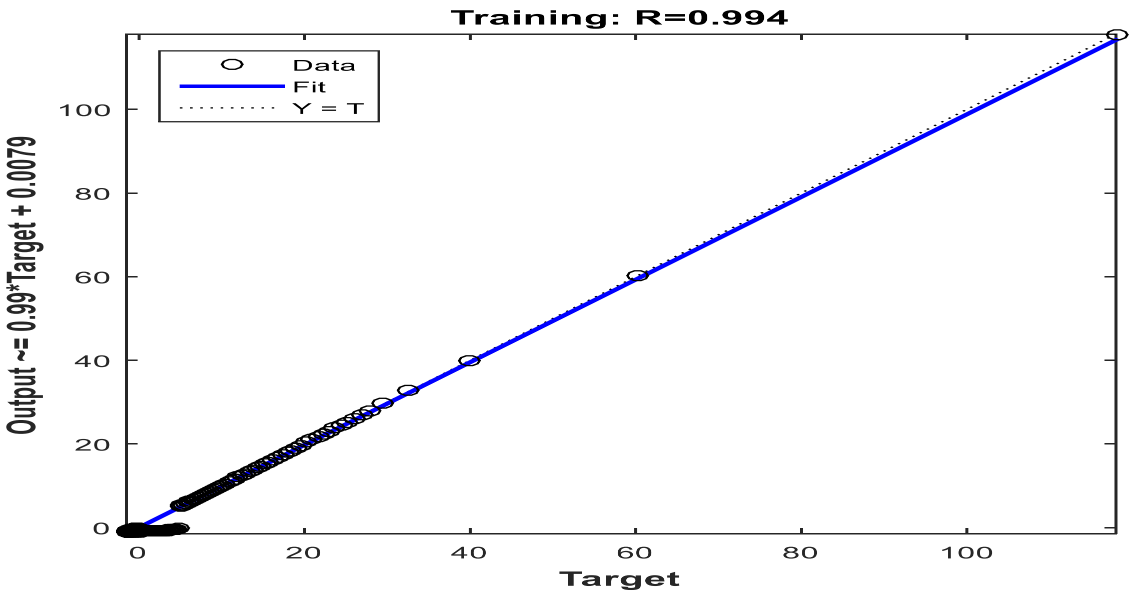


Fig.15. Simulation of ANN-Target Training.

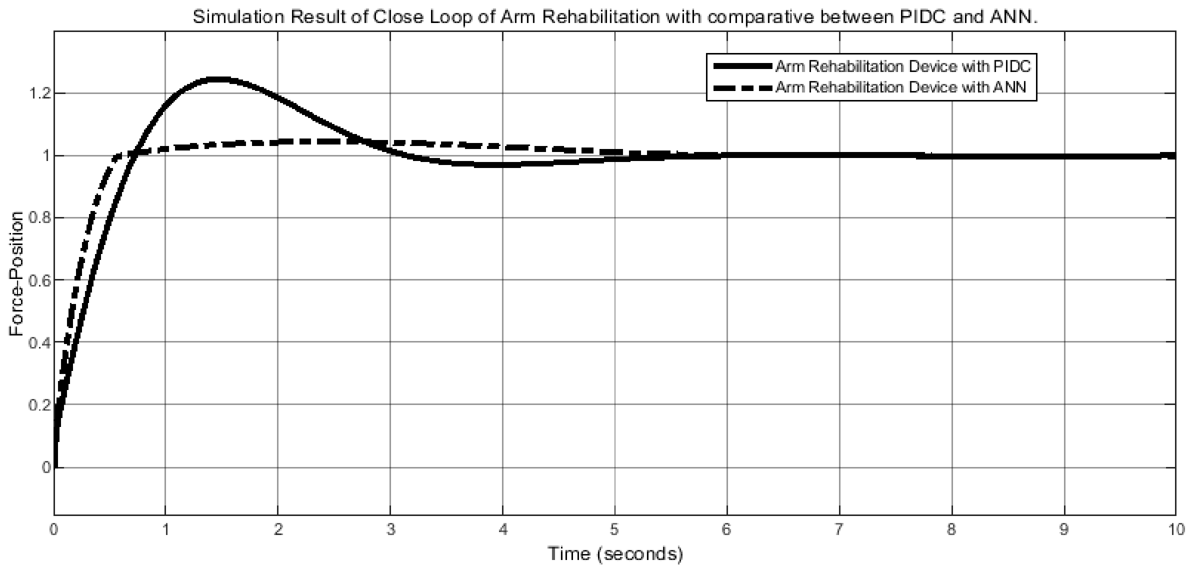


Fig. 16.Simulation Result of Close Loop of Arm Rehabilitation with comparative between PIDC and ANN.

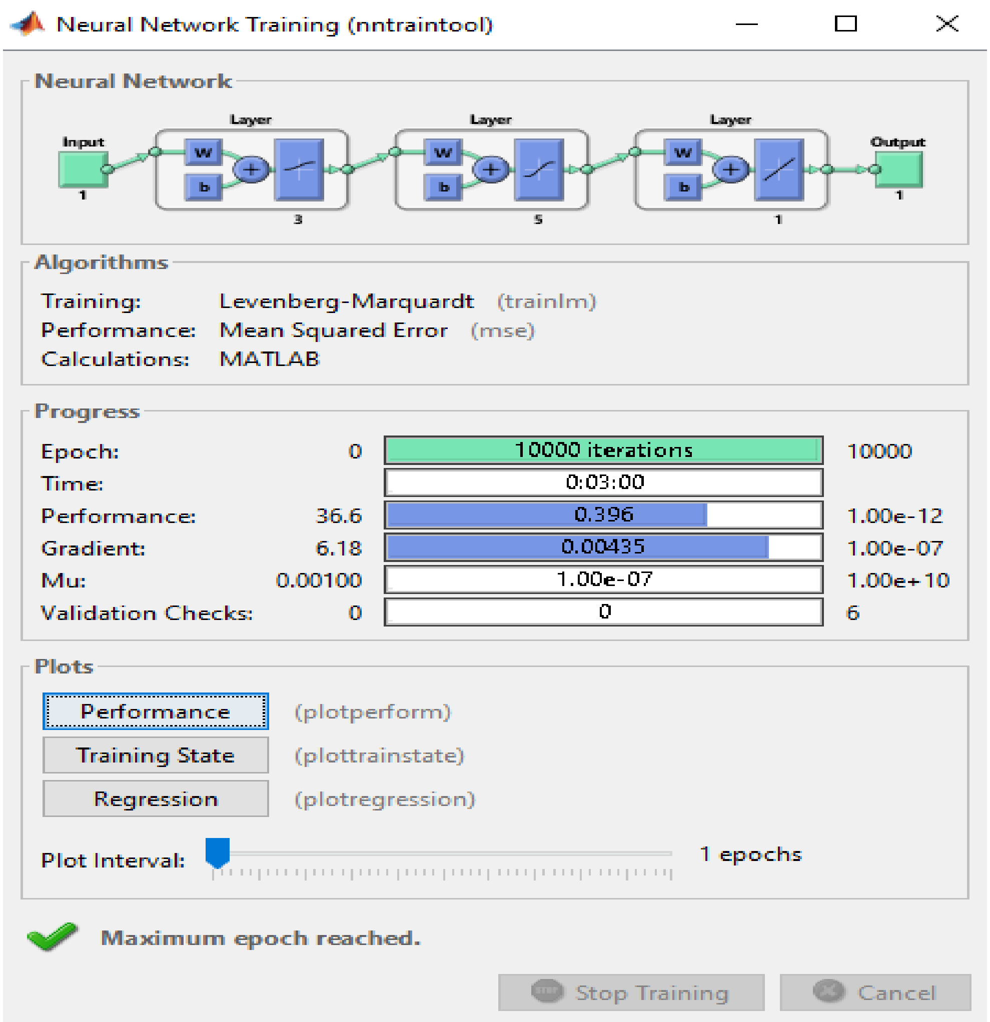


Fig.17.Simulation of ANN-Training

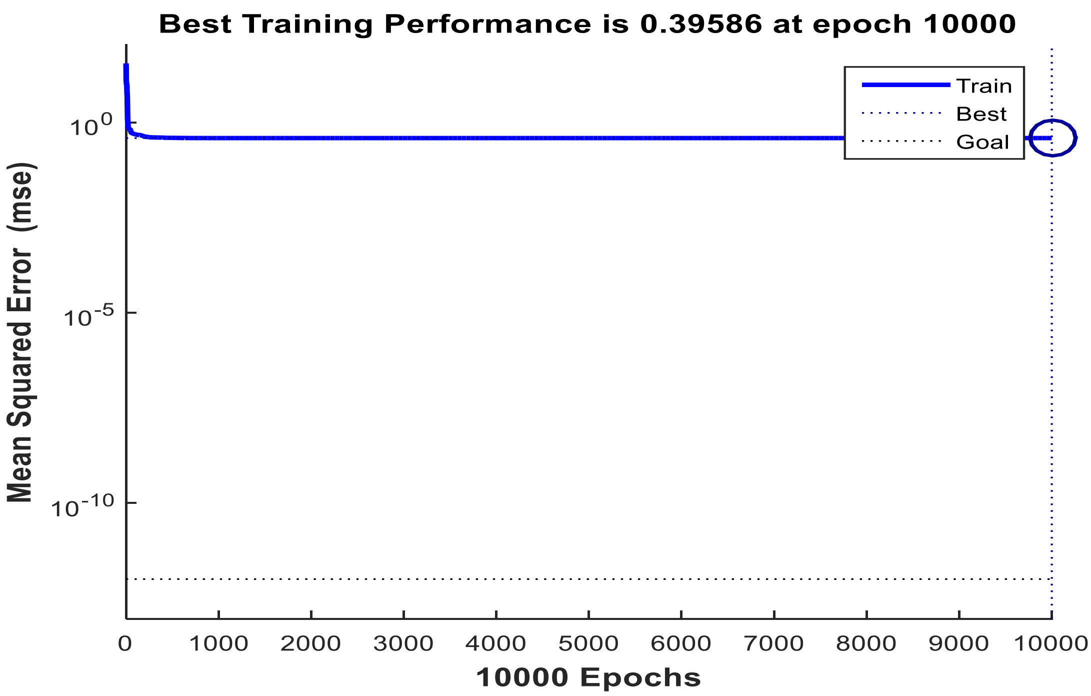


Fig.18. Simulation of ANN-Best Training Performance.

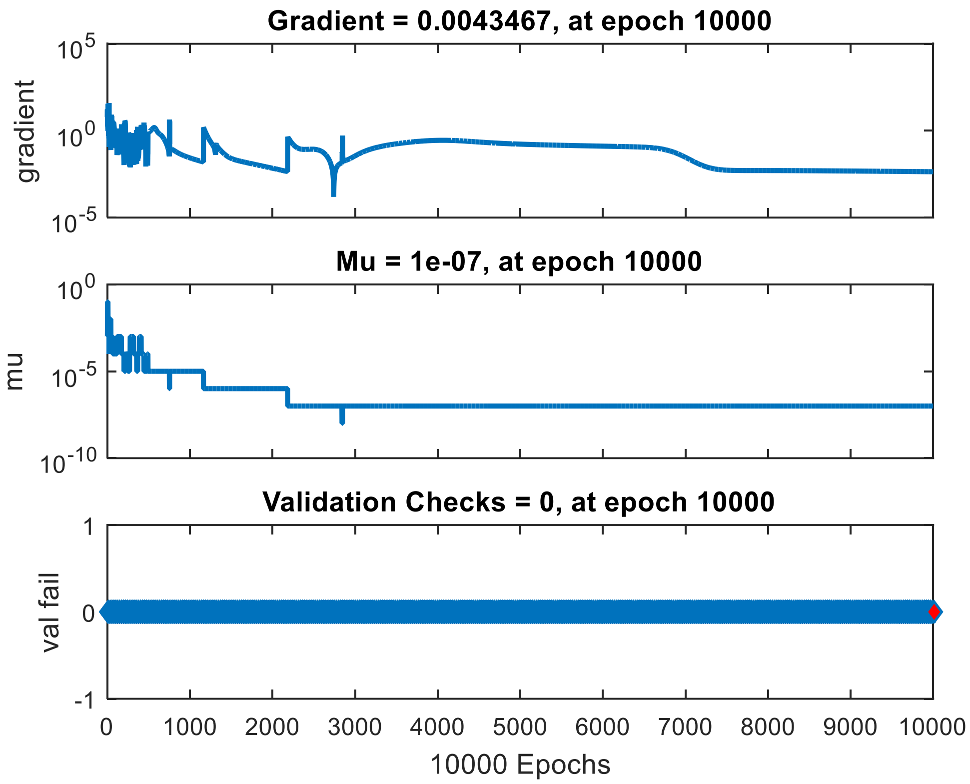


Fig.19.Simulation of ANN-Gradient, Mu & Validation Checks

8. CONCLUSIONS

Using the MATLAB program, all the proposed tests were conducted that simulate the use of a device that helps in trying to restore movement to the arm, which is called rehabilitation. The target group is people affected by stroke in order to verify the effectiveness of the proposed model. These tests were also conducted with the aim of improving performance by developing the model according to a design process that suits its characteristics, taking into account the required operational behavior of the system. Five test cases were conducted that were proposed to know the behavior of the system for all conditions that can be predicted and suit the different situations in which the system can work. Case The first test case is for the system to be without feedback, i.e. an open system, and the second test case is with feedback, which is operating a closed loop system. The third case includes a closed loop system with a traditional, closed PIDC type controller. Fourthly, by adding the expert controller type ANN, and to choose the best one, a comparison was made between the traditional controller type PIDC and the expert controller type ANN. The possibility of knowing the behavior of the system for the proposed cases and knowing the difference between the behavior of the system for all those cases was verified. The possibility of improving the performance of the movement restoration device to rehabilitate the arm of an injured person has been verified with the appropriate rate of response speed and in a time that achieves stability, i.e. a steady state, and rates that are approximately equivalent to the prescribed amount and reduce overshoot. It was also shown from the results that the performance of the system in the presence of an expert controller type of neural network. It is better than the traditional controller.

9. REFERENCES

Abdullah, Fatin Nabeel, Ghada Adel Aziz, and Salam Waley Shneen. "Simulation model of servo motor by using matlab." Journal of Robotics and Control (JRC) 3.2 (2022): 176-179.

Abdullah, Zainab B., Salam Waley Shneen, and Hashmia S. Dakheel. "Simulation Model of PID Controller for DC Servo Motor at Variable and Constant Speed by Using MATLAB." Journal of Robotics and Control (JRC) 4.1 (2023): 54-59.

Abood, Layla H., and B. Kadhim Oleiwi. "Design of fractional order PID controller for AVR system using whale optimization algorithm." Indonesian Journal of Electrical Engineering and Computer Science 23.3 (2021): 1410-1418.

Abood, Layla H., and Russul Haitham. "Design an Optimal Fractional Order PI Controller for Congestion Avoidance in Internet Routers." Mathematical Modelling of Engineering Problems 9.5 (2022).

Adetokun, Bukola Babatunde, Oghenewvogaga Oghorada, and Sufyan Ja'afar Abubakar. "Superconducting magnetic energy storage systems: Prospects and challenges for renewable energy applications." Journal of Energy Storage 55 (2022): 105663.

AKDOĞAN, Erhan. "Design, produce and control of a 2-DOF upper limb exoskeletal robot." Journal of Thermal Engineering 5.2 (2019): 119-130.

Arantes, Ana. "Development and validation of a novel adaptive assist-as-needed controller for robot-assisted rehabilitation of the upper-extremity following stroke." (2021).

Attiya, Adnan Jabbar, et al. "Variable speed control using fuzzy-pid controller for two-phase hybrid stepping motor in robotic grinding." Indonesian Journal of Electrical Engineering and Computer Science 3.1 (2016): 102-118.

Baghli, Fatima Zahra, Yassine Lakhal, and Youssef Ait El Kadi. "The Efficiency of an Optimized PID Controller Based on Ant Colony Algorithm (ACO-PID) for the Position Control of a Multi-articulated System." Journal of Robotics and Control (JRC) 4.3 (2023): 289-298.

Chavoshian, Mahdi, Mostafa Taghizadeh, and Mahmood Mazare. "Hybrid dynamic neural network and PID control of pneumatic artificial muscle using the PSO algorithm." International Journal of Automation and Computing 17.3 (2020): 428-438.

Chotikunnan, Phichitphon, and Rawiphon Chotikunnan. "Dual design PID controller for robotic manipulator application." Journal of Robotics and Control (JRC) 4.1 (2023): 23-34.

Chotikunnan, Phichitphon, and Yutthana Pititheeraphab. "Adaptive p control and adaptive fuzzy logic controller with expert system implementation for robotic manipulator application." Journal of Robotics and Control (JRC) 4.2 (2023): 217-226.

Chotikunnan, Phichitphon, Rawiphon Chotikunnan, and Panya Minyong. "Adaptive Parallel Iterative Learning Control with A Time-Varying Sign Gain Approach Empowered by Expert System." Journal of Robotics and Control (JRC) 5.1 (2024): 72-81.

Dakheel, Hashmia S., et al. "Simulation model of ANN and PID controller for direct current servo motor by using Matlab/Simulink." TELKOMNIKA (Telecommunication Computing Electronics and Control) 20.4 (2022): 922-932.

Dakheel, Hashmia S., Zainab B. Abdullah, and Salam Waley Shneen. "Advanced optimal GA-PID controller for BLDC motor." Bulletin of Electrical Engineering and Informatics 12.4 (2023): 2077-2086.

Ding, Shihong, et al. "Disturbance observer design for nonlinear systems represented by input–output models." IEEE Transactions on Industrial Electronics 67.2 (2019): 1222-1232.

Eissa, Suad Ali, Salam Waley Shneen, and Ekbal Hussain Ali. "Flower Pollination Algorithm to Tune PID Controller of TCP/AQM Wireless Networks." Journal of Robotics and Control (JRC) 4.2 (2023): 149-156.

Eski, İkbal, and Ahmet Kırnap. "Controller design for upper limb motion using measurements of shoulder, elbow and wrist joints." Neural Computing and Applications 30 (2018): 307-325.

Gazdar, Achraf, and Lotfi Hidri. "A new similarity measure for collaborative filtering based recommender systems." Knowledge-Based Systems 188 (2020): 105058.

Hassan, Ibrahim A., Issa A. Abed, and Walid A. Al-Hussaibi. "Path Planning and Trajectory Tracking Control for Two-Wheel Mobile Robot." Journal of Robotics and Control (JRC) 5.1 (2024): 1-15.

Jaber, Manal Hadi, Manal Kadhim Oudah, and Salam Waley Shneen. "Simulation model of ANN and PID controller for TCP/AQM wireless networks by using MATLAB/Simulink." Indonesian Journal of Electrical Engineering and Computer Science 30.2 (2023): 739-747.

Jali, M. H., et al. "ANFIS-PID controller for arm rehabilitation device." International Journal of Engineering and Technology (IJET) 7.5 (2015): 1589-1597.

Jali, M. H., et al. "Comparative study of EMG based joint torque estimation ANN models for arm rehabilitation device." International Journal of Applied Engineering Research 9.10 (2014): 1289-1301.

Jassim, Arkan A., Ekhlas H. Karam, and Mohammed Moanes E Ali. "Design of Optimal PID Controller for Electric Vehicle Based on Particle Swarm and Multi-Verse Optimization algorithms." Engineering and Technology Journal 41.2 (2023): 446-455.

Jayasekara, Ninura, et al. "Revolutionizing Accessibility: Smart Wheelchair Robot and Mobile Application for Mobility, Assistance, and Home Management." Journal of Robotics and Control (JRC) 5.1 (2024): 27-53.

Josiah, Princewill N., Ipeghan J. Otaraku, and Benson O. Evbuomwan. "Servo and Regulatory Response of an Industrial Fluid Catalytic Cracking (FCC) Unit under Fuzzy Logic Supervisory Control." Engineering and Technology Journal 41.9 (2023): 1139-1151.

Kabir, Ryan, et al. "Hand rehabilitation devices: A comprehensive systematic review." Micromachines 13.7 (2022): 1033.

Karis, Mohd Safirin, et al. "Analysis of ANN and Fuzzy Logic Dynamic Modelling to Control the Wrist Exoskeleton." Journal of Robotics and Control (JRC) 4.4 (2023): 572-583.

Kumar, G. Syam, et al. "Injury Prediction in Sports using Artificial Intelligence Applications: A Brief Review." Journal of Robotics and Control (JRC) 5.1 (2024): 16-26.

Medina, Francisco, et al. "Control of a hybrid upper-limb orthosis device based on a data-driven artificial neural network classifier of electromyography signals." Biomedical Signal Processing and Control 68 (2021): 102624.

Mohamed, Mohamed Jasim, et al. "Neural Fractional Order PID Controllers Design for 2-Link Rigid Robot Manipulator." Fractal and Fractional 7.9 (2023): 693.

Mossa, Mahmoud A., Houari Khouidmi, and Alfian Ma'arif. "Robust flux and speed state observer design for sensorless control of a double star induction motor." Journal of Robotics and Control (JRC) 3.4 (2022): 464-475.

Mutlag, Ashraf Abdualateef, Mohammed Kdair Abd, and Salam Waley Shneen. "Power Management and Voltage Regulation in DC Microgrid with Solar Panels and Battery Storage System." Journal of Robotics and Control (JRC) 5.2 (2024): 397-407.

Najm, Vian N., Tahseen F. Abbas, and Shukry H. Aghdeab. "Integrating Grey Relation Analysis and Artificial Neural Networks for Optimal Machining of Tungsten Carbide Composite Using Hybrid Electrochemical Discharge." Engineering and Technology Journal 41.12 (2023): 1594-1610.

Nalibayev, Nurgali, et al. "Analysis of Problems and Prospects for Improving Automatic Control Systems of Interconnected Electric Drives." Journal of Robotics and Control (JRC) 5.2 (2024): 378-387.

Penta, Samyuktha, S. Venkateshwarlu, and K. Naga Sujatha. "A novel adaptive controller with lyapunov analysis for strategy grid intelligent integrated wind turbine maximum power point tracking system." International Journal of Intelligent Systems and Applications in Engineering 11.9s (2023): 94-107.

Raheem, A. K. K. A., et al. "Design and Simulation of a Second-Order Universal Switched-Capacitor Filter as a 10-Pin Dual-In-Line Package Integrated Circuit." Engineering and Technology Journal 30.18 (2012): 3175-3191.

Saputra, Dodi, et al. "Design and Application of PLC-based Speed Control for DC Motor Using PID with Identification System and MATLAB Tuner." International Journal of Robotics and Control Systems 3.2 (2023): 233-244.

Shamseldin, Mohamed A., and Mohamed A. Abdelghany. "A New Self-Tuning Nonlinear PID Motion Control for One-Axis Servomechanism with Uncertainty Consideration." Journal of Robotics and Control (JRC) 4.2 (2023): 118-127.

Shneen, Salam Waley, Ahlam Luaibi Shuraiji, and Kassim Rasheed Hameed. "Simulation model of proportional integral controller-PWM DC-DC power converter for DC motor using matlab." Indones. J. Electr. Eng. Comput. Sci 29 (2023): 725-734.

Shneen, Salam Waley, Chengxiong Mao, and Dan Wang. "Advanced optimal PSO, Fuzzy and PI controller with PMSM and WTGS at 5Hz side of generation and 50Hz Side of Grid." International Journal of Power Electronics and Drive Systems 7.1 (2016): 173.

Shneen, Salam Waley, Dina Harith Shaker, and Fatin Nabeel Abdullah. "Simulation model of PID for DC-DC converter by using MATLAB." International Journal of Electrical and Computer Engineering 11.5 (2021): 3791.

Shneen, Salam Waley, H. S. Dakheel, and Z. B. Abdulla. "Advanced Optimal for PV system coupled with PMSM." Indonesian Journal of Electrical Engineering and Computer Science 1.3 (2016): 556-565.

Shneen, Salam Waley, Hashmia S. Dakheel, and Zainab B. Abdullah. "Design and Implementation of No Load, Constant and Variable Load for DC Servo Motor." Journal of Robotics and Control (JRC) 4.3 (2023): 323-329.

Shuraiji, Ahlam Luaibi, and Salam Waley Shneen. "Fuzzy Logic Control and PID Controller for Brushless Permanent Magnetic Direct Current Motor: A Comparative Study." Journal of Robotics and Control (JRC) 3.6 (2022): 762-768.

Su, Yun-Hsuan. Vision Based Surgical Tool Tracking and Force Estimation with Robot Kinematics Prior. University of Washington, 2020.

Triwiyanto, Triwiyanto, et al. "Single Lead EMG signal to Control an Upper Limb Exoskeleton Using Embedded Machine Learning on Raspberry Pi." Journal of Robotics and Control (JRC) 4.1 (2023): 35-45.

Umam, Faikul, et al. "Obstacle avoidance based on stereo vision navigation system for omni-directional robot." Journal of Robotics and Control (JRC) 4.2 (2023): 227-242.

Wa'il, A. H., and Layla Hattim Abood. "Design and Implementation of MC-CDMA Technique Using FPGA." Engineering and Technology Journal 31.11 Part (A) Engineering (2013).

Zadehbagheri, Mahmoud, et al. "Design of Multivariate PID Controller for Power Networks Using GEA and PSO." Journal of Robotics and Control (JRC) 4.1 (2023): 108-117.

Zhu, Feifei, et al. "TV-NARX and Coiflets WPT based time-frequency Granger causality with application to corticomuscular coupling in hand-grasping." Frontiers in Neuroscience 16 (2022): 1014495.