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# Measure of disturbance rejection for a neonate monitoring system using adapted Neuro-Fuzzy inference system

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**Abstract**
Temperature is a critical component of the environment since it significantly impacts human life, property, and product quality. A pleasant temperature is necessary for pleasant living. As a result, it is critical to monitor the temperature of humans, particularly newborns less than 30 days due to their low thermal stability. The temperature monitoring system for newborns enables the monitoring and regulation of neonatal heat levels. Adequate ambient warmth is critical for child care to sustain body heat. The typical Proportional Integral Derivative (PID) temperature controller, which is often employed, is well suited for stable systems. Additionally, there are issues with the extended settling period, the considerable time constant, overshoot, and the difficulty in obtaining an appropriate mathematical model. The purpose of these findings is to create a Neuro fuzzy-PID controller for monitoring neonatal temperature. A typical fuzzy proportional integral derivative (PID) controller was integrated with artificial neurons in the heating and cooling system design to manage the Neonate's temperature.

**Keywords:** Disturbance, inference, monitoring, neonate, neuro-fuzzy, and system

## 1. Introduction

Accurate body temperature monitoring is critical in newborns as a measure of thermal balance and thermoregulation. Neonates are newborn infants under the age of 28 days. Because newborns have poor thermal stability due to excessive heat loss and are particularly susceptible to body temperature changes [1-2], it is necessary to monitor and manage their temperature to the babies' normal body temperature to protect them from hypothermia. This may be accomplished by the development of a heating system for neonates. Though several heating techniques have been used in the past for newborns, including heating the room with a bright bulb or lantern, covering their bodies with clothing, and others that need human interaction, a more modern technique uses the PID control scheme. The proportional integral derivative (PID) controller is one of the first control algorithms and techniques utilized in control engineering. PID controllers were invented in 1940 and have been extensively employed in industries ever since [3]. PID controllers are used in businesses to regulate variables such as fluid flow, pressure, level, temperature, consistency, and density. The controller maintains a constant level of process output so that the difference between the process variable and the setpoint is as little as possible [4-5].

The conventional PID controller is frequently used for temperature control because it has a good control effect for a steady-state system and can generate an accurate mathematical model. However, due to the complexity of the actual temperature control system, varied parameters, large inertia, and large delay, the conventional PID controller has difficulty controlling its high precision [6]. The disadvantages of temperature control in a room heating system include repetitive ON/OFF switching, a longer settling time, a large time constant, and overshoot.

To address these shortcomings, a system combining PID algorithms, trained inputs, and fuzzy control need to be developed that does not require a precise mathematical model of the controlled object and instead relies on experience and knowledge to monitor the Neonate's temperature and prevent it from falling or rising above the normal room temperature.

As a result, a neuro-fuzzy adaptive PID temperature controller was created that utilizes fuzzy reasoning techniques to auto-tune PID settings. This system was suited for a time-varying, non-linear delay system.

### 1.1 Tuning Method for Minimum Error Integral Criteria

Tuning for the 1/4 decay ratio often results in oscillatory responses, and this criterion also takes just two points of the closed-loop response into account (the first two peaks). Alternatively, an engineer can construct a controller design relationship based on a performance metric that takes the full closed-loop response into account. Several of these indices are listed below.1) Integral of the absolute value of the error (IAE) [7]

$$IAE = \int_0^{\alpha} |e(t)|\,dt \quad (1)$$

2) Integral of the square value of the error (ISE)

$$ISE = \int_0^{\alpha} e^2(t) \quad (2)$$

3) Integral of the time-weighted absolute value of the error (ITAE)

$$ITAE = \int_0^{\alpha} t\,|e(t)|\,.d \quad (3)$$

4) Integral of the time-weighted square of the error (ITSE)

$$ITSE = \int_0^{\alpha} t\,.\,e^2(t)\,|\,.d \quad (4)$$

### 1.2 Fuzzy sets

Classical sets and their operations are especially advantageous for expressing classical logic since they lead to Boolean logic and its applications in digital systems [8]. On the other hand, fuzzy sets and fuzzy operations are valuable for expressing fuzzy logic concepts, resulting in applications such as fuzzy controllers. A fuzzy set is a set that allows for degrees of membership between 1 and 0. Because fuzzy sets allow for partial membership, they may more accurately represent the way clever people think. For instance, an intelligent individual will not categorize others as friends or foes; there is a spectrum between these two extremes.

### 1.3 Related Works

The boiler drum level regulations utilizing the fuzzy-PID are suggested by [11]. Liquid level control difficulties can develop power plants in a boiler drum. Compared with traditional PID, fuser-PID control is a better reaction than conventional PID, comparing the time-domain features and the simulation results. To optimize the PID parameters of the three tank levels procedure [12], the Differential Evolution (DE) method was used. The DE-based PID controller's responsiveness is better than the standard PID response. The precise demands for humidity in a range of situations were addressed by [9]. The design of a moisture fugues control system was carried out using a fuzzy control algorithm. The method provided is very accurate, has a minimal overlay, excellent stability, and intelligent moisture management.

PID and Fuzzy Controller for the smart greenhouse [8-9] have regulated various greenhouse parameters. The control activities are done based on the merger of many factors to optimize energy usage and room utilization. The PID controller was created for moisture and temperature while the fuzzy carbon dioxide enrichment inferencing system was built. The PID controller for the electric furnace temperature control has been developed by [2]. In the search for optimum PID parameters, the Flower Pollinating algorithm (FPA) was used. A restricted optimization issue is examined in the suggested PIDA framework based on FPA.

## 2. Materials and Method

P, I, and D (D). When P relies on the present error, I on the accumulation of previous mistakes, and D is calculated as a forecast of future mistakes based on the current rate of change. The values of these parameters are understood in terms of time. Figure 1 illustrates how the P, I, and D inputs are combined to generate the PID controller output.

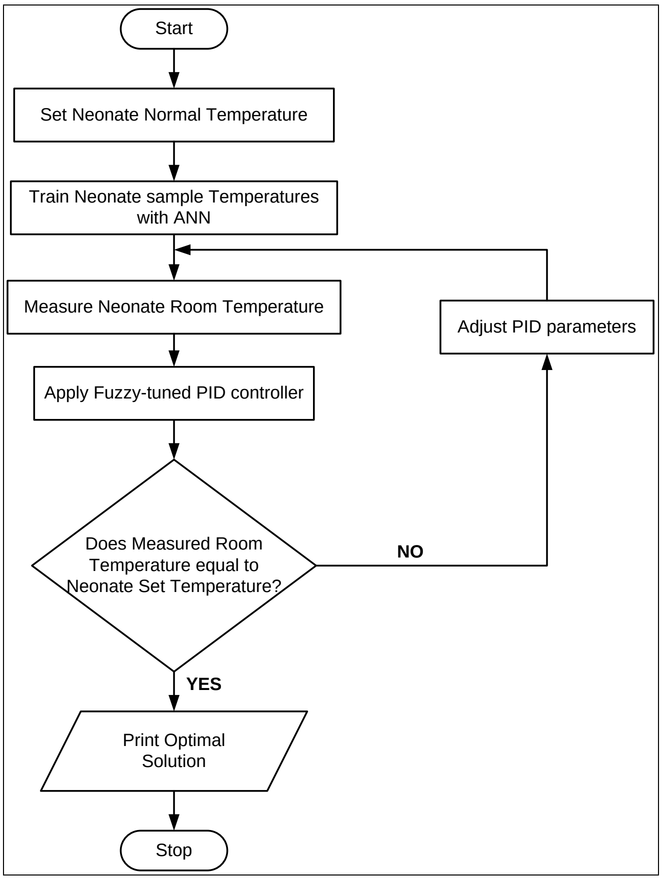


**Fig 1:** Flow chart of the proposed system
Source: Authors Fieldwork, 2021

The model of the temperature control system is given below:

Let's assume that:

$T_{in}$ = inner wall temperature of the neonates

$T_i$= air temperature of the neonate room

$T_{amb}$ = outside air
h = coefficient of convection of heat transmission, Then
1. Heat exchange between the indoor air and the inner wall temperature is given as

$$\frac{dQ_1}{dt} = h_1 A_1 (T_{in} - T_i) \quad (1)$$

Where A = Cross-sectional area

$$\frac{Q_1}{A_1} = h_1 (T_{in} - T_i) \quad (2)$$

Note that

$$\frac{Q_1}{A_1} = q$$

= heat transfer per unit area/heat flux

2. Heat exchange between the outer wall temperature and outside air is given as

$$\frac{dQ_2}{dt} = h_2 A_2 (T_{out} - T_{amb}) \quad (3)$$

$$\frac{Q_2}{A_2} = h_2 (T_{out} - T_{amb}) \quad (4)$$

3. Transmission by conduction between the inner wall and the outside wall is given as

$$\frac{dQ_3}{dt} = \frac{kA(T_{out} - T_{in})}{l} \quad (5)$$

$$\frac{Q_3}{A} = \frac{kAdT}{dl} \quad (6)$$

Where

$$\frac{Q_3}{A} = q$$

K = coefficient of thermal conductivity
A = cross-sectional Area of the wall
l = Path length

1. The heat generated by the heater is given as

$$\frac{dQ_{heating}}{dt} = \eta\rho(t) \quad (7)$$

Where

$$\eta = \frac{\text{Power delivered}}{Powerconsumed}$$

and $\rho(t)$ Represents the power consumed

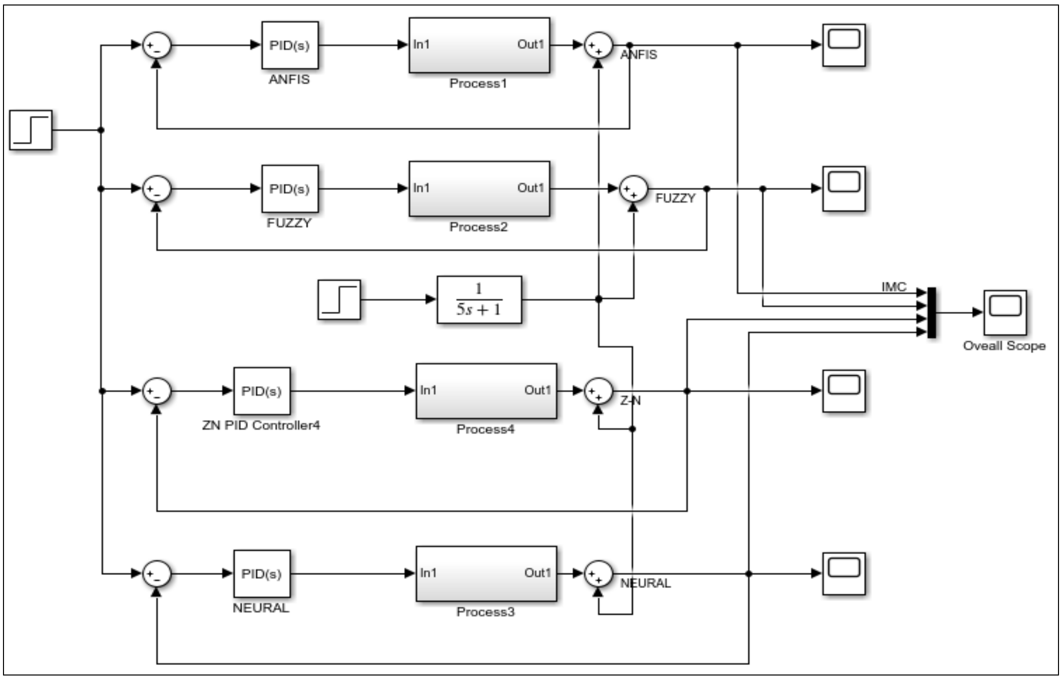


**Fig 2:** Simulink model for the response of PID controller comparing ANFIS tuning with FUZZY, ZN, and NEURAL.

Figure 2 above describes the Simulink model, which was done using Matlab 2021. Four algorithms (ANFIS, FUZZY, ZN-PID, and NEURAL NETWORK) were compared, and the transfer function was program in the process function.

### 3. Result and Discussion

Temperature control in neonates is crucial for maximizing productivity in Room Heating. The better the temperature regulation, the longer the Neonate will live. As a consequence, this study endeavor included neonate temperature control. The Neonate temperature was controlled in this study effort using a simple, adaptable, and adaptable hybrid Fuzzy-PID control system. The required temperature was set using the potentiometer, and the temperature sensor device's output signal was compared to the target temperature. The temperature sensor and the humidity sensor determine the Neonate's current temperature and relative humidity. The controller has been tasked with interpreting and simulating the sensor data streams. When the room temperature increased, the controlled signal activated the heater, and when the temperature decreased, the controlled signal activated the cooler. Consequently, the process achieved a preset fixed point in the shortest amount of time with the least amount of overshoot.

### 3.1 Disturbance Rejection

Starting at roughly 34 degrees, space was heated to a fixed point of 88 degrees or 44 degrees. During the heating phase, the cold chamber was placed in the center on the 500th iteration. ANFIS performed well in this area as well. Table 1 below shows the Disturbance Rejection

**Table 1:** Disturbance Rejection

| PID | 34.25 |
|---|---|
| NEURAL NETWORK | 45.21 |
| FUZZY | 60.27 |
| FUZZY-PID | 69.25 |
| NEURAL-PID | 62.89 |
| ANFIS | 78.91 |

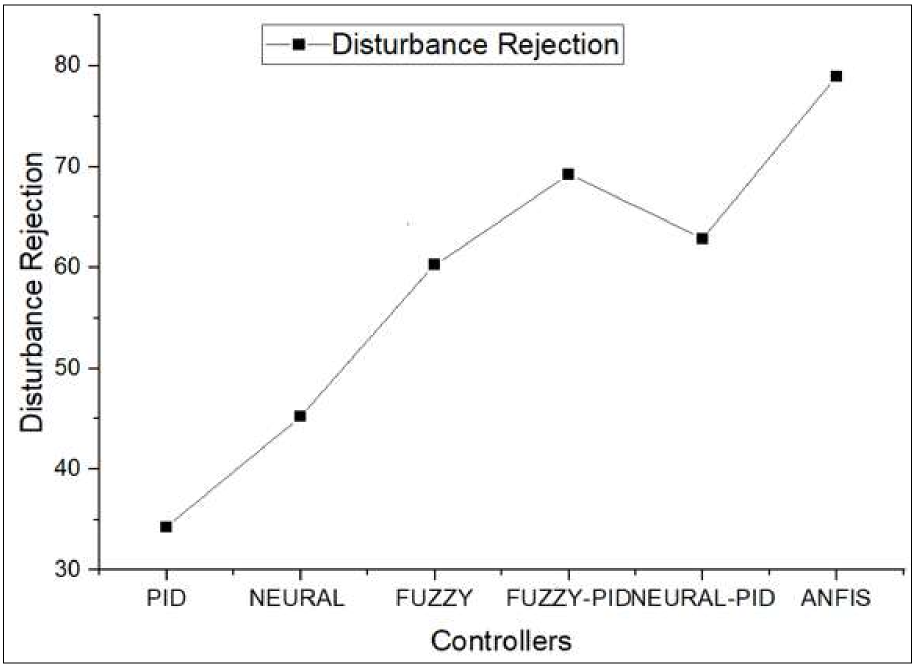


**Fig 3:** Disturbance Rejection

Figure 3 indicates that the ANFIS algorithm has the maximum disturbance rejection, which indicated that the ANFIS method is the best for controlling neonate temperature

**Table 2:** Comparison of Measured Disturbance

| Controllers | Mean Square Error | Setpoint Tracking | Disturbance Rejection |
|---|---|---|---|
| PID | 4.67 | 32.18 | 34.25 |
| Neural Network | 3.56 | 55.45 | 45.21 |
| Fuzzy | 2.89 | 72.67 | 60.27 |
| Fuzzy-PID | 2.01 | 91.54 | 69.25 |
| Neural-PID | 3.01 | 99.67 | 62.89 |
| ANFIS | 1.25 | 105.23 | 78.91 |

**Table 2** shows the comparison of the three-parameter metrics for the evaluation of the developed system. The three-parameter metrics are the experimental evaluation of the machine learning algorithm that was developed for the optimization of the findings

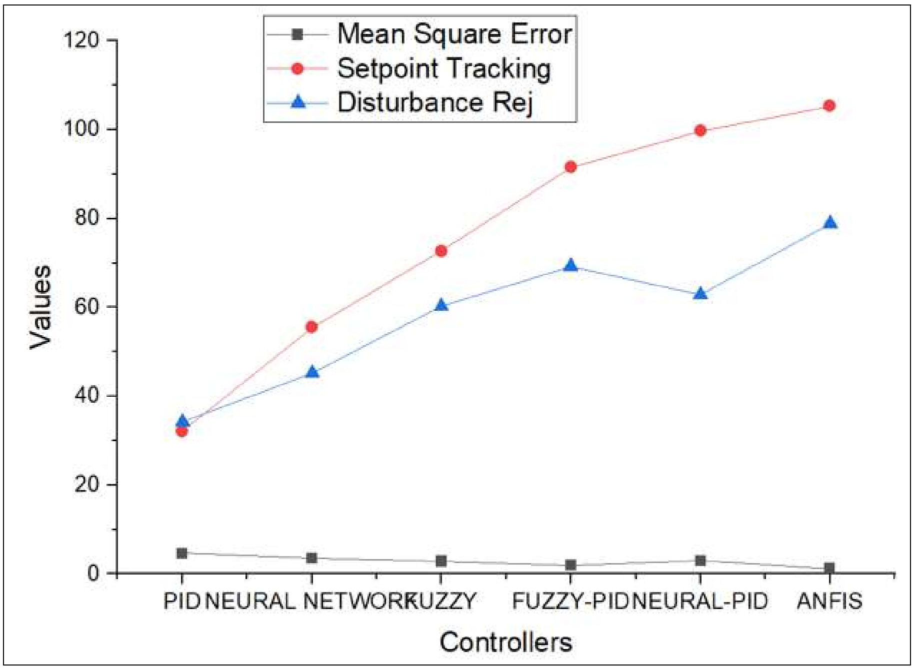


**Fig 4:** Comparative Analysis of Different Parameters

Figure 4 indicated that ANFIS has the minimum mean square error at 0 compared to existing algorithms from other research work. Also, ANFIS has the maximum setpoint tracking at 105, maximum disturbance rejection at 78 compared to other existing algorithms. This indicated that the objective was achieved.

## 4. Conclusion and Recommendation

This study contributes to the solution of the issue of inadequate neonatal temperature management. The results indicated that the ANFIS tuned PID controller step response crossed the steady-state level earlier than the other tuning methods at 2 seconds, reached stability earlier at 5 seconds, and produced the fastest rise time at 0.5 seconds, the fastest settling time at 1.7 seconds, and the lowest overshoot level at 1%. Additionally, it is recognized that the shorter the settling time, rising time, and overshoot, the quicker the system will respond and attain its intended aim. It is now established that the ANFIS-tuned PID controller provided optimal responsiveness and stability. As a result, it is stated that ANFIS is the superior approach of controller tuning among the four. The quickest rising time and settling time were obtained in the input disturbance rejection and output disturbance rejection modes, respectively, while maintaining an equal % overrun.

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