



# Intelligent Decision Support System for Home Automation - ANFIS Based Approach

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## Abstract

Internet of Things (IoT) deals with the idea of remotely multiplexing and monitoring real-world things via Internet. This idea can be incorporated at home appliances to make it smarter, safer and automated. This design focuses on constructing a smart, wireless home security system that gives alerts to the respective user through the Internet. This paper gives a smart decision support system to various home automation services using fuzzy logic. The proposed system is built on Adaptive Neuro-Fuzzy Inference System (ANFIS). It's a kind of artificial neural network that is used here for deciding on the changes taking place in the sensing unit. Through this simple method, various parameters such as temperature level, light intensity and human presence are monitored and controlled.

**Keywords** - Adaptive Neuro-Fuzzy Inference Systems (ANFISs), Intelligent Decision Support System (IDSS), Internet of Things (IoT), Home Automation, Artificial Neural Network

## 1. Introduction

Home automation is the instigation of technology within the home to intensify the quality of life for its dweller by providing various services such as healthcare, energy conservation, etc. With more advancement in the automation technology, life is becoming easier and smarter. Home automation focuses on managing digital devices for user's convenience enabling us to monitor and control multiple dwellings. Applications are vast in case of home automation since there are many parameters that can be monitored and controlled. On the other hand, the same design can be extended in various other fields like medicine, banks and industries in order to attain an efficient, low-cost design. Although it's highly efficient and cost-effective, the drawback with fuzzy is that they are not robust. Home automation provides a user-friendly interface along with web application services. The control operation is done using fuzzy logic which performs the decision making part. ANFIS is used here to perform a control operation for every change happening in the sensor unit. This design also focuses on monitoring the actions taking place at the house through a private web page. The functioning of ANFIS is very simple. The operation consists of 3 layers. The first layer is input layer. The second one is rule base layer where input works as per 'if-then' rule. The third layer is the output layer which produces an output based on the previous level using membership function.

## 2. Related work

This section reviews the related studies on various methods that have been implemented for home automation. In [1], smart home with the remote control system is designed based on Zigbee and embedded web technology to monitor as well as control the home applications remotely. The design meets the purpose of the intelligent, low cost and the portable one. It is safe, reliable and

stable. The drawback with this system is the distance and security. In [2], an intelligent design for event-triggered video recording concerning smart home applications by using PIR sensors along with wireless IP cameras that are used for recording the happenings in the home. The camera sends the actions taking place at targeted motion interval. The design is efficient one but requires security for the data and also an expensive one. In [3], a low-cost design for a smart home is implemented by deploying ATmega 32 along with REST-interface. ATmega is the main server to perform control actions. The communication with the client is done using REST interface. The motive of this design is to switch-off heater during winter and to turn it on the remaining days. The main advantage of using Representational State Transfer (REST) API is its size which is compatible with microcontrollers that have limited storage capacity. It is more reliable and scalable. Disadvantage of using REST API is that it can lose the ability to maintain its state within the sessions. In [4], an efficient and a simple home automation system is focussed where it uses an embedded web server along with IP connectivity to access and control devices using a mobile application developed for Android phones. The overall cost of implementation is very cheap and is accessible by an ordinary person. The issue with the mobile application is that others can also use the same application and control the actions of the respective home which leads to security issues. In [5], the design focuses on building a smart home to monitor home appliances and provides the result to the user through Short Message Service (SMS). There are two subsystems in this design : one for controlling Appliance and the other for ensuring security. Global System for Mobile Communications (GSM) is used for both the applications. Mobile phones communicate with GSM by radio waves. Advantages of this technique are the availability and ease of users. The system contains low-cost components easily available which cut down the overall system cost. But on the other hand, the drawback that is usually faced with GSM is that the delivery of SMS depends on the cellular network. In [6], mobile phone is used for communication purpose. It's designed to monitor the actions

happening in a home and the signals are transmitted through audio commands. The processor creates the audio commands and sends to the user’s mobile. The speech signal is passed through pre-amplifier for filtering it at sampling frequency. The signals are passed through an LPF to flatten the signals. This design is not bestin case of time-critical applications as message transfer time to the destination is variable. In [7], the system presents the design of a smart home using Bluetooth protocol. One of the most cost-effective and flexible method is adopting Bluetooth protocol. System has a Micro-controller-transducer interface by I2C bus and RS232 link between the micro-controller and the Bluetooth. The user is expected to acquire pairing password for the Arduino BT and the cell phone to access the home appliances. This adds a protection from unauthorized users. The error detection and correction facility is only handled at the Bluetooth level, though the design is easy to interface the main problem with Bluetooth is the range. In [8], a Java related home automation design is implemented that monitors the changes happening in a home and controls it through the web page designed. The design uses an off-the-shelf embedded system board which can monitor and as well as control the home appliances, user can enable remote control access to monitor and control the appliances from the web. The effectiveness of this design is a reliable one. Cost and complexity are the main issues here. In [9], the system uses the common e-mail service to communicate with the user about the actions taking place in the home. An e-mail is sent to the respective user along with the picture of the person standing at the gate. System uses image processing, embedded control and Internet of Things (IoT) into a single robust model. It’s an efficient method for secure operation. Drawback includes usage of multiple algorithms and the e-mail has to be checked by the user at frequent intervals. There is a chance of problem if the user fails to check e-mail frequently. In [10], both the monitoring and the control actions are done using FPGA and ARM cortex along with the support of web. Complete actions taking place inside the

house can be viewed and controlled on a single web page. Multiple houses can be connected over a single web page. The complete control actions of all the physical devices are done using ARM Cortex. The protocol designed for this system is AHB-lite (Advanced high performance bus-lite). Use of SOC provides high memory for the system. Flexibility is high when compared to other designs. The request-response between the FPGA and web is relatively high.

**3. Problem definition**

A lot of work has been implemented in home automation such as temperature control, water heating process, etc. Most of the applications were self-tuning. Present systems require more human support and intervention to make final decisions. To overcome this, we go for implementing automatic systems that can perform decision support using fuzzy logic. For control operations, ANFIS algorithm is employed with the help of appropriate MATLAB functions.

**4. A Neuro fuzzy-based decision-making strategy**

The Fuzzy Inference System (FIS) makes the task of an individual simple. Fig.1 shows the flow diagram of the decision making process in fuzzy; it incorporates the given input to a proper output. FIS is classified into three main sections namely a Fuzzifier, Knowledge base system and a Defuzzifier. The function of fuzzier is to map outside information into the fuzzy sets which converts it to crisp values. A knowledge base has the bunch of rules that replicate the reasoning of human experts and it is responsible for all the decision making parameters. Defuzzification is responsible for producing a quantifiable result in crisp logic.



Fig. 1: A fuzzy-based decision-making strategy

**4.1 Fuzzy Logic Control:**

The following steps have to be performed to construct fuzzy logic control system:

1. Determine and name all the inputs and specify its range
2. Identify all the outputs within this range and name them
3. Design partitions with fuzzy membership functions for every input and output
4. Build a fuzzy rule based on which the system should actually operate
5. Combine all the rules to determine the final output

Table 1 gives the threshold conditions based on which fuzzy decides the right control operation to be done. Threshold values are set based on the operating conditions, environment and the average value of the parameters.

Table 1: Fuzzification

ID	Feature	Range	Membership function
LM35	Temperature	≥ 80	Low(L), High(H)
LDR	Light Intensity	≤ 1000	Low(L), High(H)
PIR	Human Motion Detection	≥ 10	Low(L), High(H)
Switch	Authorized/ Unauthorized	-	On, Off

The decision-making operation determines how Fuzzy logic is performed. The rules are connected to perform the rule base. The description of each parameter of both the sensing and the control unit is shown in table 2.

**Table 2:** Description of every parameter

A/B, 1/2, C/D, 3/4, E/F, 5/6, G/H, 7/8			
A	Temperature High	1	FAN ON
B	Temperature Low	2	FAN OFF
C	Light Density High	3	LIGHT ON
D	Light Density low	4	LIGHT OFF
E	Control Switch ON	5	Control Switch ON
F	Control Switch OFF	6	Control Switch OFF
G	Detected	7	Person Entered
H	Not Detected	8	No Person Entered

The algorithm 1 which maps ‘X’ inputs with ‘Y’ outputs that have ‘XY’ rules with the form as below.

**4.2. Algorithm for Knowledge Base**

```

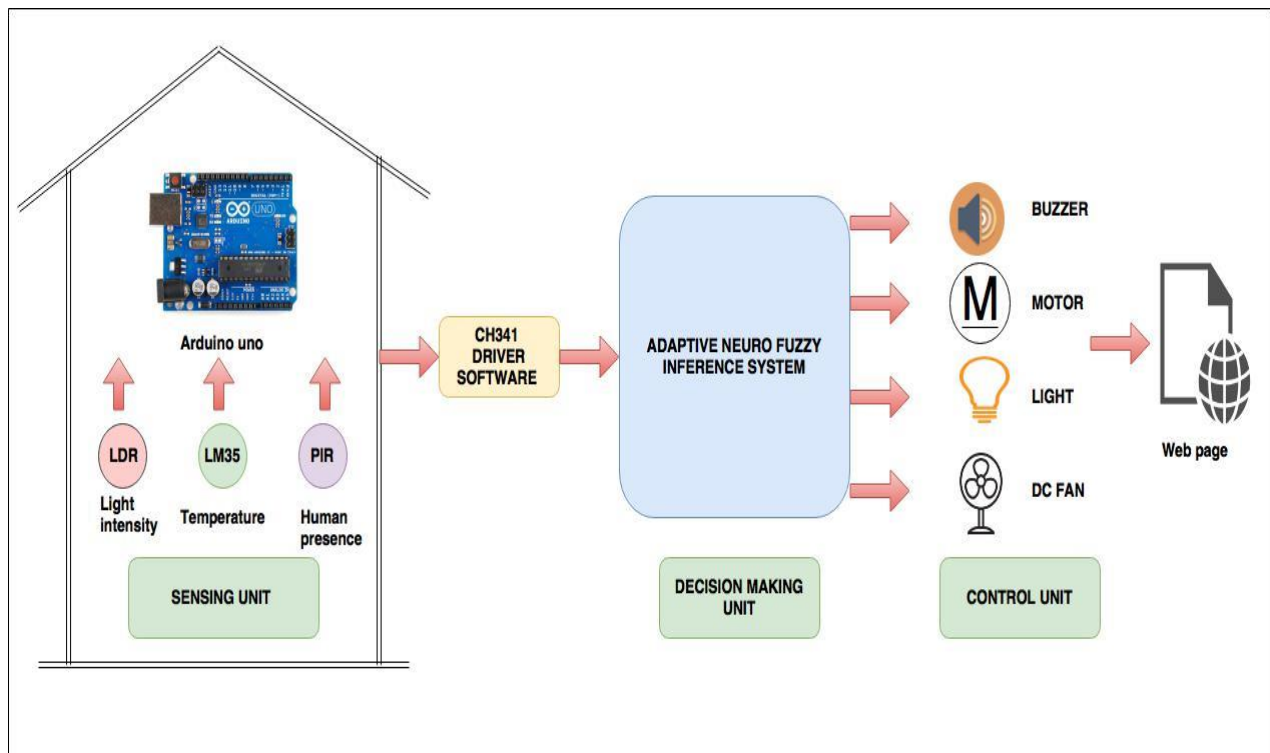
Input: X
Output: Y
Subsets: XY rules
if figs (1) = =1
    check whether X= A or B
    if A, Y=1
    else
    Y=2
    
```

```

end
if figs (2) = =1
    check whether X= C or D
    if C, Y=3
    else
    Y=4
end
if figs (3) = =1
    check whether X= E or F
    if E, Y=5
    else
    Y=6
end
if figs (4) = =1
    check whether X= G or H
    if G, Y=7
    else
    Y=8
end
else
return (“NNNN”)
    
```

**5. Proposed system and architecture**

To address the above-mentioned challenges, an automated smart home is designed in this paper at a low cost. It’s an efficient home monitoring and controlling design using ANFIS based system shown in fig. 2. It is divided into sensing unit, decision-making unit, and control unit.



**Fig. 2:** Overview of proposed system and architecture

**Sensing unit:** It’s a distributed home automation system that consists of sensors connected with Arduino board. The system monitors parameters like temperature level, light intensity and human presence using LM35, LDR and PIR sensor.

**Decision-making unit:** It is responsible for performing the right decision for making the control operation concerning every change taking place in the house. Table 3 gives the control operation for every change taking place in with the sensing unit, based on which the control operation takes place. This is done by

adopting ANFIS algorithm to perform the decision-making operation as per which the changes take place in the hardware.

**Table 3:** Fuzzy rules for control operations

SENSORS	DATA ACQUIRED	CONTROL OPERATION
PIR	Unauthorized Person	Red led, and the buzzer is high
	Authorized Person	Green led, and themotor is high
LDR	Light Intensity high	Power led is high
	Light Intensity low	Power led is low
LM35	Hot	DC fan is high
	Low	DC fan is low

**Control unit:** It performs all the control operations concerning every changes happening in the sensing unit. Once the temperature increases more than the threshold level, the Direct current (DC) fan gets on automatically, controlling the heat in the house. Similarly when the light intensity is low the power led must be on and should come back to off state when the intensity is high. In case of PIR, the operation is divided into 2 states. (a) Authorized person detected-green led, and the motor is high (b) unauthorized person-red led and the buzzer is high. A switch is connected which acts as an interface to determine if the person entered is authorized or an unauthorized one. All these control operations is achieved through ANFIS using MATLAB functions.

Additionally, a private web page is designed where the user can view all the happenings that are taking place at the respective house. The web page can be accessed only if the person knows its user id and password. The web page supports two kinds of view, mobile view and detailed summary view that provides all the information including date and time.

## 6. Results and discussion

Here we present the results of the proposed model. The design was performed using MATLAB (R2017b) with available libraries along with Arduino. Fig.3 gives the results of the changes in LDR where, power led is on when the intensity of light is high. Fig.4. Shows the results of LM35, where the DC fan is in high state at high temperature. Since the control operation of PIR sensor is an audio based signal the results are not added here. On the other hand, the value found in error histogram, performance metric, results of the experiments in hardware proofs to show the effectiveness of the design. The accuracy level attained by ANFIS has good performance obtaining the classifier error of 0.1112% (shown in fig.5) with y-axis pointing the instances and x-axis pointing the error value produced. The performance is measured by Mean Square Error (MSE) at y-axis with the epochs at x-axis, the obtained performance is approximately 50.2649 (shown in fig. 6).The evaluation time of the proposed model was relatively low. Membership function determines the output (shown in fig.7) where the input range is given in x-axis with its gradient value at y-axis. Training state of the design is shown in fig.8. The results of the web server part where the user can monitor the actions taking place at the respective house is in fig. 9.

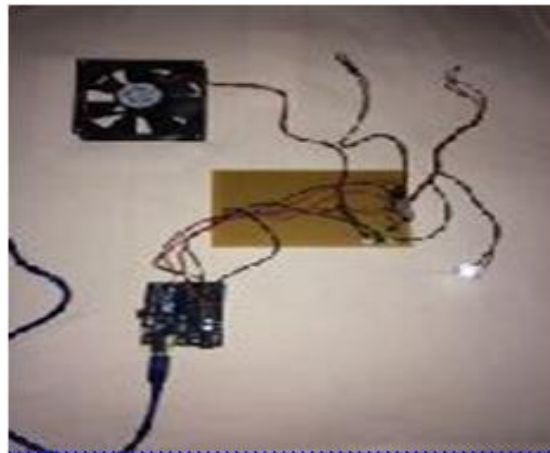
**Fig. 3:** Results of LDR sensor**Fig. 4:** Results of LM35 sensor



Fig. 5: Error histogram

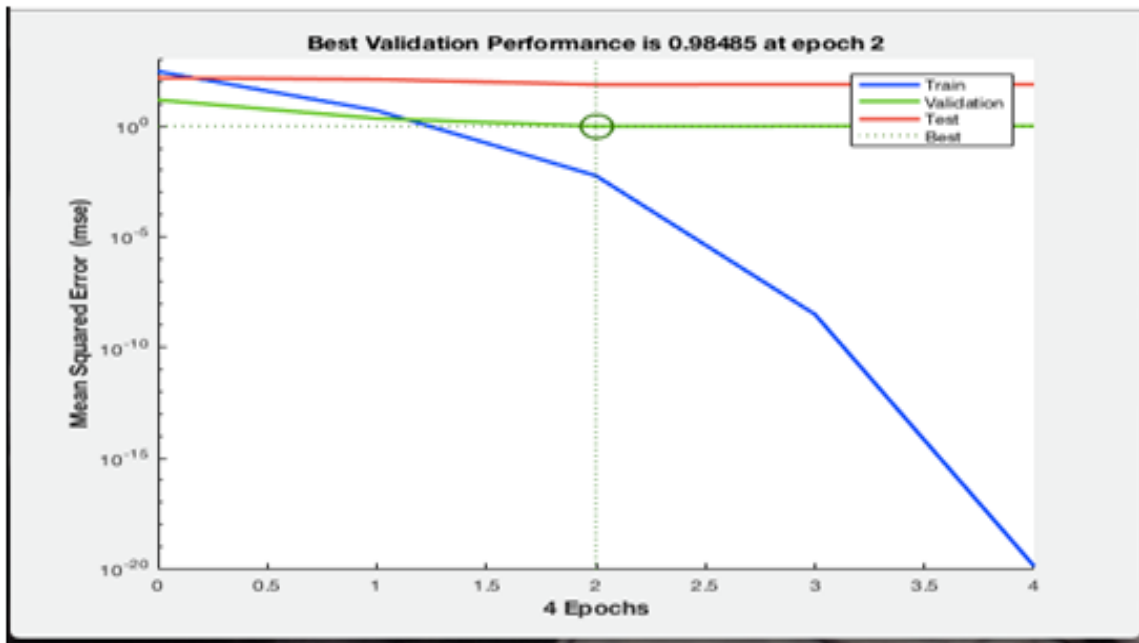


Fig. 6: Performance metric

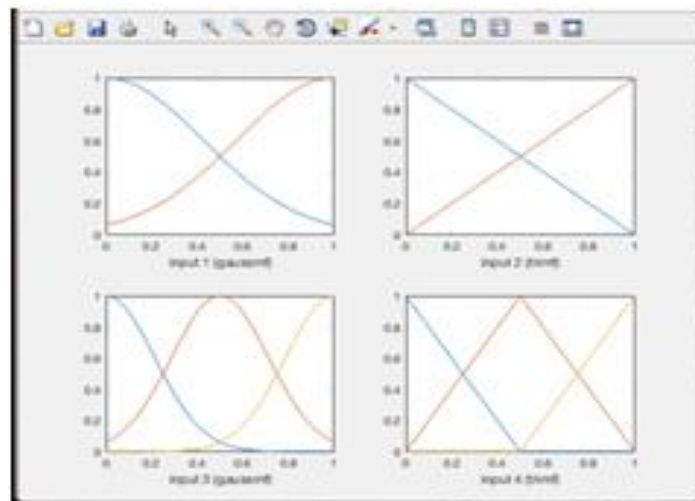


Fig. 7: Membership functions

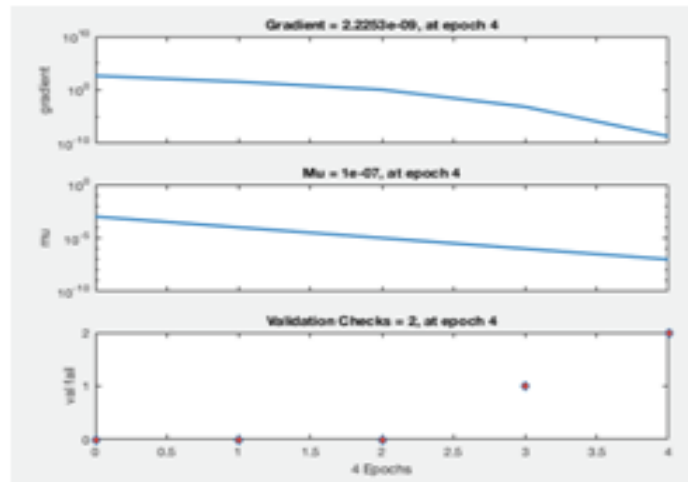


Fig. 8: Training state

## View IOT Server Data

Date Time	Temperature	Fan Status	Light Density	LDR Load Status	Control Switch	Switch Condition	PIR	PIR Status
13-Jan-2018 08:54:50 AM	Temperature Low	Fan OFF	Light Density Low	Light OFF	Switch Low	Control Switch OFF	Person Not Detected	No Person Entered
13-Jan-2018 08:48:53 AM	Temperature Low	Fan OFF	Light Density Low	Light OFF	Switch Low	Control Switch OFF	Person Not Detected	No Person Entered
13-Jan-2018 08:45:49 AM	Temperature Low	Fan OFF	Light Density Low	Light OFF	Switch High	Control Switch ON	Person Detected	Person Entered
13-Jan-2018 08:43:24 AM	Temperature High	Fan ON	Light Density High	Light ON	Switch High	Control Switch ON	Person Detected	Person Entered
13-Jan-2018 08:42:25 AM	Temperature High	Fan ON	Light Density High	Light ON	Switch High	Control Switch ON	Person Detected	Person Entered
13-Jan-2018 08:40:48 AM	Temperature Low	Fan OFF	Light Density High	Light ON	Switch High	Control Switch ON	Person Detected	Person Entered
13-Jan-2018 08:39:05 AM	Temperature High	Fan ON	Light Density Low	Light OFF	Switch Low	Control Switch OFF	Person Not Detected	No Person Entered
13-Jan-2018 08:27:21 AM	Temperature Low	Fan OFF	Light Density High	Light ON	Switch High	Control Switch ON	Person Detected	Person Entered
13-Jan-2018 07:55:21 AM	Temperature High	Fan ON	Light Density High	Light ON	Switch Low	Control Switch ON	Person Not Detected	No Person Entered

Fig. 9: Detailed summary

### 7. Conclusion and future work:

This project deals with an innovative Intelligent Decision Support System (IDSS) which adopts an ANFIS based Neuro-fuzzy approach. The system is based on feed forward network type with Gaussian membership functions. It provides a framework for all home automation services. The results validate the efficiency and high accuracy of decision support. The future research will be focused on improving the robustness of decision-making algorithms.

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