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A CONTEMPORARY ADAPTIVE NEURO-FUZZY INFERENCE FIRE WARNING SYSTEM FOR PHYSICALLY CHALLENGED PERSONS USING IoT

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Abstract: Many fire warning and alarm systems have been proposed based on a combination of a smoke sensor and an alarm device to design a life-safety system by various author. However, such fire alarm systems are sometimes error-prone and can react to non-actual indicators of fire presence classified as false warnings. There is a need for high-quality and intelligent fire alarm systems that use multiple sensor values (such as a signal from a flame detector, humidity, heat, and smoke sensors, etc.) to detect true incidents of fire. An Adaptive neuro-fuzzy Inference System (ACNFIS) is used in this paper to calculate the maximum likelihood of the true presence of fire and generate fire alert. The novel idea proposed in this paper is to use ACNFIS for the identification of a true fire incident by using change rate of smoke, the change rate of temperature, and humidity in the presence of fire. The model consists of sensors to collect vital data from sensor nodes where Fuzzy logic converts the raw data in a linguistic variable which is trained in ACNFIS to get the probability of fire occurrence. The proposed idea also generates alerts with a message sent directly to the user's smartphone. Our system uses small size, cost-effective sensors and ensures that this solution is reproducible. MATLAB-based simulation is used for the experiments and the results show a satisfactory output which focused on disabled persons.

Index Terms – Fuzzy logic, ACNFS, Sensors, Fire warning

I. INTRODUCTION

Fire and smoke kill more people every year than many other forces. While controlled fire serves us in so many instances, uncontrolled fire can be of harm, however, the rapid detection of fire and its control can save lives and property damage worth millions. Conventional and addressable are two main types of fire alarm systems, but unfortunately, these fire alarm systems often generate false alarms. The ratio of false alarm is higher in conventional alarm systems compared to addressable, but addressable alarm fire systems are more expensive. The most likely cause of a false warning is different for distinct types of detection systems, such as a smoke sensor often being activated falsely due to an environmental effect. So, there is a need for a cost-effective multi-sensors expert alarm system that is artificially trained and assists FDWS (fire detection and warning system) to make the right decisions and to reduce the number of false alarms. False alarm warnings are so common that London fire brigade alone is called out almost every 10 min to attend a false alarm causing them a loss of about £37 million per year. To achieve the aforementioned goal, in this paper, we introduced a home-based FDMS that uses a microcontroller Arduino UNO R3 (Arduino, Somerville, TX, USA) based on the atmega328p. It is easily available and programmed using the Arduino Software (IDE) with a set of cost-effective sensors. The proposed solution effectively uses a smoke sensor with flame sensors with a particular increase in room temperature; to further investigate the true presence of fire and to avoid false alarm, the FDWS is trained with a neuro-fuzzy designer. The purpose of this intelligent fire alarm system is to sense true occurrences of fire, alert the proper authorities, and notify the occupants via GSM to take necessary action immediately. A false alarm can burden the fire brigade and can turn out to be a costly event; so many studies conducted to reduce them. Previous studies proposed different methods such as autonomous firefighting robots, fire alarm systems with notification appliances, and wireless warning systems. Fire alarm systems with notification appliances can be costly because they use visible and audible stimuli to notify residents. The primary objective of this paper is to develop a reproducible and economical solution with minimum false alarms and a system that alerts via GSM (global system for mobile communication). The innovative idea is to use neuro-fuzzy logic to design a smart alarm system. Our proposed system is ACNFIS-simulated in MATLAB environment; the obtained results show effectiveness and the robustness with good performances compared with the FIS method (in Section 3). The ACNFIS idea was originally proposed by Jang [1] in 1993. Typically, an ACDNFIS is a combination of a neural network and a fuzzy inference system (FIS) and is effective in making decisions.

II. RELATED WORK

This section discusses different AI techniques and other fire detection methods used in the past to mitigate risks of fire by early detection and reduce false warnings, but our main focus is ACNFIS technology. Efforts were made for early fire detection and risk mitigation. Diverse technologies developed by researchers have been used such as fuzzy logic, neural networks, video-based techniques, Image Processing color-based fire detection methods, etc. Early Fire detection always has been an important research Topic for researchers.

The idea of using multiple sensors was proposed by Faisal et al. [2]. The proposed wireless sensor network (WSN) consists of different sensors that share a single wireless network and used GSM. The proposed system results were tested in a smart home to reduce false warnings. Elias et al. also provided a solution using wireless sensor network that was embedded in a micro-controller board for fire hazard detection and fire monitoring purpose [3].

Hamdy et al. Built a “Smart Forest Fire Early Detection Sensory System (SFFEDSS)”, by combining the wireless sensor networks and artificial neural networks for the detection of forest fire [4].

Yu et al. [5] collected the sensor readings for smoke intensity, humidity, temperature to use it in fire detection using Feed-forward neural network approach. The disadvantage of a Feed-forward approach is it demands high processing at the node level resulting in a large amount of power consumption which reduces the lifespan of the node. Also, cluster head destruction in the fire badly affects the robustness of the system.

III.MATERIALS AND METHODS

3.1. Adaptive Neuro-Fuzzy Inference System (ANFIS) Architecture

For generating an intelligent fire detection system that can monitor the parameters required for the actual presence of fire so that a false alarm can be decreased up to a minimum level, a combination of two important technologies fuzzy logic and artificial neural network (Ann) called the adaptive neural fuzzy interface system (ACNFIS) can logically generate fuzzy rules according to training data to make the system robust. A fire detection system is developed using this aforementioned technology and presented in this paper to find the probability of fire. The ANFIS neural network works until the output matches the desired value for the given input. So, considering these abilities, an adaptive neuro-fuzzy interference system is used for detection of fire. ANFIS is a five-layer architecture that was developed in the early 1990s. The first layer is called the input layer. The second layer of ACNFIS, called inputmf, is a fixed input membership function layer. The third layer depicts norms. The fourth layer, outputmf, is a fixed output membership function layer and the last is the output.

The basic block diagram of ANFIS with input and output is illustrated in Figure 1. Figure 1 contains different units of the ACNFIS system. Input collected from sensors is trained in various steps. In the first step of fuzzification, raw data is collected, and the fuzzy interface system creates different rules artificially. The created rules are then further trained using the Sugeno method in MATLAB with the help of the artificial neuro-network. In the last step of de-fuzzification, the fuzzified data are again converted into raw variables.

The main goal of this entire process is to minimize human effort and overcome manual errors. There is a need to prioritize the actual parameters of fire so that false alarms could be reduced. To solve this particular problem, a fire monitoring system should be developed to monitor these parameters in real-time and quick action should be taken to reduce fire damage and save human life.

The proposed based adaptive neuro-fuzzy interference system decides the presence of fire according to fuzzy rules and vital parameters collected from different sensors.

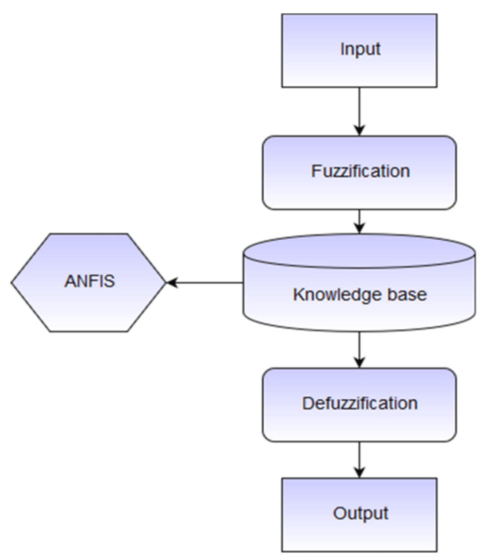

Figure 1. Overall Architecture of Proposed System

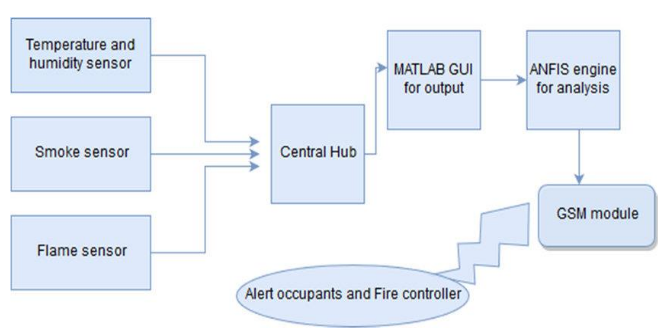

Figure 2. Architecture of Proposed Fire Warning System

The architecture of the proposed fire detection and warning system is illustrated in Figure 3.2. The combination of software and hardware together create an automatic fire detection system.

The system has different sensors such as a smoke sensor, temperature and humidity sensor, and a flame sensor. These sensors collect data from sensor nodes and then transmit it to the GUI in MATLAB.

The data gathered from sensors is then provided as a raw data to fuzzy logic as a linguistic variable which is trained in adaptive neuro-fuzzy system to detect fire status. If the parameters show that the probability of fire is critical, then a message will be sent through GSM regarding the fire condition to the fire controllers and the house owner.The whole system consists of two phases. The first phase of the hardware design includes the development of sensor nodes and the other phase consists of a MATLAB simulation. Both phases are further described in detail.

3.2 Hardware Development in Proposed System

In this phase, we designed sensor nodes for fire monitoring employing multi-sensors such as temperature, humidity, smoke, and flame. An Arduino UNO atmega328p micro-controller is used to embed the sensors. For gathering heat and humidity measurements, DHT22 is used which gives us two important measurements required for a smart fire monitoring system. It gives an output in degrees Celsius for temperature and percentage of humidity.

Figure 3. Humidity Sensor

The used flame sensor detects the flame at the range of 3 feet and at a 60 degree angle. The LED light shows the presence of fire.

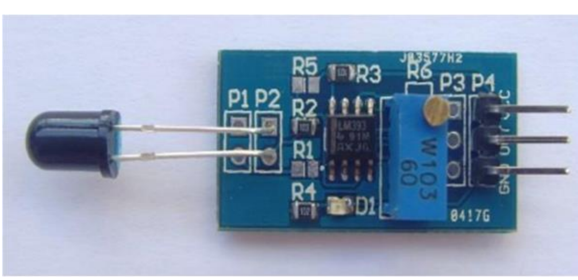

Figure 4. Fire Sensor

The MQ-7 Gas Sensor is used for the proposed system which is sensitive to carbon monoxide. Carbon monoxide results in a burning process. Its output boots with the concentration of CO level. It Can detect CO anywhere from 20 to 2000 ppm.

Figure 5. MQ-3 Sensor

All these sensors are attached to the Arduino UNO ATmega328p board.

3.3 Coding in Arduino IDE

Arduino version 1.8.9 is used to program the hardware configuration of sensors. Coding is done in C language and built in libraries like dht.h for temperature and humidity sensor and MQ7.h for the gas sensor is used. The downloaded code is customized a little bit to get the desired results.

The Arduino UNO is a simple way of communication between computer and microcontroller. The AT MEGA328p connects the UNO serial port, e.g., COM3 with the computer USB port which appears as a virtual COM in the PLX-DAQ. It is simple to use and just need to define connection settings to connect it with an Arduino. The embedded program code in the Arduino UNO board acquires sensor readings and represents it in the PLX-DAQ spreadsheet.

IV.ACNFIS IMPLEMENTATION FOR PROPOSED FDWS

The normal people can easily escaped from the fire accident but physically challenged people can’t be able to move from the situation so we implement this project for physically challenged people It is implemented using the components MQ-2 sensor, Fire sensor Buzzer and GSM module. All components are interfaced with the UNO board and works by automation as per uploaded code. When fire is detected within the deployed area, the notification regarding the fire accident will be send to our mobile , with the specifications of the accident location will be send to the fire station along with the alarm buzzing, alerting the physically challenged people around.

With this system, we can overcome the problem which is in the existing system. The fire sensors are deployed in small black box around the space to be monitored. If any fire is detected by the sensor, it sends the information to the GSM module. We have designed the code in such a way that whenever the fire is detected by the sensor the alarm rings, a notification will be sent to the firestation. GSM module is used for sending the notification to the near fire station.

Jang (1993) was the father of ACNFIS which was based on the Sugeno fuzzy logic model. Generally, ANFIS combines the least square estimation and back-propagation for membership function measurements. The integration of fuzzy logic with neural networks increases the learning ability of neural network and fuzzy system.

Each generated rule is a linear combination of inputs and a constant term. The final output is calculated by weighing the output of each rule. Rules should not be more than output member functions. The proposed system has four inputs, but for simplicity purposes, two inputs x and y and one output z are used. The rules based on the Sugeno if-then rules are as follows:

Rule 1: If x is a1 and y is b1,
then f1 = p1A + q1B + r1 (1)
Rule 2: If x is a2 and y is b2,
then f2 = p2A + q2B + r2 (2)

The ANFIS structure model is has five layers. The input layer called layer 0 is not part of the five layers. The presented system has four inputs (CR-temperature, CR-humidity, Time (the rate at which input changes), and CR-smoke).

V.CONCLUSION AND FUTURE WORK

This paper proposed an intelligent and smart fire warning system in buildings for disabled persons. This system not only analyses the fire presence, but also notifies the concerned people for severe fire chances in case of an emergency or critical situation. ACNFIS architecture model makes the proposed system more efficient, robust and reliable; and reduces false alarms; the proposed system used easily available, lightweight and cost-effective sensors and is more reliable than conventional fire detection systems. This system can be used at the commercial level and results are reproducible. Further advancement in the proposed system can be achieved by researching more into precise and lightweight sensors that provide more accurate signals for analysis.

Furthermore, the use of IoT (Internet-of-things) can enhance the system by talking with various other devices and smart systems like sending the message to smart gas meters to stop the supply of gas in critical conditions, etc. This system is particularly designed for indoors, as the flame sensor is sensitive to sunlight and, secondly, the reading and training data may differ in open areas, but the minor change in training can overcome this problem.

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