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Analysis of Automatic Fire Classification and Extinguish System using Embedded based Neural Network

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Abstract

This study discusses the development of a fire fighting system that is capable of detecting fire in its early stage and also of classifying the fire based on the smell of the smoke in the environment. Arrays of sensors along with a neural network are used. The model of the Artificial Neural Network (ANN) is implemented in a general purpose microcontroller. The result is a low cost intelligent embedded fire classifier that can be used in real life situations for fire hazards minimization. This intelligent fire classifier can be used for the development of a smart extinguisher that detects the fire, classifies it and then uses appropriate extinguishing material required for extinguishing the class of fire. The response of the proposed system takes about 17 seconds including the training time to detect class A comparing to 24 seconds for detecting class B.

Keywords: *Embedded Neural Network, Fire Classification, Gas Detectors, Neural Network Training and Fire Extinguishing.*

1. Introduction

Fire is one of the most dangerous threats that may take place in various environments. The easiest way to detect a fire at residential places is using the proper detectors, which are usually sensitive to ionization or obscuration [4]. The problem with such detectors is that they may make false alarms. This means that in noisy conditions, such as burning a normal material, a fire alarm may be generated wrongly. The inability discriminate between sources is a significant limitation. Data from U.S. fire incidents during the 1980Is indicates that 95% of all alarms from smoke detectors were unnecessary [4].

According to its class, fire can be extinguished by water, fuel removal, or chemical flame inhibition. Fires are sometimes categorized as "one alarm", "all hands", "two alarm", "three alarm" (or higher) fires. There is no standard definition for what this means quantifiable though it always refers to the level response by the local authorities. In some cities, the numeric rating refers to the number of fire stations that have been summoned to the fire. In others, the number counts the number of "dispatches" for additional personnel and equipment [1]

One solution proposed for minimizing unnecessary alarms without sacrificing prompt activation involves using intelligence along with current detector technology. Some recently developed intelligent detectors provide a step in this direction where a correction can be made for background noise, ambient conditions or changes in detector sensitivity.

Generally, to reduce false alarms and perform fire detection accurately, two approaches are used [8]. The first approach uses one type of sensor and conducts the fire detection by a complex algorithm. In contrast, the second approach uses multiple sensors and performs the detection by a simple mathematical operation. The work presented in [7] is an example of the second approach, which uses CO and ionization (ION) sensors and a simple mathematic operation. Some researchers also tried to combine both approaches by using multiple sensors and an appropriate algorithm. The use of Artificial Neural Network is very promising in this field. In recent studies, which uses a feed forward neural network (FFNN) and Three sensors, i.e., temperature, MQ-3and MQ-5, and their rising rates to discriminate fires from nuisance sources. This work is focused about the classification fire sources and activates the proper extinguisher using Arduino based system. The Neural Network is trained to estimate the fire types. The proposed system is a monitoring and control system. The monitoring process is implemented using three types of sensors. According to the sensed parameters the system will estimate the source of fire and initiate the control functions to sustain the fire using corresponding extinguisher. The neural system is trained using three types of sensors value; the modified weighted values will be stored in the Arduino. In monitoring process, the embedded system will predict the fire and determine its types using values from Gas and Temperature Sensors, which are deployed in the field and also responsible to control the fire by activate the respective extinguisher.

2. Fire Classification and Extinguish

Fires are classified by the types of fuel they burn. As follow [4]

Class A: Ordinary, combustible materials i.e. wood, cloth, paper, some rubber and plastic materials.

Class B: includes: Flammable liquids, gases, greases, and some rubber and plastic materials.

Class C: Live electrical equipment, when equipment is reenergized, extinguishers for class A or B fires could be used safely; however, in fighting an electrical fire there are two important things to be taken into consideration: namely (a) damage to the equipment far beyond what the fire could do, and (b) danger to the individuals fighting the fire. To avoid these two possibilities, de energize the circuit and use only the types of extinguishment recommended for class C fires.

Class D: Combustible metals such as magnesium, titanium, sodium, potassium, lithium, and zirconium. The International Maritime Organization (IMO) mentions two standards in IMO Resolution A. 602(15) which define the various classes of fires. The first is the International Standards Organization (ISO) Standard 3941, and the second is the National Fire Protection Agency (NFPA).

3. Overview of Artificial Neural Networks (ANN)

Work on artificial neural networks, commonly referred to as “Neural Networks “has been motivated right from its inception by the recognition that human brain computes in an entirely different way from the conventional digital computer. An artificial neural network, which is the formal name for the term neural networks used here, is one of many attempts to build an intelligent machine or to create artificial intelligence. It is based on biological neural networks. The basic idea to model this is to make a very simplified model of biological neurons and their synapses. [6]

Artificial Neural Network (ANN) is a part and parcel of intelligent based systems, designed distinctively to improve the performance of conventional computing techniques [3]. The biggest drawback associated with the so called conventional methods is the inability to learn and identify patterns in dynamic systems. Thus the need to eliminate this shortcoming through learning is proven essential [5]. A simplified model for the neural network is shown below:

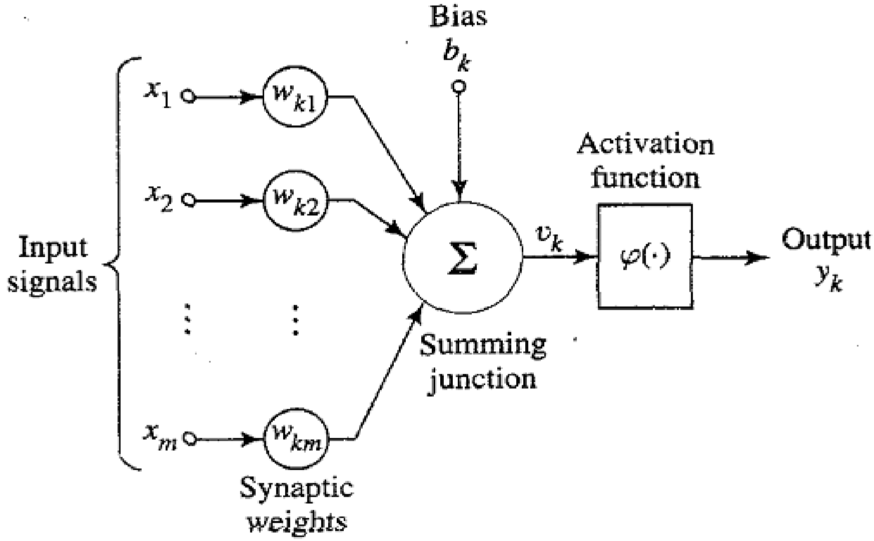

Figure 1: Neural Network Model [6]

In mathematical terms we may describe a neuron k by writing the following pair of equations:

$$u_k = \sum_{j=1}^{m} w_{kj} x_j \tag{1}$$

and

$$y_k = \varphi(u_k + b_k) \tag{2}$$

Where

$x_1, x_2, \ldots, x_m$ are the input signals.

$w_{k1,} w_{k2}, \ldots, w_{km}$ are the synaptic weights of the neuron k.

u_k is the linear combiner output due to input signals.

u_k is the bias.

$\varphi(.)$ is the activation function.

y_k is the output signal of the neuron.

4. Methodology

The sensors response (voltage) which used to train the neural network is shown in the Figures (2and3). This characteristic confirms the non-linear features of the response.

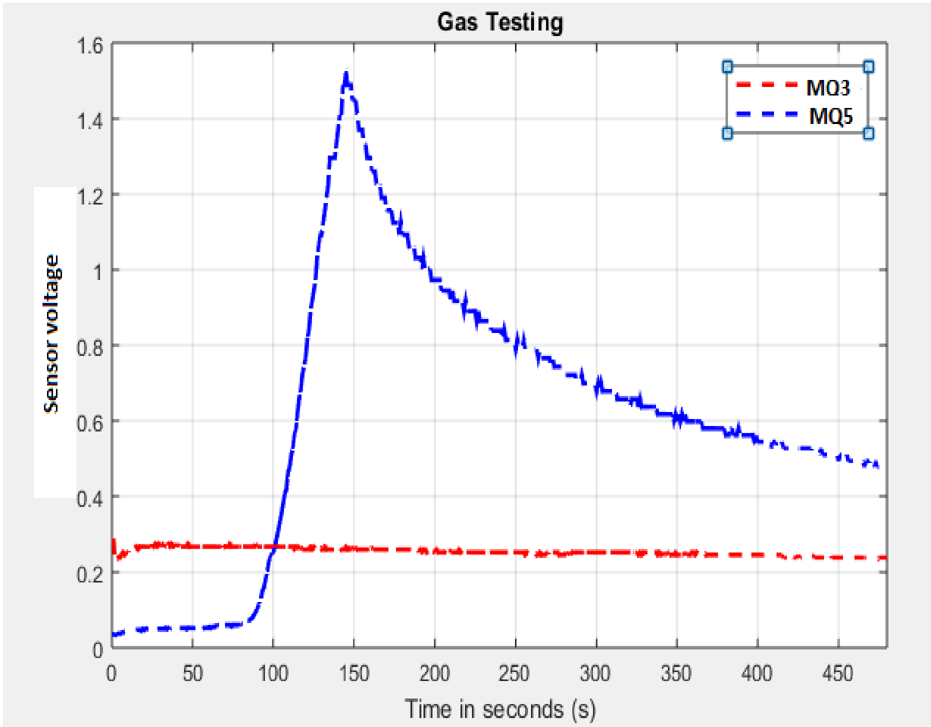

Figure 2: Sensor Testing Graph for MQ-3 and MQ-5 for LPG [2]

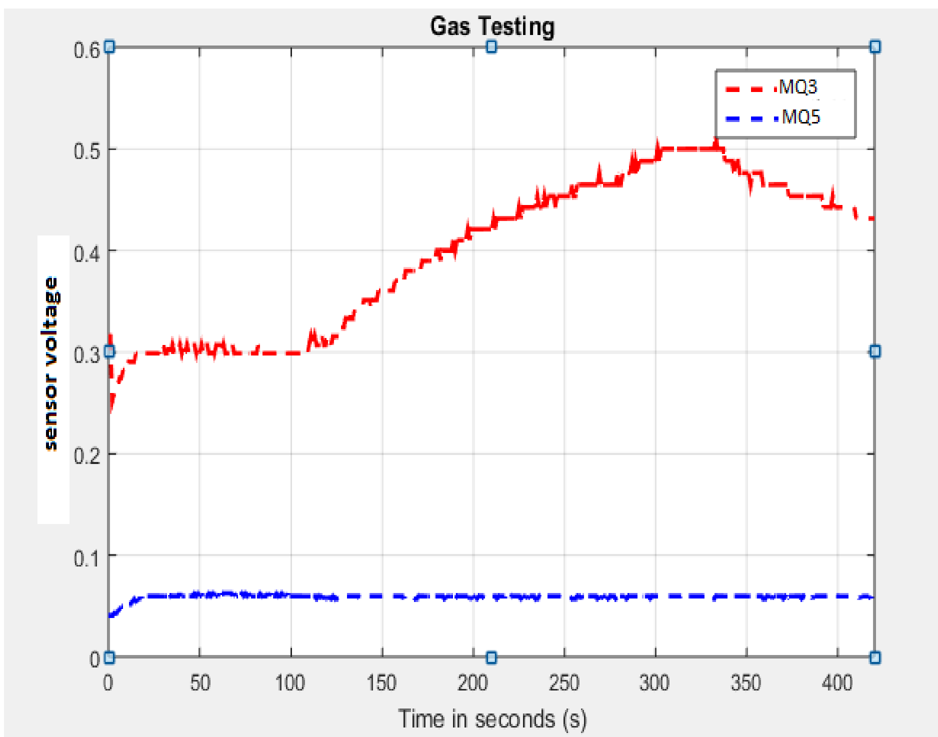

Figure 3: Sensor Testing Graph for MQ-3 and MQ-5 for Paper [2]

Methodology is separated into two parts. The first part is the hardware implementation. The hardware implementation involves three types of sensor namely: temperature sensor, MQ-3 and MQ-5. Arduino is the microcontroller used with the sensor in this project. The second part of the methodology is the software implementation which is the data analysis to display the class of the gases detected using arduino. Figure (4) shows the project block diagram representation.

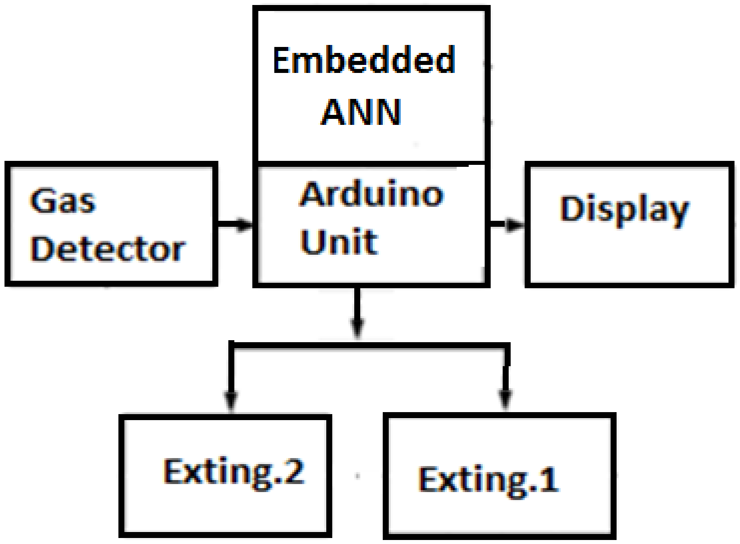

Figure 4: Block Diagram of the Proposed System

The scope of this project is to classify fire type according to NFPA. Therefore, gas sensor MQ-3 and MQ-5 are chosen based on the specification of gas detection. Other than that, LM-38 temperature sensor is used. For both gas sensors to operate The proposed ANN model is a two layers feed-forward ANN, has 7 inputs, one hidden layer with 8 neurons, and 4 neurons in the output layer, with tan-sigmoid activation function in the hidden layer, and linear function in the output layer. Figure (5) illustrate the flow chart of the project.

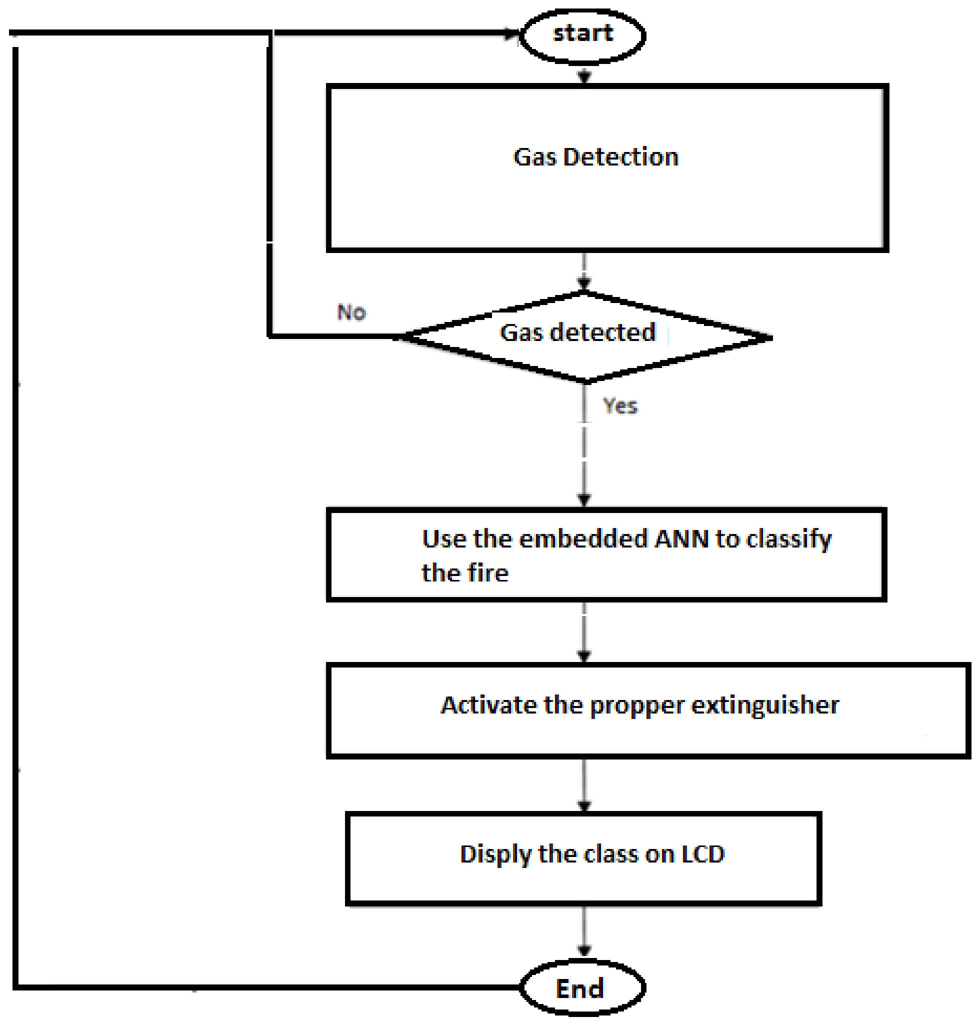

Figure 5: Flow Chart for Development of a Supervised ANN-based Model to Classify the Fire Type

The software implementation involves the using of ANN and Arduino. The combination of ANN and Arduino is able to produce a real-time classifier and display system. The input-output schematic for Fire classification model is shown in Figure (6).

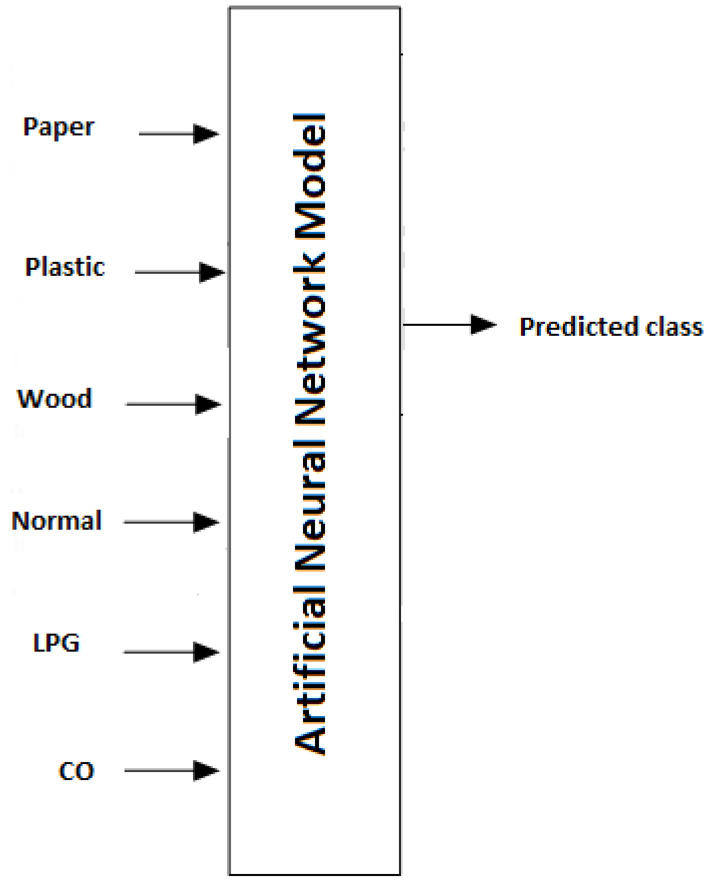

Figure 6: Input-Output Schematic for Fire Classification Model

The inputs given are: Normalized readings of gas sensors for different materials, and the outputs obtained were the predicted class of fire according to NFPA. The data set consists of 3 samples of gas sensor readings. "Input mat" is the input matrix; it is a (n×3) matrix, “target mat” is a (nx1) matrix represents class of fire, where (n) is the number of materials used to train the system.

5. Results

The network parameters for the model are given in Table (1). The network comprises 8 hidden layer neurons and 1 output neuron. For activations, a tan sigmoid transfer function was used for the hidden layer. Both momentum factor and learning rate were held constant throughout the training at 0.9 and 0.3 respectively.

Table 1: Network Topology for the Total Load Models

Network	Hidden layer	Hidden neurons	Transfer function	Momentum factor	Learning rate	Training algorithm
Feed forward	1	8	Tan sigmoid,	0.9	0.3	Back propagation

The results obtained from testing the trained neural network on new data for sensor readings are presented below in table form. Three materials are chosen randomly for testing the model. The models discussed in this study were subsequently trained under Arduino 1.6.12 environment using Neural Network equations, the presents results emerged from this model.

Table 2: System Tests

Material Type	Number of Tests	Correct Class	Predict Class	Success %	Average Response time (Training time + testing time)
Paper	9	A	A	100%	17 sec
Plastic	9	A	A	100%	20 sec
Wood	9	A	A	100%	18 sec
Normal	9	-	-	100%	12 sec
LPG	9	B	B	100%	24 sec

6. Discussion

The model was able to fit the class of the fire correctly as it appears from the table above, in addition the system was able to activate the proper extinguisher. The system has been tested for two classes, however by increasing number of detectors it will be able to classify more types.

7. Conclusion

This work presents a solution for neural networks across many types of Fire production system. Which clearly shows that fire classification and extinguishes can be achieved by using embedded based artificial neural network tool along with the general purpose gas and temperature sensors. Moreover, the memory limitation of the neural network can be minimized enough to fit in a limited memory space of a low cost microcontroller. The approach results a versatile intelligent fire classification and extinguishes system at a much lower price and thus can be used in real life situations to minimize fire hazards.

The proposed system claims a good response in detection material included in class A like paper and wood, the response time include training time and detection time.

8. Future Work

While finishing this project many challenges faced regarding the gas sensor implementation especially the MQ3 sensor. This is because MQ3 sensor is not a specific LPG sensor. For future project, a specific and better quality of LPG sensor should be use. Another problem faced are MQ5 is not so sensitive when it comes to sensing gas in a large space area, therefore a better class A sensor also should be implement for better future project. Other than that, rather than produced alert system only by using buzzer, this project also can be improve in sending the data direct to the house owner's mobile phone using GSM module.

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