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A Fuzzy Decision in Smart Fire and Home Security System

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Abstract

There has been a major rise in the fire incidents occurring over the past few years in the Pacific Island Countries (PICs) and especially property fires are a major concern. Often it is noticed that these usually lead to loss of homes, personal belongings and even lives of people. Objective of this paper to present a monitoring device that is able to detect the presence of a gas leak and take action before there is an actual fire. To optimize the decision of the system, a fuzzy logic based smart rules are developed to avoid false alarming. The prototype system is designed considering cost, simplicity and reliability. Further, the proposed system helps to reduce fire accident by triggering alarm well-in advance and therefore it can react as an early warning system.

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Keywords: Fuzzy decision; Safety device; Early warning system; Pacific Island Countries

1. Introduction

A lit cigarette, a burning lantern, an overheated electrical appliance or any of these can cause a fire [1]. Fire incidents hardly need a few minutes to make people helpless even before they realize what is happening. Similarly, a crime known as theft which is a general term embracing the massive variety of misconduct which also leaves a person improperly deprived of his property. Fire incidents and theft cases such as burglary and house breaking are both increasing in the households and office buildings in the Pacific Island Countries (PICs) and has become a major concern especially for the people of Fiji. The companies that deal with security systems offer products such as intruder alarm and fire alarm systems. The fire and intruder alarm systems that have been designed by these companies are highly sophisticated, expensive and both do not come integrated in one system. These systems require more

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maintenance work which can only be carried out by authorized company personnel and causes delay with increase in costs.

Property fire incidents in the PICs, especially in Fijian households, are a disturbingly common occurrence. According to the National Fire Authority (NFA) of Fiji, there were over 1800 fire incidents in just year 2009 in Fiji alone [2]. Out of these, over 200 were property fires. While these numbers have reduced over the years, they still hover in the double to triple digits annually. With this, second issue which is a raising concern in the PICs is Burglary and House Breaking. According to the Fiji 2012 Crime and Safety report [3], the crime rate in Fiji is "HIGH" by the U.S Department of State which involves 2178 burglary cases and 7321 theft cases in the year 2012 [4] and the numbers are increasing.

Firstly, fire hazards and accidental fires are a serious concern in the Fijian communities and in the pacific nations in general, especially due to carelessness and lack of fire monitoring systems. According to the fire prevention handbook [5], most fires at home occur in the kitchen as a result of people being careless and getting distracted for some moments while cooking. As stated by National Fire Protection Association [6], 40% of house fires are caused by cooking related incidents. According to the statistics of NFA Fiji [7], about 90 cases of electrical fires are reported each day in Fiji which are mostly caused by overheating from circuit (wiring) and defective or worn out insulation. Not only houses but commercial buildings are also experiencing fires caused by fault in electrical wirings. According to Richard et al. [8], "the danger from smoke is a function of the toxic potency of the smoke and the exposure a person experiences to the (changing) smoke concentration and thermal stress over time they are in the vicinity of the fire".

Secondly, most robberies occur at night when everybody is sleeping or during the day when everybody is in school or at work and the house is left unattended. It was discussed in [3] that houses located near impoverished settlements have a higher rate of breaking and entering and burglaries. Usually most burglars are surreptitious and do not involve violence. However, some burglars do not hesitate in breaking and entering an occupied residence or office building with brandished weapons usually pocket knives, cane knives (similar to machetes) and iron rods. People who tend to engage in criminal activities are often jobless and impoverished [9, 10]. Despite of conventional solutions exist for the house and office fires and burglaries, are quite expensive and this is one of the key reasons why many houses do not install these units. In literature, a simple solution has been developed by Ravindran and Letchamanan [1], which comprises sensing devices like infrared smoke, thermistor heat and infrared sensors. The infrared smoke sensor detects the fire by sensing the smoke at its early stage mimicking the human sense of smell. The thermistor detects the temperature level of the environment and substantial increase in temperature would trigger the alarm. The infrared sensor is for intruder monitor which sounds the burglar alarm when it senses movement. All of these sensors are wired to a PIC 16 micro-controller, which is the brain of the system. This system is cost effective yet is a bit difficult for the end users to understand and carry out maintenance work.

The other existing solution using wireless sensor network for fire hazard detection and monitoring was proposed by Elias et al. [11]. In this system, a wireless sensor was embedded in a micro-controller board and controlled the fire monitoring system. Furthermore, few solutions were proposed utilizing the high end computing systems to monitor fire hazard. The concept is the same as above mentioned solutions but in this system there is less maintenance required; end user can communicate properly with the monitoring system via the computer, stores databases of incidents for future reference. However, this system was developed on 80C31 basic micro-controller [12]. Now, highlighting the second issue which was house and office building robbery, there are existing solutions such as, an intelligent wireless monitoring for home security designed by Jun Hou et al. [13]. A real-time surveillance for the home security was implemented using ZigBee technology and GSM network [14] which was incorporated the Pyroelectric Infrared Sensors (PIR) and ultrasonic sensors. In this embedded surveillance system, signals are triggered by majority voting mechanism. Generally, a PIR sensor detects the temperature changes in human and environment. To overcome the miss rate of PIR sensor, ultrasonic sensors are incorporated to compliment the PIR.

In this work, a user friendly but low cost solution for fire and home security system has been developed. The proposed embedded device is portable and easily adoptable. The application is extended with integrating GSM technology with three main subsystems; monitoring, detection and warning systems. A new decision system is tested with fuzzy logic decision maker to verify the actual threshold levels of fire and gas leaks. The system is first verified using Simulink models to illustrate the potential outputs in various conditions of inputs. A monitoring system incorporates flammable gases and smoke sensor (MQ-2) which constantly monitors the ambient atmosphere for any form of gas leaks or occurrence of smoke. There is a temperature sensor (TMP-36) which monitors the ambient

temperature of the room. It also has a motion sensor (PIR) which monitors the room for any trespassing intruders. Secondly, the detection system is associated with the monitoring system whereby the gas and smoke intensity is given a threshold and likewise for the temperature and PIR sensor. If the sensor values exceed the given thresholds of the respective sensors, the alarm will be triggered.

An effort is made to develop new early warning system similar to the common smoke detectors or security systems whereby it sounds a local alarm upon detection of threat. However, that is the only similarity relating to our device. Our monitoring device is able to detect the presence of a flammable gas leaks or intruders and take action before there is an actual fire or robbery in the house. It is also able to notify concerned people such as family members via text message over the cellular network and by calling a single person. It allows user to take preventative measures to avoid a potential fire incident or house robbery. In general, the number of fire incidents and burglary in the households and

2. Design Method and Modeling

Looking at the hardware aspect of the system, the Gas Sensor MQ-2, temperature sensor (TMP-36) and PIR sensor are used as input devices to the system. These sensors monitor and continuously give feedback to the micro-controller (Arduino Uno R3) for processing. The output side is the warning systems which include by the means of SMS and voice calls. Firstly, the operational logic is calibrated using fuzzy logic considering the inputs to the system which are gas/smoke concentration, temperature and motion detection as well as the output alarm variable is defined with appropriate range of values. Figure 1 shows the fuzzy system modeling.

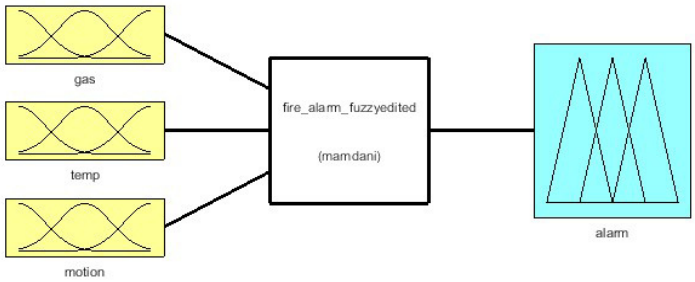


Fig.1. Fuzzy modeling of the system

The following rules define the logic behind the operation of the Fire and Home Security System for fuzzy interference process.

- if (gas and smoke is low concentration) and (temp is normal) and (motion is not detected) then (alarm is off)
- if (gas and smoke is high concentration) then (alarm is on)
- if (gas is medium concentration) then (alarm is on)
- if (temp is hot) then (alarm is on)
- if (motion is detected) then (alarm is on)

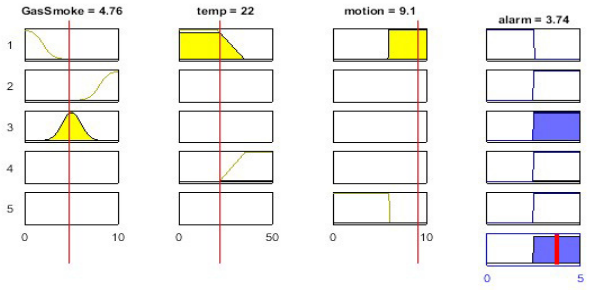


Fig.2. Fuzzy rules

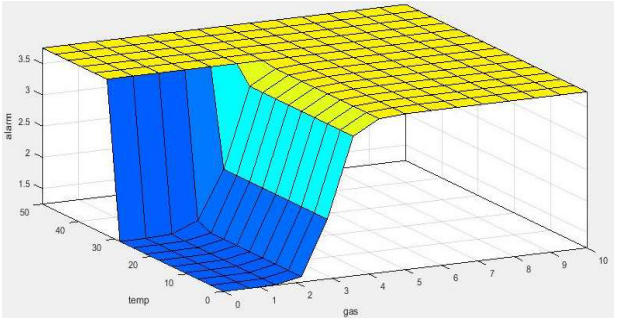


Fig.3. Surface view of output with respect to gas and temperature values

In the Fig. 2, the five rules are specified accordingly. Using the fuzzy inference process, the Centre of Gravity (COG) value is calculated automatically. The COG value determines the ON and OFF state of the alarm. Rule 3 is taken into consideration as the gas concentration is medium the alarm is on. Temperature is normal (22 degrees Celsius) and Motion is not detected in range of 0-6 m.

Fig. 3 shows the output from the system bases on input values of gas and temperature. The yellow shaded region is where the alarm is triggered. For the gas and smoke, the alarm is triggered when the sensor value pass 3. Likewise for temperature, the alarm is triggered when the temperature value increases above 28 degrees Celsius. The curvature of the graph shows how the fuzzy system determines output based on the rules. Fig. 4 shows the modeling diagram of the entire system including fuzzy controller in the loop. The modeling result examines the overall system performance with various conditions and results the decision for alarm.

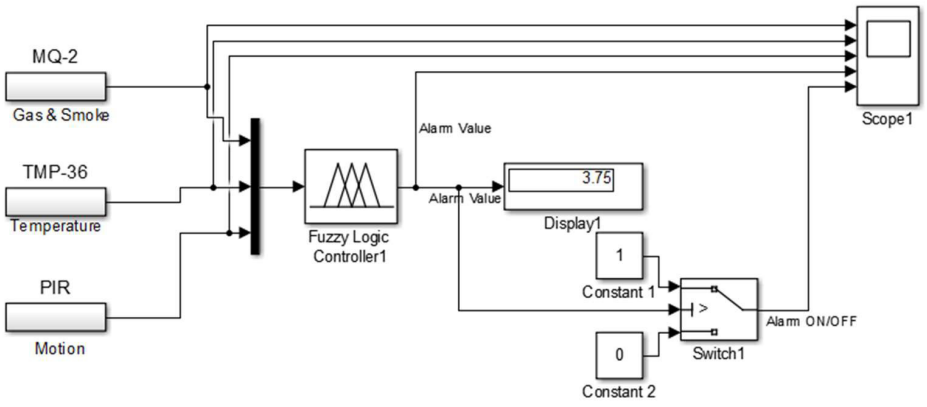


Fig. 4. SIMULINK model of the system

3. Hardware and verification

The overall system is operated as follows. Initially, the system calibrates itself for first few seconds and updates the display information. For the first mode, the system normally checks gas and or smoke in the surround environment as well as sudden increase in the room temperature. The values are continuously monitored against the threshold values which are calibrated during initial setup. Obviously, if the current measured values go above the threshold for any one of the case, first local alarm will be sounded via the speaker and together the GSM modem sends short message.
A practical verification was performed with two different cases. Following Table 1 and 2 show the comparison of the result during the unit is mounted on the wall and other when mounted on the ceiling.

Table 1. Sensitivity of Wall Mount Unit

Wall Mount Unit	**Motion Detected**		
Distance from wall (m)	Detection range (degrees)	Yes	No
3.5	28	✓	
4.2	44	✓	
5	10	✓	
6	-30		✓
10	110		✓
7.5	-25		✓
2	12	✓	

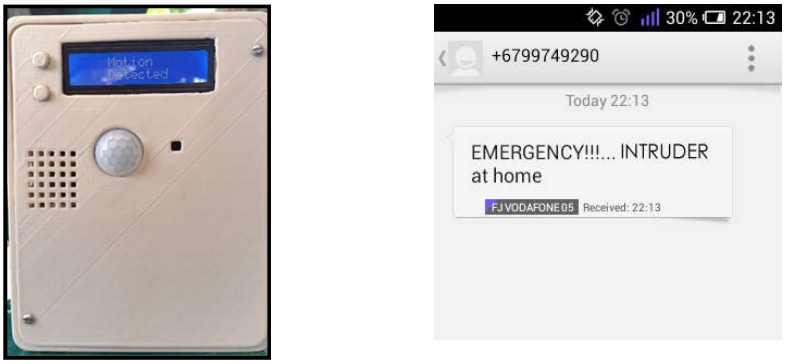
Table 2. Sensitivity of Ceiling Mount Unit

Ceiling Mount Unit		**Motion Detected**	
Distance from ceiling (m)	Detection range (degrees)	Yes	No
1.5	+45	✓	
2.4	-33	✓	
3.5	23		✓
6	50		✓
2.8	10		✓
2	-12	✓	
2.9	36		✓
1.8	28	✓	

The sensitivity range of the PIR sensor in a Wall mount unit is much better than a Ceiling mount unit as the detecting zone distance decreases. According to the PIR sensor datasheet, maximum distance of detecting zone from ceiling is just 2.4m. A wall mount unit can detect in a range of 5 to 6 meters and is very reliable. Gas and smoke are less dense than air so they would definitely rise up towards the ceiling. The system should be mounted in such a way on the wall so that it can detect gas/smoke together with motion. Fig. 5 shows the actual system built for proposed objectives and the SMS message that will be sent during the warning alert. Apart from this SMS, a voice call would be made on the resister mobile number. Once the person receives the call, a sound (speech) will be played, for example, “Some intruder at home” for the person to hear. Therefore, the person can take appropriate action and inform the local authorities remotely. The simulated results are similar to the results obtained during prototyping phase. The system has behaved accordingly, matching the results of simulations. Some minor technical issues were noticed. One was related to PIR motion sensor range of detection. At some instances the sensor remained detected motion and remained high for some time even if there was no motion present. When the alarm is sounded, GSM is activated and it does its task of sending SMS and making voice call to family members. The actual time of event is recoded using real-time clock features embedded in proposed smart device.

4. Conclusions

In this work, a smart early warning system was developed to reduce the number of life-threating fires and robbery incidents at homes and offices. With the help of fuzzy decision logic, the robust results have obtained together with fast communicating technology. Early warning device helps to inform the user well in advance to take precautionary actions. The experiment demonstrates the use of fuzzy decision as a powerful tool which is customized to monitor and to detect together for fire safety and security.



(a) (b)

Fig.5. (a) Actual prototype unit and (b) SMS alert warning

References

[1]. Letchamanan R. Microcontroller Based in Fire Alarm System Using Sensory and Monitoring System [Bachelor's Degree of Electric Engineering]. Universiti Teknikal Malaysia Melaka; 2007.
[2]. Annual Report [Internet]. National Fire Authority Fiji. 2016 [cited 30 October 2015]. Available from: http://www.nfa.com.fj.php53-2.dfw1-websitetestlink.com/sites/default/files/pdf/annual-report-2008-2009.pdf.
[3]. Reports [Internet]. OSAC. 2016 [cited 30 October 2015]. Available from: https://www.osac.gov/pages/ContentReportDetails.aspx?cid=12230.
[4]. Releases [Internet]. FIji Bureau of Stastics. 2016 [cited 30 October 2015]. Available from: http://www.statsfiji.gov.fj/index.php/component/content/article/53-other-statistics/crime/129-crimes-offences34.
[5]. [Internet]. Cne-siar.gov.uk. 2016 [cited 5 May 2016]. Available from: http://www.cne-siar.gov.uk/emergencyplanning/documents/Fire%20Prevention%20handbook-english.pdf.
[6]. [Internet]. Nfa.com.fj. 2016 [cited 5 May 2016]. Available from: http://www.nfa.com.fj
[7]. Electrical fault cause of office fire - Fiji Times Online [Internet]. Fijitimes.com. 2016 [cited 5 May 2016]. Available from: http://www.fijitimes.com/story.aspx?id=263044
[8]. Peacock R, Averill J, Reneke P, Jones W. Characteristics of Fire Scenarios in Which Sublethal Effects of Smoke are Important. Fire Technology. 2004;40(2):127-147.
[9]. Profile V. Ilmu Anyar: The Causes of Robbery [Internet]. Ilmuanyar.blogspot.com. 2012 [cited 5 May 2016]. Available from: http://ilmuanyar.blogspot.com/2012/10/the-causes-of-robbery.html
[10]. [Internet]. 2016. Available from: http://www.nation.co.ke/news/world/Fiji-police-chief-foils-armed-robbery-with-chair/-/1068/2725194/-/xl6qefz/-/index.html
[11]. Manolakos E, Logaras E, Paschos F. Wireless Sensor Network Application or Fire Hazard Detection and Monitoring. , Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering. 2012; 29:1-15.
[12]. Thiravasin P, Sinthusonthichat J. Fire Alarm System Controlled by Using Computer. International Conference on Accelerator and Large Experimental Physics Control Systems. Trieste; 1999.
[13]. Hou J, Wu C, Zhongjia Y, Qiaoqiao W, Yun Z. Research of Intelligent Home Security Surveillance System Based on ZingBee. Intelligent Information Technology Application. 2008.
[14]. Bai Y, Li Z, Xie Z. Enhancement of the complement of an embedded surveillance system with PIR sensors and ultrasonic sensors. IEEE 14th International Symposium Conference. Braunschweig: IEEE; 2016