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Design and in Prototype Implementation of Fire Detection and Intelligent Alarm System

[Daniel D. Dasig, Jr.]

Abstract— **The design has been developed since the social and economic cost of natural disasters which has increased in recent years due to population growth, change in land use patterns, migration and unplanned urbanization, environmental degradation and global climate change. Catastrophic disasters include fires, earthquakes, volcanic eruptions, tropical cyclones, floods, and droughts. Fire considered being natural or man-made, thus the management shall provide safety of the building occupant. The design consists of five major circuits to compensate the system operation. It includes Detection and Initiating Devices (DEADS), Notification Devices (NODES), Central Station Monitor (CSM), Annunciation Devices (ANODES) and the Suppression Circuitry. The DEADS is composed of a smoke detector and smoke ionization sensors which transmit initiated signal to CSM. The NODES are active devices like smoke alarms, and speakers attached to every room designed to give alarms to the room occupants. The Central Station Monitor designed with Arduino Uno as the Microcontroller served as the brain of the system interfaced with PHP & MySQL. The ANODES works once fire cannot be suppressed by the system itself, thereby when the fire department and other incident team needs to be contacted. The suppressor composed of robotic-arm connected to the water supply, fire hydrants, and sprinkler heads.**

Keywords— **fire detection, fire alarm, ionization sensor, Arduino Uno, suppression system**

I. Introduction

The Philippines is considered as one of the most hazards prone countries in the world [1] brought about by man-made and natural disasters due to its geographic circumstance which is exposed to catastrophic earthquakes, volcanic eruptions, tropical cyclones, floods droughts and fires [1]. Based on the reports; devastations of these natural hazards and disasters including fires have increased in recent years of about 50 per year in the early 1970’5 to 400 per year in 2005 [2]. The risk of fire occurrence is high especially during summer [3], Christmas and New Year celebration due to firecrackers. In the Philippines where house fires are prevalent, it has effect to derail the economic growth, destroyed social and physical capital including infrastructures, which resort to reallocation of ongoing programs to finance relief operations to fatalities and inhabitants and reconstruction efforts [1] which diverts funds to social services. Fires are considered natural and man-made hazards. In fire prevention and fire suppression; it requires the adoption of uniform fire safety standards, the incorporation of fire safety, construction and provision of protective and safety devices in buildings and structures [4].

Daniel D. Dasig, Jr.
College of Computer Studies and Engineering, Jose Rizal University
Philippines

In compliance to the same presidential declaration, a strategic plan for safety and security was defined as one of the best available concept, design, material, system and technology to provide a responsive, effective and supportive intelligent environment for achieving the occupants’ objectives over the full life-span of the building and properties.

Compared with traditional or conventional fire alarm system, this design reduces energy consumption, reduction of maintenance and service operation costs, improved security services, and increase the satisfaction of building occupants. Other benefits include adaptability to changing uses and technology, and the dimensional change in environmental performance. This study aimed to design and develop fire detection and intelligent alarm system for educational facilities under bureau of fire protection classification.

II. Methods and Materials

The methodologies described in this paper heavily rely on integration of web science to an embedded system. This section provides associated information on the materials, methods and tools used in the project development.

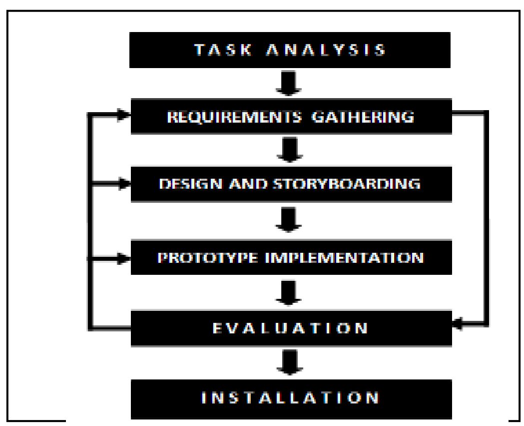

Figure 1. User Centered Design Methodology

The study used the environment scan and developmental research designs. Environment scanning is used as an opportunity to identify the internal and external sources shifts in the current project dynamics, social, economic and technological contexts. The result of environment scan has been used as the basis for the project development. The study is a project development based endeavor, therefore a User Centered Design (UCD) methodology was used during the development stage. The UCD encompasses the stages in the conceptualization, analysis of project tasks, requirements gathering. Functional and non-functional requirements have been considered in the study.

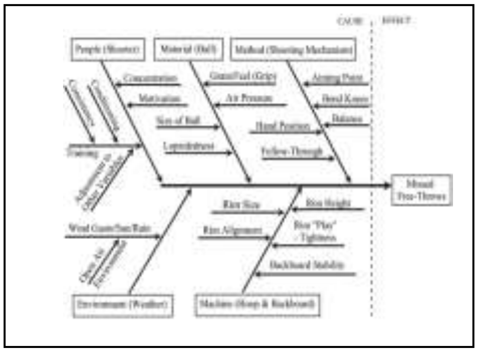

Figure 2. The Fishbone Diagram

The Fishbone diagram (also called the Ishikawa diagram) is a tool for identifying the root causes of quality problems [5]. In this study, consistent to software quality and system performance, Fishbone Diagram has been used to identify primary and secondary causes of errors and failures. A purposive sampling has been employed to identify respondents for system evaluation composed of Incident Team including the Incident Commander and Triage Personnel. System evaluation is based on the ISO 9126 an international standard for software evaluation on its underpinning characteristics such as, functionality, reliability, usability, efficiency, maintainability and portability.

A. Hardware Design and Development

The hardware components include the *(a)* Detection and Initiating Devices (DEADS), *(b)* Notification Devices (NODES), *(c)* Central Station Monitor (CSM), *(d)* Annunciating Devices (ANODES), and the *(e)* Suppression system.

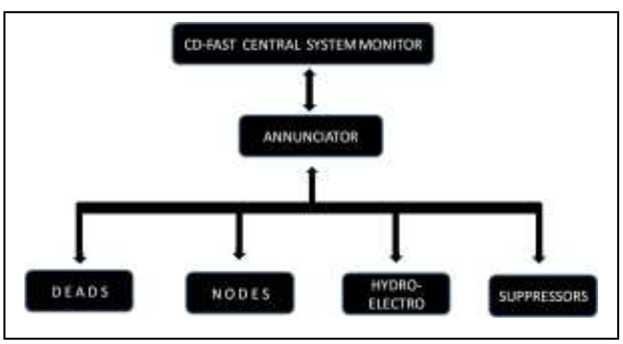

Figure 3. The Hardware Components of the System

Detection and Initiating Devices (DEADS) includes smoke ionization sensors and smoke detectors deployed in the facility. The smoke sensors and detectors transmit signal in a participatory network. When a smoke is detected, the sensor transmits a signal to the network that sets the sensitivity or smoke trip point which provides hysteresis and reduces false triggering. The detector input has a diode protection internally to guard against static damages.

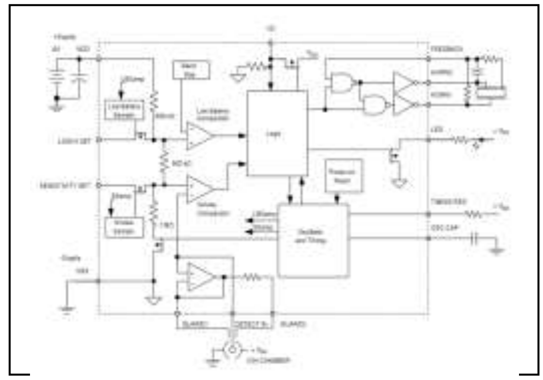

Figure 4. Functional Block Diagram of Ionization Smoke Detector with Interconnect

The A5364 is a low-current, CMOS circuit providing all of the required features for an ionization-type smoke detectors, in a participatory network it allows as many as 125 units to be interconnected so that if any unit senses smoke all units will sound their alarm [6]. This also facilitates alignment and test of the finished smoke detector. The internal oscillator and timing circuitry keep standby power to a minimum by powering down the device for 1.66 seconds and sensing for smoke for only 10 ms. Every 24 on-off cycles, a check is made for a low battery condition [6].

The Notification Devices (NODES) facilitates the alarm notification is by probe units or speakers in place of horns with a pre-recorded message that is played in the event that there is an alarm. The speaker is built-in the conventional smoke detector/ alarm. The message usually informs the building occupants to immediately be alerted of the emergency situation and readily directs the occupants to exit quickly in the facility through emergency exits which emergency lights are auto-lit by the system. The Central Station will now deploy a notification alarm to the speakers attached/ installed per room with a pre-defined sounds.

The Central Station Monitor (CSM) holds the database and relational reports of network sensors and detectors. The CSM has the list of Incident Team for the facility, emergency contact number and personnel. For fire incident reported by personnel near the facility proximity, the SMS Gateway can be used to facilitate communication. In cases, the fire spreads quickly to the extent that the Suppression System could not afford to suppress the fire, the CSM special feature will be activated. Figure 5 shows the functional integration of system components in a block diagram. The CSM sends an SMS to emergency responsders' teams such as Bureau of Fire Protection, Department of Social Welfare and Development and/or the Regional or National Disaster Coordinating Council. It displays rooms were the smoke alarm detected and transmitted.

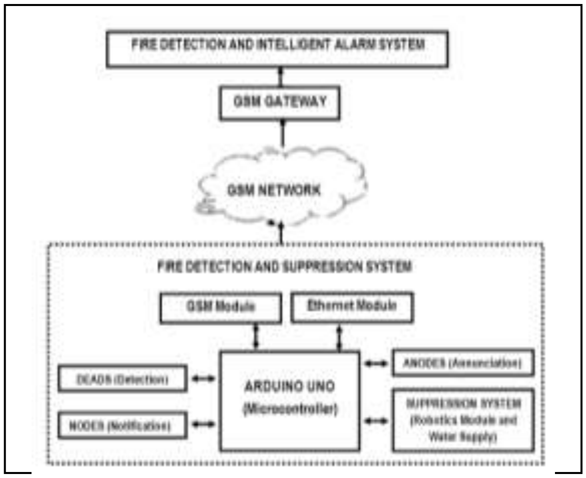

Figure 5. The System Functional Block Diagram

The diagram in Figure 5 depicts the Information Technology Infrastructure such as the, Embedded System, Fire Detection and Suppression System, Global System for Mobile Communications (GSM) Infrastructure, the Short Messaging System (SMS), The Computer System Infrastructure includes the database systems, control system and monitoring and reporting system. The hardware was designed based on the structure in figure 5.

The system development was divided into two general categories as (a) Hardware Design and (b) Software Design. Hardware design involves the development of the power regulation circuitry, control system, embedded system and integration of the project hardware requirement. The power regulation is up with a 9V and 6V based on the commercial 7809 and 7806 voltage regulator IC. This simplifies the design and layout of the circuit because all of the regulating circuit as well as current limiters and overload protection are built into the IC. The 9V is supplied to the smoke detection; 6V is connected to the relays which require 6V supply.

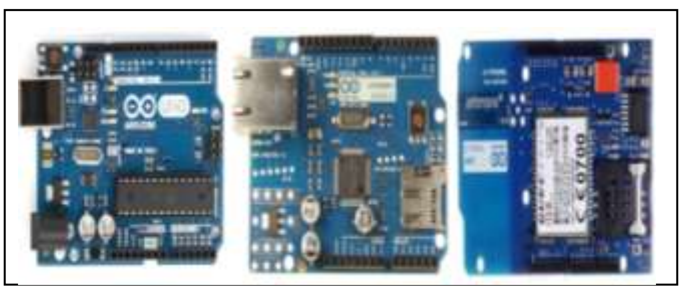

Figure 6. Arduino Uno Board, and compatible GSM and Ethernet Shields

The hardware components includes but not limited to the following: smoke ionization sensors; GSM module; Ethernet shield compatible for Arduino Uno, DC motor; Arduino Uno microcontroller and other passive and active electronic and electrical components. Arduino is an open-source electronics platform based on easy-to-use hardware and software. It's intended for anyone making interactive projects [7]. The system used Arduino Uno compatible shields for special purpose and functions being defined.

The Arduino GSM Shield is used to connect the Arduino to the internet using the GPRS wireless network with a SIM card from an operator offering GPRS coverage [8]. The shield is also used for the system SMS and calling features for the emergency response team. Arduino Ethernet Shield is also used which connects Arduino to the internet [9].

B. Software Design and Interfacing

The software includes design and development of Graphical User Interface for the CSM, integration of hardware functionalities to that of the software mechanism, database design and development using the PHP front-end and MySQL as back-end. The software serves as a mediator between the hardware and its functionalities.

Figure 7. Arduino with Skecthes (Left) and PHP & MySQL(right) Integrated Development Environment

C. System Application and Selective Area Coverage

The system is applied to an educational facility to provide early notifications to the building occupants such as school administrators, faculty and students, non-teaching personnel, concessionaire, and other building occupants. The coverage of the system covers most areas below the ceiling where sensors are attached, beneath stairs, computer rooms and other similar locations except kitchen, closets, and parking areas. The system uses ionization smoke detector, spot type for conventional areas and photoelectric smoke detectors in computer rooms and laboratories. However, for expected protection, environmental condition is considered such as the ceiling height, and materials and assemblies used in the structure or interior design of the facility.

Paramount to the considerations is time response of the system, and ability to provide notification and automatically transmit and alarm to summon local or nearer fire departments and other emergency agencies. The suppression system is limited only to the water supply which runs through the piping assembly and sprinkler system. The pipe fitting, PVC elbows, and the system assembly check and functionality test is conducted at a frequency that is mandated by the Bureau of Fire Protection and Building Code of the Philippines. Fire Protection Panel is embedded to a fire-proof facility.

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III. Results and Discussion

System and software quality requirements identified based on the Quality Characteristics and sub-characteristics defined in the ISO 9126 Model. Relative weights had been assigned to quality in use, external and internal quality which allows evaluators' measurement.

TABLE I. SOFTWARE EVALUATION (ISO/IEC 9126 QUALITY MODEL)

No	Criterion		Weighted Mean
	Characteristics	**Subcharacteristics**	
1	**Functionality**		**4.6**
		Suitability	4.5
		Accurateness	4.5
		Interoperability	4.7
		Compliance	4.8
		Security	4.3
2	**Reliability**		**4.3**
		Maturity	4.2
		Fault tolerance	4.5
		Recoverability	4.3
3	**Usability**		**4.6**
		Understandability	4.5
		Learnability	4.6
		Operability	4.8
4	**Efficiency**		**4.6**
		Time behavior	4.6
		Resource behavior	4.7
5	**Maintainability**		**4.5**
		Analyzability	4.5
		Changeability	4.3
		Stability	4.5
		Testability	4.6
6	**Portability**		**4.6**
		Adaptability	4.6
		Installability	4.7
		Conformance	4.5
		Replaceability	4.4
		Average Mean	**4.5**

Computed weighted mean for each system functionality criteria as reflected in the table I have been interpreted using 5 points Likert Scale as follows: very functional, highly functional, functional, poorly functional and not functional at all. The sub-characteristics being considered in the functionality includes; suitability**,** accurateness**,** interoperability**,** compliance**,** security**.**

As reflected in the table the computed functionality level in all criterions ranges from 4.3 to 4.8 which can be interpreted that the functionality level of the system is highly functional. And the overall computed mean for all criterions is 4.6 which again can be interpreted that the system has an overall functionality level of very functional as evaluated by the respondents.

Computed weighted mean for each system reliability criteria as reflected in the table I have been interpreted again using 5 points Likert Scale as follows: very reliable, highly reliable, reliable, questionable and not reliable at all. The sub-characteristics being considered in the functionality includes; maturity**,** fault tolerance, and recoverability**.** Based on the evaluation depicted in the table, the system reliability level in all criterions ranges from 4.2 to 4.5 which can be interpreted that the reliability level of the system is highly functional; the overall computed mean for all criterions is 4.3 which again can be interpreted that the system has an overall reliability level of highly reliable.

The sub-characteristics being considered in the ***usability*** includes; understandability, learnability, operability; ***efficiency***, time behavior, resource behavior maintainability, analyzability, changeability, stability, testability, ***portability***, adaptability, installability, conformance, replaceability. Based on the respondents evaluation depicted in the table, the system usability level, efficiency and portability is 4.6, while maintainability is 4.5, and these can be interpreted that the system is very usable, very efficient, very portable and very maintainable.

TABLE II. USER NEEDS CHARACTERISTICS AND WEIGHTS

Quality in Use		
	CHARACTERISTIC	WEIGHT (High/Medium/Low)
	Effectiveness	H
	Productivity	H
	Safety	H
	Satisfaction	H

Table 1 reflects the average computed mean for all criterions is 4.5 which again can be interpreted that the system has an overall high quality. On the other hand, table 2 depicts measurement of respondents on software based on accuracy and completeness, measures of productivity relate the level of effectiveness achieved by the expenditure of resources, the risk of operating the software product over time, and extent to which users are free from discomfort and their attitudes towards the use of the product [10] is High.

IV. Conclusion and Recommendation

The design revealed the effectiveness of the practical application and development of fire alarm system for an educational facility. Hence, it is recommended that system developers/designers should make use of the same methodologies and materials and that further studies be done by conducting experimental validation on the materials and empirical investigation of the processes involved in the design and development .

Further studies may include designs for vertical and horizontal structures which includes duct detector, elevator recall, use of heat detectors, infrared and ultraviolet flame detectors for oil refineries, manufacturing industries, carbon monoxide detectors, and gas detectors embedded in a special purpose or general -purpose intelligent fire alarm system.

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About Author:

Engr. Daniel D. Dasig, Jr. is currently a Research Fellow of Jose Rizal University, Philippines. He is a recipient of research grants and awards. He is a member of - Universal Association of Computer and Electronics Engineers (UACEE), The Society of Digital Information and Wireless Communications (SDIWC), Member-The International Association of Engineers (IAENG); Global Member-and Philippines Chapter Member of Internet Society (ISOC). He is one of the Editorial Board- International Scientific Journal in Business Economics, Commerce and Trade Management; Editorial Board - International Journal of Artificial Intelligence and Applications; Editorial Board- Computer Applications: International Journal. He is a faculty member of College of Computer Studies and Engineering of Jose Rizal University, and currently holds a Technology Analyst II-Officer 3 position in TELUS International Philippines, Inc. as an industry practitioner. He is a Lean Six Sigma Certified for Business Process Improvement and ITILv3 Certified in IT Service Management. He is on his thesis for Master of Science in Engineering-Computer Engineering at the Polytechnic University of the Philippines-Manila, and a candidate for Master in Information System from the University of Makati, Makati City. He graduated a degree of Bachelor of Science in Computer Engineering from Samar State University and finished a Certificate in Professional Teaching from Kester Grant College, Philippines, Inc., Quezon City.

As an educator, he is actively involved in faculty development programs as member of Institute of Computer Engineers of the Philippines (ICPEP), Philippine Society of Information Technology Educators (PSITE), and Philippine Society for Study of Nature (PSSN). Author and co-authored papers presented and accepted in local and international conferences and published in referred journals. He serves as Technical Paper Reviewer of several international conferences in Busan, Korea; Kuala Lumpur, Malaysia; Ostrava, Czech Republic; Bangkok, Thailand; Chennai India, and Islamabad, Pakistan. He is also an organizer of local and international conferences.