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ROBUMBERO: SMART FIREFIGHTING ROBOT

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Abstract *- This study aimed to develop a fire-fighting robot called Robumbero. This smart fire-fighting robot can be operated automatically or manually using a remote control. It can extinguish fires at an early phase without the actual presence of the firefighters and without exposing one's self to the danger of fire. It is equipped with an ABC fire extinguisher, and sensors to detect fire and obstructions. It also has a camera that allows users to have a real-time view of the robot's surroundings for easy manipulation. The robot's overall performance was assessed using a descriptive research method. It was evaluated by the twenty students and employees from Don Honorio Venture State University, BFP and ten engineers. The data obtained were analyzed and it was revealed that the robot has met all the criteria of ISO25010 and that its overall performance can be deemed efficient and effective.*

Keywords – *Automation, Extinguish Fire, Firefighting Robotics, Remote-controlled, Robot*

INTRODUCTION

Fire is defined as the result of combustion or the chemical interaction between three elements consisting of the fire triangle: heat, fuel, and oxygen. When an adequate amount of heat is applied to a fuel source, the atoms making up the fuel begin to heat up and vibrate. When heat is consistently applied, the atoms will eventually separate from the bond holding them together causing them to be released as volatile gasses. These gasses would then react with oxygen producing heat energy that is excessive enough to drive or sustain the chemical reaction and release some of the energy as light, in the form of flames [1].

In the Philippines, around 13,029 fire incidents were posted by the Bureau of Fire Protection (BFP) for the year 2022. This is 4.02 percent lower than the 13, 574 fires recorded in 2021 [2]. The BFP continues to observe this downward trend this year, as the reported 1,984 fire incidents from January 1 to March 1, 2023, is 21 percent lower than the 2,520 fires recorded last year [3]. However, despite the reduction in the said fire-related figures the BFP remains to be vigilant in educating the public about fire prevention and mitigation to prevent unwanted and significant losses.

These sources of fuel are present everywhere similar to oxygen, thus, with heat, fire incidents can happen in any place such as homes, workplaces, outdoor places, and even schools. In the U.S., an average of 3,230 fire incidents at schools were recorded from 2014 to 2018. This has caused one civilian death, 39 civilian injuries, and approximately USD 37 million in direct property damage [4]. In the Philippines, no recent statistics could identify the fire incidents rate among schools but various articles have reported some fire occurrences at schools. This includes the fire that broke out on May 2022 at the University of the Philippines Diliman leaving eight individuals dead and about 250 families affected or completely displaced [5]. And also, the fire that started in an unplugged electric fan and has caused Php 50,000 in damage at a school in Dumaguete City last September 2022 [6]

There are many other fire-protective robots that are operated using Raspberry Pi such as the Fire Fighting Robot Chassis [7], Fire Fighting Robot AML [8], Automated Fire Extinguisher Robot [9], and Firefighting Exploration Device [10]. They mostly differ in the structure, Raspberry Pi model used, and codes implemented that is whether the firefighting robot is automated or remotely controlled, but they all perform one common function and that is to detect and extinguish fires. They all have their own advantages in agents, sizes, and functions, but none of them are done and tested specifically in the Philippines where humidity and temperature are usually high. It is not clear whether these existing robots would accurately work in extremely hot weather or when surrounded by heated objects, appliances, or equipment.

Fires can happen in any location as there are fuel sources available in our daily surroundings. The occurrence of fires in public places like Don Honorio Ventura State University can cause extensive destruction and pose a threat to life for students and employees. Fire extinguishers are a valuable resource for preventing and stopping fires and there are different types of fire extinguishers that are accessible depending on the type of fuel source that is present.

OBJECTIVES OF THE STUDY

The objectives of the researchers are focused on the development of a smart firefighting robot that automatically extinguishes fire at an early stage. Specifically

1. To be able to automatically detect fire in a room.
2. To be able to extinguish indoor fires at early stage.
3. To have remote control feature that is easy to operate.
4. To evaluate the

MATERIALS AND METHOD

The researchers use Descriptive Research as a research method. The mentioned conduct is a type of research method used to gather information on the current state of a person or item. It is used to define the existing state of affairs in terms of situations [11]. This method was used to identify the difficulties and issues encountered by students, employees, and their safety and health at Don Honorio Ventura State University. This method was also used in testing and improving the proposed prototype.

The researchers used a Scrum Agile Method as the project development method, which is used primarily for software development. It is characterized by its iterative and incremental approach to project management and product development. Each phase was utilized to develop the proposed system.

The study was also evaluated by experts based on functionality, performance, compatibility, usability, reliability, security, maintainability, and portability of the prototype and evaluated the quality in the use of the prototype device based on effectiveness, efficiency, satisfaction, freedom from risk and context coverage to test its degree of compliance according to the ISO25010.

Likert Scale was used by the researchers to interpret the result of the survey questionnaire. It is basically often used five (5) point format. Results were obtained by calculating the average of the results added together.

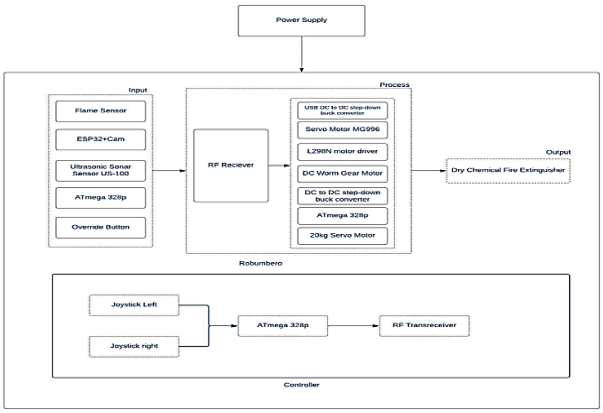

Figure 1. Block Diagram of Robumbero

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The figure 1 shows the block diagram that the power supply serves as the main source of power for the devices, the robot, and the remote to be particular. Then the flame sensor detects the presence of flames inside the rooms which serve as the trigger of the system.

Also, an ESP32 + Cam which is a microcontroller that serves as the eye of the system to have view inside the classroom it is equipped with an ESP+Cam and has a robotic arm with a 9g servo motor to move left, right, upward and downward directions that has to connect in the user mobile phone and has a view in the intensity of the flame. Then the ultrasonic sonar sensors will use ultrasonic waves to detect the presence of obstacles and provide data to the system to avoid what is in front of the device.

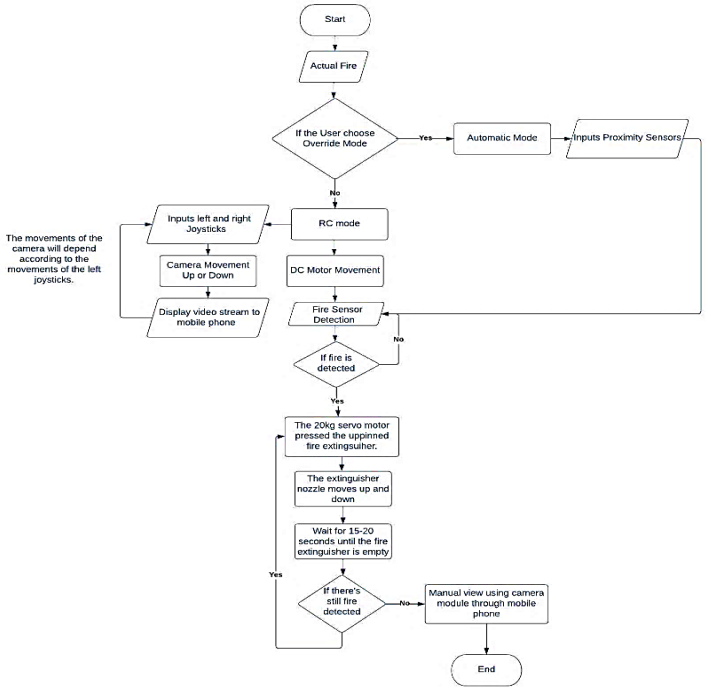

Figure 2. Flowchart of Robumbero

The figure 2 shows the flowchart of the Robumbero will start when there is already an actual fire inside the classroom the user had two options override mode which means it can be automatic ode or by using the remote controller and if the device is on automation mode the inputs for proximity sensors will help to avoid obstacles inside the room. If it is controlled, the user will control the movement based on the joystick.

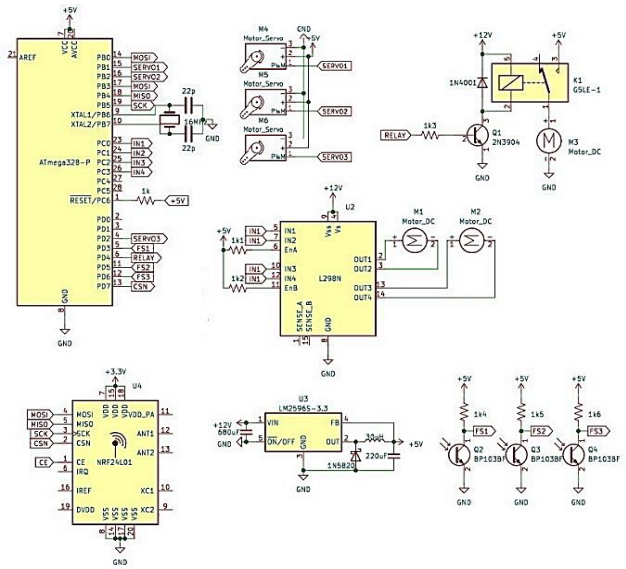

Figure 3. Schematic Diagram of the main ATMega 328P

The schematic diagram of the main ATMega 328p and the connection of the components. Its system consists of ATMega 328p. Flame sensors, L298N Motor Driver, Relay, Servo Motors, NRF24L01 Receiver. The ATMega328p serves as the main control unit of the system. It is connected to the motor driver module, which controls the direction and speed of the 4 wheels of Robumbero. The RF transceiver module allows the user to control the car from a distance using a remote controller to put it in the nearest entrance. The flame sensor is positioned in the middle of the schematic diagram and is used to detect the presence of flames. When the sensor detects a flame, it sends a signal to the ATmega328P microcontroller board to activate the Robumbero's fire extinguisher and move toward the fire to extinguish it.

This is the schematic diagram of the second ATMega 328P, 3 HC-SR04 Ultrasonic

Distance Sensors, and their connections. The main microcontroller ATMega 328P controls the 3 HC-SR04 Ultrasonic sensors. The 3 HC-SR04

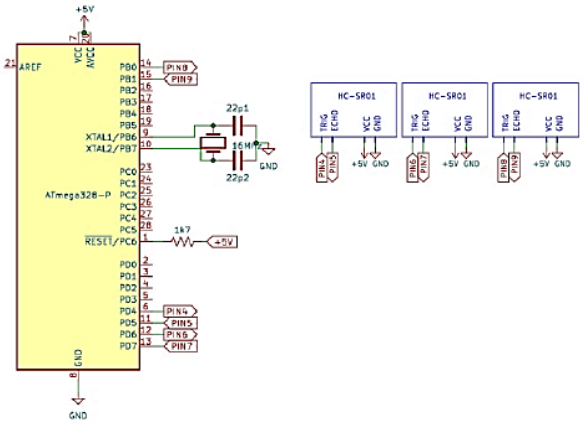

Figure 4. Schematic Diagram of the second ATMega 328P

The schematic diagram of wireless remote control for Robumbero, which is based on an ATmega328p microcontroller. The system comprises an ATmega238p microcontroller, The ATmega328P microcontroller is the central component of the system, which controls the overall operation. The power source for the ATmega328p is not specified in the figure. The RF transceiver is responsible for establishing a wireless connection. ESP+Cam enables camera monitoring and alerts the user's mobile phone that can be viewable. The nRF24L01 transceiver utilizes the custom-built controller to command the L298N motor driver, which in turn controls the 2x servo motors.

As shown in table 1, Likert Scale was used by the researchers to interpret the result of the survey questionnaire. It is basically often used five (5) point format. Results were obtained by calculated the average of the results added together.

Table 1: *Likert Scale*

RATING	DESCRIPTION	LIMIT OF INDEX
5	(E) EXCELLENT	4.51-5.00
4	(VG) VERY GOOD	3.51-4.50
3	(G) GOOD	2.51-3.50
2	(F) FAIR	1.51-2.50
1	(P) POOR	0.51-1.50

The research statistical formula below in calculating the results of the study (Mababa, 2017).

$$P = \frac{F * 100}{N}$$

where:

P = Percentage
F = Frequency
N= Total number of populations

The researchers' data were summarized by percentages and frequency counts to get the most responses and conclusions was derived. The formula used in getting the arithmetic mean or to compute the average of the criteria as identified in the automation and manually mode testing tool based on the ISO25010.

$$\mathbf{X}=\frac{\sum fx}{N}$$

where:

X = mean
f = frequency
x = responses
n =total frequency

RESULTS AND DISCUSSION

Presents the data gathered by the researchers to show how the proposed prototype addresses the problem statement. It includes the development of the system and how it benefits Don Honorio Ventura State University. The results of the device will determine the quality of the product based on its functionality, performance, compatibility, usability, reliability, security, maintainability, and portability. Additionally, the quality in the use of the prototype device was evaluated based on its effectiveness, efficiency, satisfaction, freedom from risk, and coverage of the developed proposed prototype titled "Robumbero: Smart Firefighting Robot.

Upon getting the gathering data of students and employees of Don Honorio Ventura State University and interviewing the director of safety and health of the campus university problems with the use of fire extinguishers were identified: Only 54 percent out of 100 students and employees know how to use a fire extinguisher; 77 percent out of 100 students and employees do not know to apply the PASS method; Merely 8 percent out of 100 students and employees experienced using a fire extinguisher in a fire drill in school; 92 percent out of 100 students and employees have not yet experienced using a fire extinguisher; 56 percent out of 100 students and employees said that they are willing to risk their safety and health even if they are not trained to use fire extinguishers.

Table 2 is a summary of the survey results. Respondents rated all ISO25010 characteristics as excellent, yielding a general weighted average of 4.57 for functional suitability, 3.77 for performance efficiency, 4.05 for compatibility, 3.97 for usability, 3.75 for reliability, and 2.6 for security, 4.3 for maintainability, 4.13 for portability, 4.5 for effectiveness, 4.6 for the efficiency, 3.85 for satisfaction, 4.4 for freedom of risk and 3.65 for context coverage that sums up to a total general weighted average of 4.03. This demonstrates that respondents with knowledge in automation, hardware, and software, and robotics have accepted the proposed prototype.

Table 3 is a summary of the survey results in Users' Evaluation. Respondents rated all ISO25010-based. The total mean for users evaluation for the researchers Robumbero is 3.99 the verbal interpretation for this is Very Good.

Table 4 shows a summary of the survey results in the Bureau of Fire and Protection Evaluation. Respondents rated all ISO25010-based and the total mean for BFP evaluation for the researchers Robumbero is 3.53 the verbal interpretation for this is Very Good.

Table 2. *Survey Result Summary*

ISO 25010 Characteristic	General Weighted Mean	Description
PRODUCT QUALITY		
Functional Suitability	4.57	Excellent
Performance Efficiency	3.77	Very Good
Compatibility	4.05	Very Good
Usability	3.97	Very Good
Reliability	3.75	Very Good
Security	2.6	Fair
Maintainability	4.3	Very Good
MEAN	**3.86**	**Very Good**
QUALITY IN USE		
Portability	4.13	Very Good
Effectiveness	4.5	Very Good
Efficiency	4.6	Excellent
Satisfaction	3.85	Very Good
Freedom from risk	4.4	Very Good
Context coverage	3.65	Very Good
MEAN	**4.19**	**Very Good**
GENERAL MEAN	**4.03**	**Very Good**

Table 3. *Survey Results on User Evaluation Summary*

USABILITY	General Weighted Mean	Description
How easy was it to understand and operate the Robumbero firefighting robot during the fire emergency?	4.2	Very Good
Did the user interface of the Robumbero firefighting robot make it easy to identify and select the necessary functions?	4	Very Good
Were the instructions for using the Robumbero firefighting robot clear and easy to follow?	4.1	Very Good
RELIABILTY		
Did the Robumbero firefighting robot perform consistently and accurately during the fire emergency?	3.8	Very Good
How confident are you in the Robumbero firefighting robot's ability to effectively extinguish fires?	4.1	Very Good
PERFORMANCE EFFICIENCY		
Did the Robumbero firefighting robot to reach and extinguish the fire in an appropriate time?	4.1	Very Good
Was the speed of the Robumbero firefighting robot appropriate for the size and severity of the fire?	3.9	Very Good
Did the Robumbero firefighting robot use resources efficiently (e.g. water, foam) during the fire suppression operation?	4	Very Good
COMPATIBILITY		
Did the Robumbero firefighting robot integrate well with other firefighting equipment and resources (e.g. fire alarm systems, fire extinguishers)?	4.1	Very Good
Was the Robumbero firefighting robot compatible with the existing fire safety procedures and protocols in the building or facility?	4	Very Good
Was the Robumbero firefighting robot compatible with other electronic devices or systems?	4.2	Very Good
SECURITY		
How safe did you feel while operating the Robumbero firefighting robot during the fire emergency?	3.9	Very Good
Did the Robumbero firefighting robot comply with relevant safety regulations and standards?	3.7	Very Good
Were there any safety measures in place to ensure the proper use and operation of the Robumbero firefighting robot?	3.8	Very Good
TOTAL MEAN	**3.99**	**Very Good**

Table 4. *Survey Results on BFP Evaluation Summary*

USABILITY	General Weighted Mean	Description
How easy was it to understand and operate the Robumbero firefighting robot during the fire emergency?	3.7	Very Good
Did the user interface of the Robumbero firefighting robot make it easy to identify and select the necessary functions?	3.7	Very Good
Were the instructions for using the Robumbero firefighting robot clear and easy to follow?	3.6	Very Good
RELIABILTY		
Did the Robumbero firefighting robot perform consistently and accurately during the fire emergency?	3.3	Good
How confident are you in the Robumbero firefighting robot's ability to effectively extinguish fires?	3.5	Good
PERFORMANCE EFFICIENCY		
Did the Robumbero firefighting robot to reach and extinguish the fire in an appropriate time?	3.5	Good
Was the speed of the Robumbero firefighting robot appropriate for the size and severity of the fire?	3.5	Good
Did the Robumbero firefighting robot use resources efficiently (e.g. water, foam) during the fire suppression operation?	3.9	Very Good
COMPATIBILITY		
Did the Robumbero firefighting robot integrate well with other firefighting equipment and resources (e.g. fire alarm systems, fire extinguishers)?	3.2	Good
Was the Robumbero firefighting robot compatible with the existing fire safety procedures and protocols in the building or facility?	3.5	Good
Was the Robumbero firefighting robot compatible with other electronic devices or systems?	3.6	Very Good
SECURITY		
How safe did you feel while operating the Robumbero firefighting robot during the fire emergency?	3.4	Good
Did the Robumbero firefighting robot comply with relevant safety regulations and standards?	3.2	Good
Were there any safety measures in place to ensure the proper use and operation of the Robumbero firefighting robot?	3.8	Very Good
TOTAL MEAN	3.53	Very Good

CONCLUSION AND RECOMMENDATION

The developed robotic device entitled "Robumbero: Smart Firefighting Robot" is a machine that can stop fires unmanned or without the need for actual firefighters. The researchers recommend that future researchers improve this robotic device by analyzing and making a cabinet or protection of all the components inside the Robumbero. The protection must be fixed so that when refilling the fire extinguisher the components will not be damaged. It is also recommended to have an antenna for both the remote and robot to ensure smooth movement and prevent any delays in extinguishing fires. The protection must be fixed so that when refilling the fire extinguisher the components will not be damaged. It is also recommended to have an antenna for both the remote and robot to ensure smooth movement and prevent any delays in extinguishing fires. Additionally, it is suggested that the temperature sensor must have a robotic movement as well to be able to conduct an inspection of the surroundings and identify the primary source of fire if it is scattered.

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