ICFBE 2024

The 8th International Conference on Family Business and Entrepreneurship

DEVELOPMENT AND INTEGRATION OF SEARCH ROBOT (SR PYROTERRA) WITH THERMAL SENSOR

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ABSTRACT

Rescue robots are essential instruments during emergencies and natural disasters since they are outfitted with sophisticated thermal sensors, can withstand extreme temperatures, and can move in close proximity to the person in need. By operating in environments that are hazardous and unsafe for human responders such as burning or collapsed buildings, toxic chemical spills, or extreme weather conditions, rescue robots minimize risk and improve response durations. Generally, this study aimed to determine the functionality in terms of a) duration of flight, capabilities of device thermal range detection, c) device's control range. The electrical parts of the robot prototype were tested to determine if they are functional before the robot was assembled. In constructing the Search Robot, we used Phantom 3 Motherboard and Motors, Thermal Sensor, 3D modelled parts using Fusion 360 were then sliced using CURA and 3D printed using the Ender 3D printer. The robot was programmed with embedded C++ coding and were all assembled and placed with 3D printed parts and attachments. The functionality of the robot in terms of detecting the person and fire was tested two times. It can be determined in the thermal sensor if there is a person or object by displaying a dark blue highlight, and fires can be detected by the sensor and the highlight's color may vary depending on the flame's temperature, mostly being yellow to red highlights. The success rate was computed to determine the average functionality. A 100% success rate shows that SR Pyroterra Thermatron can successfully navigate and locate the person.

Keywords: *rescue, robot, search*

1. INTRODUCTION

Natural disasters pose significant risks to human lives, often leading to fatalities due to a lack of preparedness and adequate equipment during rescue missions (Arabboev et al., 2021). Uddin & Islam (2016) further noted that ineffective rescue efforts, particularly in hard-to-reach areas, result in lost lives and property. The inability to locate trapped individuals exacerbates this problem, highlighting the need for advanced search-and-rescue tools. This study seeks to address this issue by exploring robotic solutions to improve rescue operations, potentially saving lives in disaster-prone areas.

Prior research, for instance, work done by Arabboev et al. (2021) and Yano et al. (2020), has proven the use of robotics in disaster scenarios. Arabboev et al. made the multifunctional Karo robot which can be used for urban search and rescue missions while Yano et al. designed a victim finding robot which uses real time tracking cameras and a FPV camera. Other advancements like thermal drones and heron type drones with infra-red cameras have also assisted greatly in search and rescue operations especially with locating individuals in areas where visibility is highly compromised.

In response to these challenges, this study proposes the development of "Pyroterra Thermatron," a search-and-rescue robot with enhanced thermal imaging capabilities for fire and human detection. By improving upon existing technologies, such as increasing the thermal camera range and resolution, this device aims to increase the efficiency of rescue missions, ultimately reducing disaster-related fatalities and

property damage. The outcomes of this research will contribute to advancing search-and-rescue technology, offering practical solutions for more effective disaster response.

Statement of the Problem

Generally, this study aimed to develop and integrate a search and rescue robot with thermal sensors. Specifically, this study aimed to answer the following questions:

1. Is the device functional in terms of fire detection using thermal imagery?
2. Is the device functional in terms of human detection using thermal imagery?

Objectives of the Study

Generally, this study aimed to develop and integrate a search and rescue robot with thermal sensors. Specifically, this study aimed to determine if:

1. The device is functional in terms of fire detection using thermal imagery.
2. The device is functional in terms of human detection using thermal imagery.

Hypotheses of the Study

Based on the problems verbalized, the following assumption is drawn:

1. The device is functional in terms of fire detection using thermal imagery.
2. The device is functional in terms of human detection using thermal imagery.

Theoretical Framework

One of the major improvements in the field of disaster management is the use of search and rescue robots especially those with thermal sensors. These robots are expected to operate even in extremely hot conditions and are very helpful in the rescue of those trapped in danger zones. Erdelj et al. (2017) showed that such autonomous systems are capable of carrying out tasks in a situational environment with great effectiveness, in particular, when it is too dangerous to employ human personnel. With the help of thermal imaging, it is also possible to locate people in dark and dusty situations such as inside rubble or smoke, which increases the probability of their timely and successful rescue. This corresponds to the systems of robotics developed for the management of disasters which consider both safety and efficacy (Murphy, 2016).

The introduction of thermal sensors in robots' composition expands their possibilities due to the provision of up-to-date operational information, which is very important for the conducting of the rescue mission. According to Houssein et al. (2020), it is sensor technology that enables a rescuing team to enjoy an enhanced understanding of the environment which in turn allows them to make and implement decisions more quickly. As technology in search and rescue robotics improves, their application is beneficial not only in disaster management but also in law enforcement, security, and other important areas. These frameworks envisage that further developments can be expected in tools that will be more sophisticated and functional for conducting life-saving missions in dangerous environments.

Conceptual Framework

The Pyroterra Thermatron drone has been developed within a clearly defined conceptual framework and combines advanced thermal imaging capabilities with height-wise characterization of fire hazardous areas from 10 meters bypassing which is quite a risky region for firefighters. The drone works with an Ardupilot in the GPS navigation and thermal imaging mode to assess the affected region and turn the images taken to the ground epicenter where base station operators help ascertain loss assessment as quick as possible. Following the principle of flying 'using vision' in low visibility conditions, as well as through smoke, the drone minimizes to a great extent the human element in fire forecasting thereby improving safety and response times. The Pyroterra Thermatron aims to expand the thermal range capabilities, with specifications allowing detection from -20℃ to 400℃, thus improving the effectiveness of rescue operations in critical situations.

2. Literature Review

According to Arabboev et al. (2021), finding victims in a disaster area can be made easily and quickly by using robotic systems to expedite search and rescue operations so that more lives will be saved. With this concept, they developed multifunctional search and rescue robot system equipment to use in the pursuit of rescue operations and made it even possible to employ it in far-away areas and monitor it away from

hit zones in real time. With this concept, they developed multifunctional search and rescue robot system equipment to use in the pursuit of rescue operations and made it even possible to employ it in far-away areas and monitor it away from hit zones in real time.Among the enthusiasts was Arabboev et al. (2021) who planned and designed and implemented project Karo. It was land based mobile robot that upon testing manifested high level of flexibility, a quality needed for every automated product. Also, it maintained the standard adroitness as well as investigation competences for urban search and rescue (USAR) missions. Similarly, the work of Yano et al. (2020) which is about a sample model describing compact assistant surveillance robot intended to look for recuees and saving missions. This surveillance robot was created to secure information that would guide rescuers in their mission especially in difficult terrains and areas to free victims.They used Arduino Mega 2560 that serve as main microcontroller. The controller has an FPV camera fastened to a stand and tilted to facilitate instantaneous video streaming and tracking of terrains to exactly locate the area where the victims are situated. Based on the features of the model, it can be used for basic rescue tasks like identifying injured people and assessing obstacles in collapsed structures.Different search and rescue robots are also available in the market. Hydronalix's Emergency Integrated Lifesaving Lanyard (EMILY), is controlled through a remote device and has underwater sonar vehicle which can show debris and used to reach people who needed assistance. Likewise,Ireland-based DroneSAR robot was created to detect vibrations and movement. Specifically, it is capable of monitoring chest movement and breathing among humans. Further, the authors Entrop et al. (2017)claim the computer vision gadget is capable of differentiating whether the object seen in its vision is a person or dummies. Moreover, an unmanned aerial vehicles equipped with infrared cameras (IR-UAVs) were among the latest model. The IR and UAV ability to search directions has to be refined fully especially when something need to be bridged in the construction domain. Thus, the research aimed to develop a protocol for IR-UAV flights to survey building thermography. It was noted during the last test flight that surveyed PV panels and a building's thermal shell, the protocol was valid. They added to the conversation on the application of IR-UAVs in the construction industry by describing the system, creating a protocol, and sharing their first hand observations.However, varying drone types were utilized by Nithyavathy et al. (2021) which are currently necessary in relation to the frequent occurrence of calamities and exceedingly in demand due to its adaptable applications for accomplishing improvements in human life. They are proficient in carrying out repetitive tasks while at the same time maintain quality standard products. In any ongoing work be it in infrastructure, marine transportation, air and inland water works, drones become a facility surveillance substitute that save human life from danger.

3. RESEARCH METHOD

Assembling and Programming of Robot

The functionality of the various electrical components of the controller and drone was tested. Subsequently, the drone kit and customized controller were assembled. The components of the drone controller—including the GPS M-1 antenna, GPS M-2 antenna, joystick modules 1 and 2, signal antenna, battery pack, and charging module—were connected according to the wiring diagram presented in Figure 1. Similarly, the drone components, such as the motors, blinker, GPS module, battery pack, and Phantom 3STA motherboard, were assembled following the wiring diagrams and designs illustrated in Figures 2 and 3, with the exception of the thermal camera. After the hardware assembly, the programming was conducted using the C++ programming language through the Arduino IDE, which was then compiled and verified for errors before being uploaded to the drone's main board.

Figure 1

Wiring Diagram of the Controller

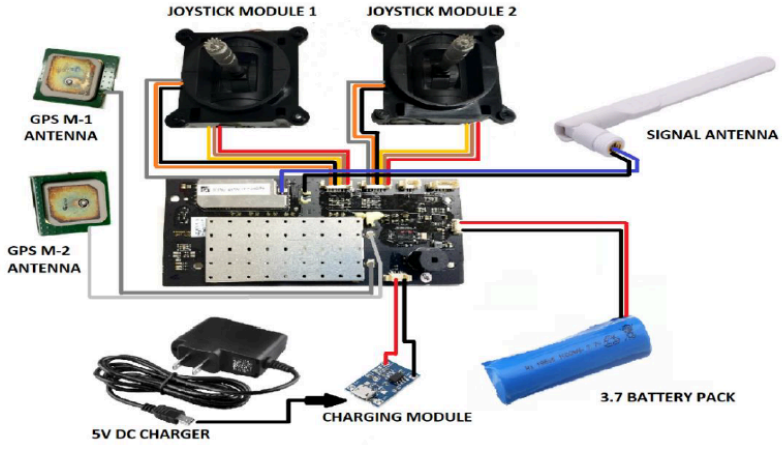

Figure 2
Wiring Diagram of the Drone

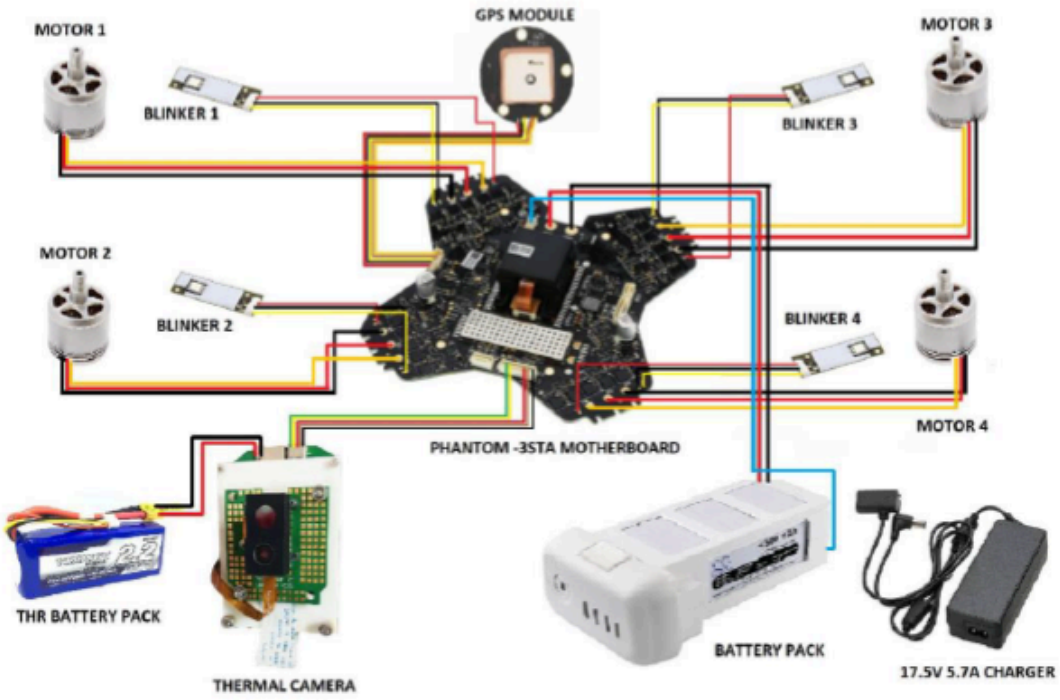

Figure 3
Actual Sr Pyroterra Thermatron

Testing of Robot and Project Consultation with Target Agencies

The thermal testing of the robot was conducted in the Bureau of Fire Protection (BFP) situated at Brgy. Lawaan, Roxas City. In this phase, the evaluation of the robot's capabilities in detecting fire and detecting a human using a thermal imaging camera was conducted. Representatives from the BFP and the

Provincial Disaster Risk Reduction and Management Office were in attendance to monitor the testing process. Their comments and recommendations were requested for improvements in the enhancement of the robot.

4. RESULTS

Table 1 shows that Pyroterra Thermatron is functional in terms of detecting fire, and humans using thermal energy with a success rate of 100%. Fire and human heat signatures are different as shown on the drone controller.

Table 1

Functionality of Pyroterra Thermatron in Fire Detection, and Human Detection Capability using Thermal Energy

Parameter	Functionality			Number of Successful Trials	Success Rate
	Trial 1	Trial 2	Trial 3		
Fire Detection	Yes	Yes	Yes	3	100%
Human Detection	Yes	Yes	Yes	3	100%

Legend: Yes - Detects, No - Did not detect

DISCUSSION

The findings of this study contribute to the existing body of knowledge by demonstrating the effectiveness of the Pyroterra Thermatron in enhancing search-and-rescue operations through advanced thermal imaging capabilities. This robot's ability to detect both fire and human heat signatures with a 100% success rate presents a significant advancement in disaster response technology. Previous studies, such as those by Arabboev et al. (2021) and Yano et al. (2020), demonstrated the utility of robots for search and rescue operations, but the Pyroterra Thermatron takes this further by integrating more refined thermal detection capabilities, making it especially suitable for scenarios with compromised visibility, such as during fires or in smoke-filled environments.

However, while the Pyroterra Thermatron offers significant advancements, there are notable strengths and limitations in the study. One of the strengths lies in the successful application of a drone equipped with high-resolution thermal cameras for effective detection. The limitation, however, is that the high specification of the equipment, particularly the thermal sensor, led to a shorter flight duration (30 minutes) and compromised stability, which made the drone prone to crashes during testing. In comparison to previous models, such as the Karo robot and other infrared-equipped drones (Entrop et al., 2017), the Pyroterra Thermatron is more advanced in terms of thermal range, but it still requires improvements in flight stability and endurance. These factors highlight the need for further optimization before large-scale deployment.

The scientific implications of these findings are substantial. The research demonstrates the potential of high-precision thermal drones like the Pyroterra Thermatron to enhance search-and-rescue missions, particularly in environments where visibility is limited and human intervention is dangerous. By improving the range and sensitivity of thermal detection (-20℃ to 400℃), this study advances the field of disaster robotics. It underscores the importance of refining drone technology to ensure that it can be reliably used in real-world emergency situations, potentially leading to quicker response times and reduced fatalities. This research supports the continued development of robotic systems as integral tools in future disaster preparedness and response efforts.

5. Conclusions

This study confirms the functionality of the Pyroterra Thermatron in detecting both fire and human heat signatures using thermal imagery, achieving a remarkable success rate of 100%. The findings indicate that the device effectively differentiates between varying heat signatures, as represented by color-coded displays on the drone controller, thus validating its utility as a search-and-rescue robot in fire-related scenarios. Despite these strengths, the study also identified limitations, including a constrained flight duration of 30 minutes and stability issues stemming from the weight of the thermal sensor, which necessitate further calibration and optimization. Given its thermal camera capabilities, including a range of -20℃ to 400℃, and a resolution of 120×90 with 10,800 infrared pixels, the Pyroterra Thermatron holds promise for enhancing search operations in challenging environments, particularly in the aftermath of disasters where traditional rescue methods may be compromised.

Recommendations

Based on the findings, it is recommended to further optimize the Pyroterra Thermatron by addressing the issues of limited flight duration and stability. This can be achieved by exploring lightweight thermal sensors and more efficient power sources to extend operational time and improve drone stability. Additionally, field testing in diverse environmental conditions, such as strong winds or bad weather, is advised to assess and enhance the drone's performance in real-world disaster scenarios. Future upgrades may also focus on integrating autonomous navigation features to reduce human intervention and improve precision in locating victims in inaccessible or hazardous areas.

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