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Study on Thermal Signature Detection using AMG 8833 Sensor for Low Visibility Rescue Operations

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Abstract - The AMG8833 Thermal Sensor is an affordable sensor that can be interfaced with a microcontroller to measure temperatures ranging from 0^{0}C to 80^{0}C. The Sensor, once connected to a microcontroller, can output an array of 64 temperature readings which is used to generate a thermal image. This study focuses on Thermal Signature Detection for Low Visibility Rescue Operations. A UAV drone prototype was designed to use the AMG8833 thermal Sensor for its field of vision when surveying a low visibility area. An Arduino Mega was used to interface the AMG8833, and an HC-05 Bluetooth module was used for wireless communication between the Arduino Mega and Laptop. The initial output of the AMG8833 Thermal only offers an 8x8 resolution which made it difficult to interpret the thermal image output. Bilinear interpolation using MATLAB was applied to resize the image into an 80x80 resolution to improve the thermal images. The processed thermal images were tested with varying distances and heat sources for its subject. The results were able to show that for ten trials, an average of 5.39 seconds processing time for the thermal images exists, and an improvement in thermal signature detection was found. The AMG 8833 Sensor can be used in Heat detection in low visibility environments but must be within 35-45cm from the Sensor. More complex image processing techniques may be applied further to enhance the image output of the low-resolution Sensor. It is recommended that a high-resolution thermal sensor be used for these applications for better results.

Keywords: *AMG8833; Thermal Images; Image Processing*

INTRODUCTION

Time, Environment, and Equipment are the factors that rescuers consider during rescue operations. There are cases during Search and Rescue (SAR) wherein the environment affects the duration of a rescue mission. This may be due to low visibility, wherein victims are challenging to locate. Having the right tools and equipment improves how fast victims can be rescued. A reconnaissance drone with thermal imaging capability can help find victims in low visibility areas. For this study, the AMG 8833 Thermal sensor is used to develop a UAV drone that aims to detect heat signatures in an area of interest.

Performing reconnaissance surveys allows determining the number of people in each area, what obstructions and the situation ahead, and what equipment to use to help people effectively. The rescuers need to do reconnaissance surveys to know the problem they will encounter and what they should do once they are there. The rescuers need gadgets to help them do reconnaissance surveys in the area that will not involve the study. Various Research papers support using thermal sensors in rescue operations. Perdana et al. [1] noted that a thermal sensor is needed to identify victims from the complex background, and it is much better if it is in aerial view. The thermal sensors will detect heat signatures that can easily distinguish through heavy intensity colors. Thus, helping the rescuers to visualize the surroundings within the rescue operation if there is a victim.

The researchers observed different studies to improve the existing research when creating a reconnaissance system. In flooded areas, the rescuers mostly use boats as their equipment for rescuing people. Consequently, limited vision while traversing the flooded area [2]. Considering the need for a wide view that would easily spot the people who need help, developers should create a system that could widen the search area and easily spot the victim. Navigation is critical when traversing a disaster site; thus, developing a navigation system for the UAV is a must [3]. Considering that a navigation system was implemented, there are still obstructions that could affect the flying of the UAV. However, there is a lack of papers and journals that use UAVs as a reconnaissance system in a low visibility environment. In a low visibility environment, rescue operations will be on halt due to having no visuals, which affects the response time of the rescuers. Also, they may encounter obstacles while traversing the flooded area that could lead to injuries. It further proves the need to use a technology that could give information while making a rescue operation in a low visibility environment.

This research aims to develop a remote-controlled reconnaissance system for rescue operations in low visibility environments to help locate victims. Specifically, the study seeks to detect the presence of humans in low visibility environments like nighttime flooding in low to no lighting using thermal sensors.

The study is limited to using the AMG8833 Thermal Sensor for its field of vision in a low visibility area. An affordable UAV drone was used in this study and was piloted by the researchers during data gathering. The testing area is in an enclosed home environment to eliminate other external factors such as wind. The data range also depends on the HC-05 Bluetooth module, rated from 36 meters to 44 meters. The flight time of the UAV drone is also dependent on its battery.

METHODOLOGY

This chapter discusses the function and the development of the remote-controlled reconnaissance system. The methodology emphasizes the design of the Sensor, system flowchart, and data gathering methods.

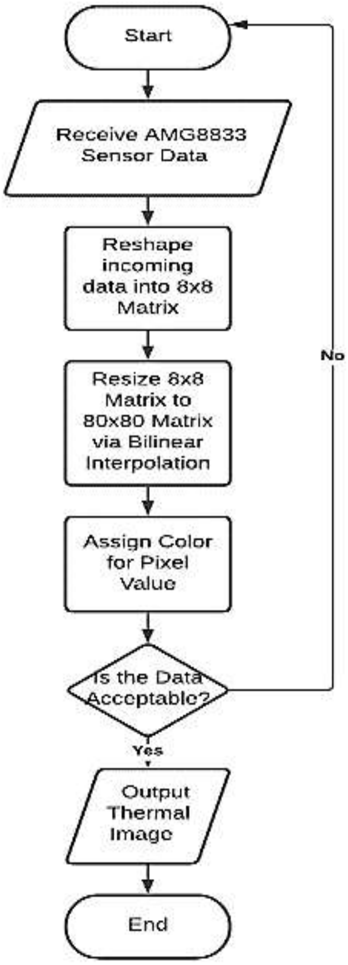


Figure 2.1. System Process Flow chart

In figure 2.1 shows the system process flow chart. This shows the process involved in enhancing the output of the AMG8833 Thermal Sensor. The process starts by receiving the data from the Sensor; the Sensor's output is only an array of eight temperature values. The values were designed to be reshaped into an 8x8 grid representing the image. This 8x8 image is considerably a low-resolution output, which is seen in further parts of this study labelled as unprocessed images. The 8x8 output is processed using MATLAB to make the image much clearer. The 8x8 output was resized to an 80x80 output using the image toolbox library. The process involved bilinear interpolation in approximating the values in between known variables. Once the output was interpolated, colors were assigned depending on its temperature value. A higher resolution thermal image was generated based form the initial 8x8 array data.

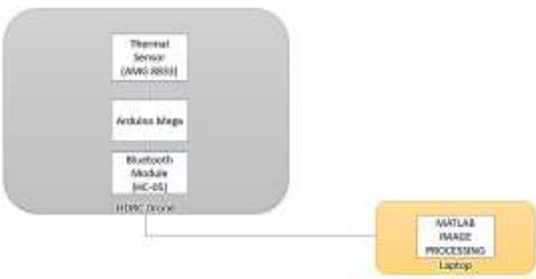


Figure 2.2. Block Diagram for Remote Controlled Reconnaissance System.

In figure 2.2, shows the block diagram for the prototype. Since the device is intended for reconnaissance in low visibility environments, this study uses a UAV drone wherein the AMG8833 and the microcontroller is placed. To have a wireless transmission of data from the microcontroller to the laptop, an HC-05 Bluetooth module was used for data communication. The image processing application installed in the computer is the one that will interpret and generate heat signatures based on the output from the AMG8833 Thermal Sensor.

Figure 2.3. Thermal Sensor Location

In figure 2.3, it was shown that the AMG8833 could detect heat signatures which helps determine the presence of humans in the area. The heat radiated from the body of people will appear as hot spots in the thermal sensor output. To further enhance the output of the AMG8833 Sensor, image processing techniques are based on this paper [4].

RESULTS AND DISCUSSION

This chapter discusses the Results of Heat signature Detection with the Image processing application. The results also compare the unprocessed 8x8 resolution output and the processed 80x80 resolution output.

Figure 3. Set Up for Single Heat Source (Human)

In figure 3, it shows the initial setup with a Single Person as a Heat Source. This test will compare the results of the unprocessed image and the processed image while also considering the distance of the Heat Source from the AMG 8833 Sensor.

Table 3.1. Single Heat Source

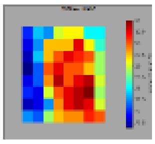
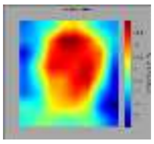
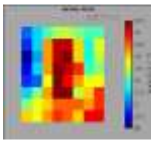
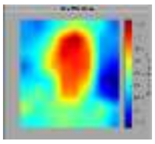
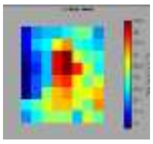
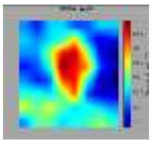
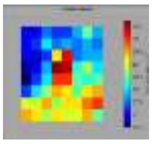
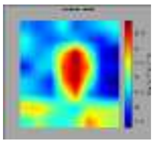
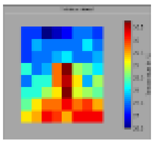
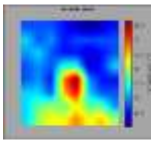
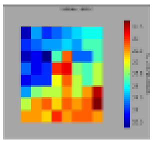
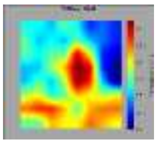
SINGLE PERSON HEAT SOURCE		
Distance to Sensor	Unprocessed Image	Processed Image
15cm		
25cm		
35cm		
40cm		
45cm		
50cm		

Table 3.1 shows the unprocessed and processed image of a single heat source. In the unprocessed image, the shape and the heat signatures are scattered as the single heat source moves away from the thermal Sensor. It does not give a clear picture of whether it is a human or not. In the processed image, the shape and the heat signatures are clearly defined, wherein it can detect the heat source that emits high temperature and low temperature. As the source moves away, the hotness of the single heat source dissipates, as can be seen on the image's shape in 50cm.

Figure 3.2. Set up for Single Heat Source (Artificial Heat Source)

Figure 4.1 shows the initial setup with a lamp or an artificial source of heat as a Heat Source. This test will compare the results of the unprocessed image and the processed image while also considering the distance of the Heat Source from the AMG 8833 Sensor.

Table 3.2. Artificial Heat Source

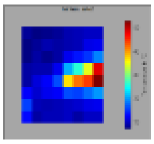
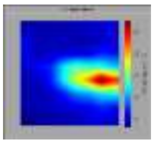
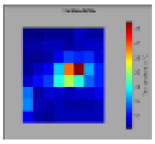
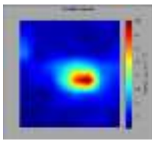
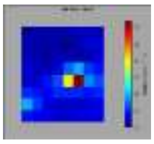
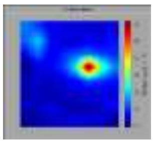
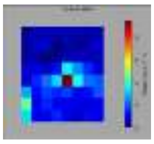
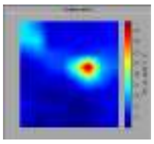
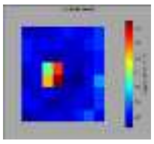
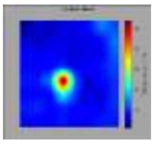
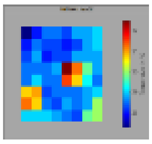
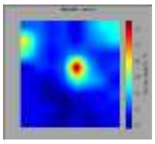
ARTIFICIAL HEAT SOURCE (LAMP)		
Distance to Sensor	Unprocessed Image	Processed Image
15cm		
25cm		
35cm		
40cm		
45cm		
50cm		

Table 3.2 shows the unprocessed and processed image of an alternative heat source, which is the lamp. In the unprocessed image, the artificial heat source is not defined, and the element in the array is not exact. As the artificial heat source moves away, it becomes fuzzy, and the artificial heat source cannot be seen clearly. The processed image is defined and clear where the heat is coming from. As it moves away, the artificial heat source becomes a small circle.

Figure 3.3. Set up for Two Heat Sources (Human and Dog)

Figure 3.3 shows the initial setup with two Heat Sources, which used a Human and a dog as Heat Source. This test will compare the results of the unprocessed image and the processed image while also considering the distance of the Heat Source from the AMG 8833 Sensor.

Table 3.3. Human and Dog

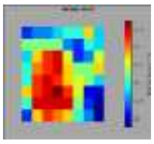
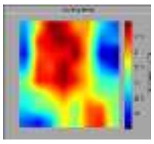
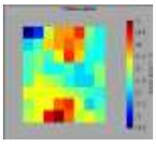
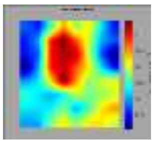
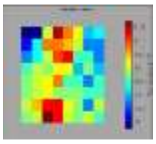
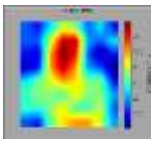
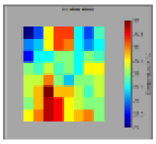
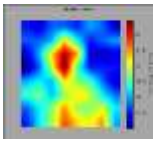
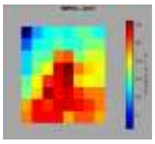
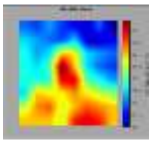
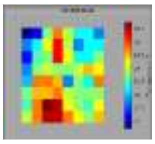
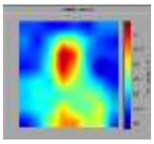
2 HEAT SOURCES (HUMAN AND DOG)		
Distance to Sensor	Unprocessed Image	Processed Image
15cm		
25cm		
35cm		
40cm		
45cm		
50cm		

Table 3.3 shows the unprocessed and processed image of a human and dog. In the unprocessed image, the shape and heat signatures are scattered and cannot identify human and dog. As it moves away, the heat source in the image is scattered even the shape is unidentifiable. The dog cannot be clearly identified in the processed image because of its fur. The thermal Sensor clearly detects the high temperature the human gives off. It was known that animals give off a higher temperature than humans, but the thermal Sensor cannot detect their hotness and shape because of their fur.

Figure 3.4. Set Up for Two Heat Sources (Human and Human)

Figure 3.4 shows the initial setup with Two Heat Sources with Two Humans as Heat Sources. This test will compare the results of the unprocessed image and the processed image while also considering the distance of the Heat Source from the AMG 8833 Sensor.

Table 3.4. Human and Human

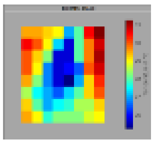
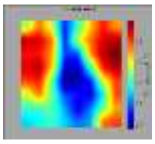
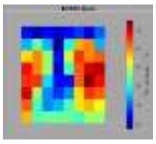
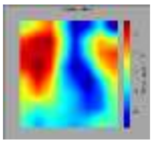
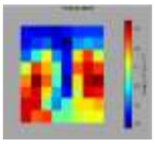
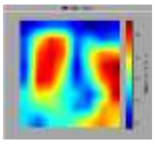
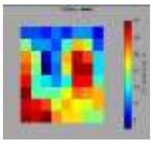
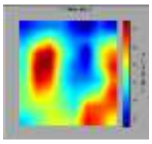
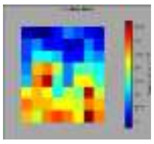
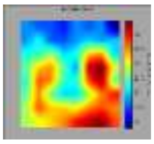
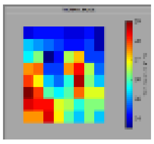
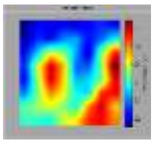
2 HEAT SOURCES (HUMAN AND HUMAN)		
Distance to Sensor	Unprocessed Image	Processed Image
15cm		
25cm		
35cm		
40cm		
45cm		
50cm		

Table 3.4 shows the unprocessed and processed image of two humans. In the unprocessed image, two heat sources can be seen easily and as it moves far away one heat source is not clearly defined in the thermal image. In the processed image, the shape and heat signature are clearly detected. It gives off the same heat signature seen in the temperature gradient. As it moves away, two human shapes are still clearly defined in the thermal image.

Figure 3.5. Set up for Two Heat sources (Human and Artificial Heat Source)

Figure 3.5 shows the initial setup with Two Heat Sources. A Human and a lamp served as Heat Sources. This test will compare the results of the unprocessed image and the processed image while also considering the distance of the Heat Source from the AMG 8833 Sensor.

Table 3.5. Human and Artificial Heat Source

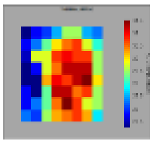
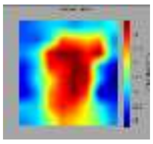
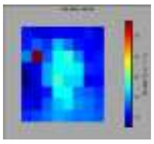
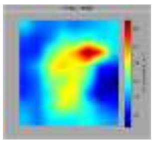
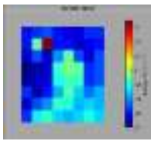
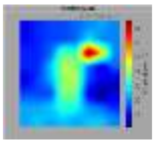
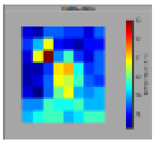
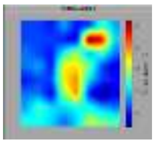
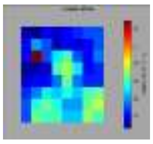
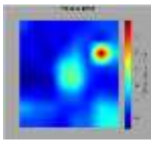
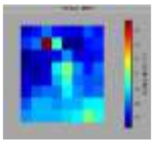
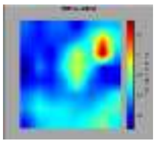
2 HEAT SOURCES (HUMAN AND ARTIFICIAL)		
Distance to Sensor	Unprocessed Image	Processed Image
15cm		
25cm		
35cm		
40cm		
45cm		
50cm		

Table 3.5 shows the unprocessed and processed image of a human and an artificial heat source. In the unprocessed image, it is not clear which is the human and the artificial heat source. As it moves away, the heat source is not detected, and a blue temperature gradient can be seen. In the processed image, the human and the artificial heat source cannot be identified while they are both near the Sensor, but the high temperature is clearly defined. As it moves away, the human is not detected, and the artificial heat source was shown. The thermal Sensor detects the highest temperature and makes it clear in the image.

Table 3.6. Processing Time of Thermal Image

Trial	Processing Time (sec)
1	5
2	4.99
3	5.12
4	5.25
5	5.32
6	5.77
7	5.45
8	5.51
9	5.58
10	5.91
Average	**5.39**

Table 3.36 shows the processing time of the thermal image from Bluetooth to the laptop. Ten trials were conducted, and the processing time averaged 5.39 seconds. This shows that a delay of approximately 5 seconds exists in data transmission and image processing time.

H_O: Detection of other heat sources in low visibility environments is not improved due to added sensors.

H_A: Detection of other heat sources in low visibility environments is improved due to added sensors.

Table 3.7. Testing Heat Detection

TESTING HEAT DETECTION		
Trial	Number of Heat detected using Sensor	Number of Heat detected without Sensor
1	4	0
2	3	0
3	3	0
4	4	0
5	4	0
Average	**$x_1 = 3.6$**	**$x_2 = 0$**
Standard Deviation	**s_1=0.5477**	**s_2=0**

Table 3.8. Images of Testing Heat Detection

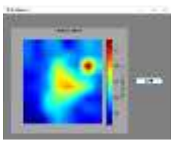
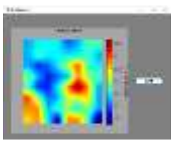
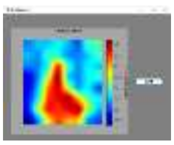
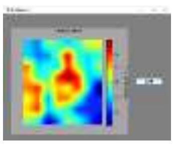
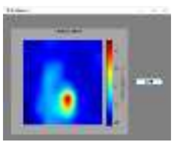
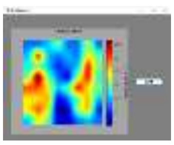
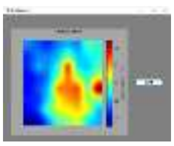
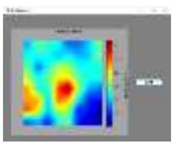
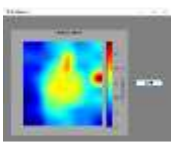
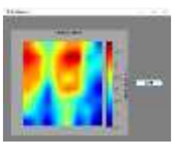
IMAGES OF TESTING HEAT DETECTION			
Trial	Thermal Image		Number of Heat Sources Detected
1			4
2			3
3			3
4			4
5			4

Table 3.8 shows the thermal images captured during the five trials for Heat detection.

Having five samples for each parameter, the degree of freedom for the t-test is 8. Considering the set p-value is 0.05, the critical value used in the t-test is 2.132. The resulting value must be higher than 2.132 to reject the given null hypothesis.

Conducting the statistical analysis on the testing of heat detection on numbers of heat detected with and without sensors showed t-value of 14.70. This means the null hypothesis of detecting other sources of heat in low visibility environments is not improved due to added sensors will be rejected. Thus, detection of other sources of heat in low visibility environments has improved due to added sensors.

CONCLUSION AND RECOMMENDATIONS

The researchers were able to design a Remote-Controlled Reconnaissance System for low visibility Rescue Operations using AMG8833 Thermal Sensor. This was achieved by installing Arduino Microcontrollers to the Drone. The Arduino receives and interprets data from its Sensor.

The objective of this study was to detect the presence of humans in low visibility environments such as in low to no lighting using thermal sensors. This was achieved by using the AMG8833 Thermal Sensor. However, this Sensor outputs a low-resolution 8x8 image. To meet the objective using this Sensor, image processing techniques were used. Using MATLAB, image processing such as bilinear interpolation allowed the researchers to expand the 8x8 image into an 80x80 resolution. The processed output thermal image showed an improvement and was able to approximate the shape or figure of the heat source.

Based on the results of this study, low-resolution outputs can only be processed to a certain degree of clarity. It may not accurately represent the temperature and figure of the heat source. For the case of this Sensor, the best heat signature representation can be generated when the distance of the Sensor to the target is between 35cm to 50cm. The Sensor can better detect when there is a single heat source. In cases wherein there were multiple heat sources, if the temperature difference of the heat sources was high, the Sensor outputs the higher temperature. It is recommended to have a thermal sensor with a high frame rate and resolution to easily detect and distinguish a human and other source of heat.

The study was able to show that AMG8833 thermal imaging for low visibility rescue operations can be used only for close-range applications such as a distance of 35cm to 50cm from the subject. This also shows that long-range application using the AMG8833 is not recommended due to its low resolution and frame rate. It is suggested to use other thermal Sensors with higher resolution for similar applications.

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