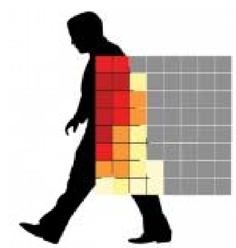
Department of Electrical and Computer Engineering

1867
HOWARD
UNIVERSITY

Senior Design Project:
Multi Target Thermal Detection Grid-Eye Sensor



By:
Daley Gunter
Pierre Charles
Shaddy Abdelaal

Advisor	**Name**	**Signature**	**Date**
Class Instructor	**Name**	**Signature**	**Date**

Table of Contents

1. Introduction

1.1 Objective of the Project

The aim of this project is to propose the use of a GRID-EYE sensor as part of a device which shall detect both the position and the intensity of the heat radiated by the surface of either a single or multiple targets or to utilize a Hot Target Mode (HTM) to track the target with the highest temperature when multiple elements of interest are involved at the same time. A windows-based computer system will also interface with the Grid-Eye Sensor system by means of wireless communication to control the operating mode of the sensor and to provide a thermal image of the target on the computer screen.

1.2 Background of the project

This project is sponsored and has been proposed by Northrop Grumman Corporation (NGC). The requirements for this project are principally set by NGC and must serve as the framework within which we will design the proposed system. Our focus will address the need of our client for the design and the development of a mode-controlled Grid-Eye Sensor System which tracks a target or the hottest target among many, then feedback visual reference and description of the object on a computer monitor by way of a wireless communication liaison. Once the system has been successfully tested and delivered, our client will thus utilize the finished product for both commercial and military purposes as they see fit in satisfying their needs.

2. Problem

2.1 Problem Formulation

Our client finds it necessary to propose the development and the design of this system as an alternative solution to the issues of increasing casualties upon our troops in combat zone from undetected enemies at close proximity. A sensor system of this nature has a wide range of uses in the military as-well-as the commercial world. During the course of the wars in Afghanistan and Iraq, casualties inflicted upon our soldiers as a result of enemies surprised attacks at a very close distance are second only to those resulted from Improvised Explosive device (IED). Therefore, the realization of this system will be advantageous in providing advanced knowledge and visual reference about enemy position in the field and will allow soldiers to neutralize these threats before they are fully materialized in terms of casualties among their ranks and loss of logistics. The Grid-Eye sensor is sufficiently small that it can also be concealed for the purpose of surveillance. The size of the sensor and its tracking ability are definitely important parameters that add to the efficiency of the device in detecting and helping to take out fast approaching and close enemy targets. We are sure that this system can be used on a variety of military vehicles and equipment and therefore will ensure the safety of our troops while helping to curb significantly the number of casualties during close engagement in combat.

2.2 Problem Definition

Design a device which uses a bimodal Grid-Eye sensor that has the ability to detect single or multiple targets by way of thermal sensing mechanism and can also be made to track the one with the hottest temperature through a graphical user interface set between a microcontroller and a base computer where the end user can operate a user friendly program to switch between usage modes of the sensor and thus setting it to HTM when desired to get the sensor to track the one with the hottest temperature among all the objects.

2.3 Design Requirements

The following requirements are set by the client around the following parameters and constitute the framework within which our design must and will be realized:

1. The requirements shall apply to the overall Grid-Eye System Assembly and shall comprise all individual subcomponents. Workmanship shall conform to Guideline 9 of MIL-HDBK-454 and be guided by Guidelines 5 and 17.

2. Requirements can be waived pending supplier and NGC agreement.

3. Any agreement to modify or change the requirements document shall be solely between supplier and NGC. There shall be no third part intervention. Any changes in this document shall be document by rev control. i.e., 01, 02, 03, etc…
   All hardware/software final products shall be the property of NGC and are considered deliverables

4. Safety
   - The Grid-Eye System Assembly shall be designed to include safety features to eliminate or control potential hazards to personnel and equipment without impairing performance. The Grid-Eye System Assembly shall implement design features using MIL-HDBK-454, Requirement 1, MIL-STD-1472 paragraph 5.13, and SAE AS 50881 as a guide.
   - The principal design criteria shall be that no malfunction, failure, or event occurring in the Assembly shall result in a personnel hazard or damage to other portions of the Assembly or a higher-level assembly. No failures, malfunctions, or events within the Assembly hardware shall have the potential of creating a safety of event or personnel hazard.

5. Preparation for Delivery
   - Preservation, packaging, and packing of Grid-Eye System Assembly shall be accomplished in a manner, which will afford protection against physical and electrical damage during shipment from the Supplier to Northrop Grumman Corporation.

6. Environmental
   - The Grid-Eye System Assembly shall meet the performance requirements as specified herein when subjected to the environments specified below in any sequence or combination unless otherwise stated.
   - During and after exposure to these environments, there shall be no deterioration of protective coatings, pitting or other destructive corrosion, deformation, warping or other loss of dimensional integrity, binding of moving units, cracking, loose parts, or detrimental damage of any type and the Grid-Eye System Assembly shall meet the requirements of this specification except as otherwise noted.

7. Thermal
   - The Grid-Eye System Assembly shall meet the ambient-temperature requirements.

8. Operational Temperature
   - The Grid-Eye System Assembly shall meet all performance specifications while suffering neither damage nor degradation of performance, when operating within any ambient temperature in the range from –15 °C to +49 °C.

9. Non-Operational Temperature
    - The Grid-Eye System Assembly shall meet all operational-performance specifications (in particular, suffering neither damage nor degradation of performance) following prolonged exposure in a non-operational mode to any fixed ambient temperature in the range from –20 °C to +71 °C.

10. Humidity
    - The Grid-Eye System Assembly shall meet all performance specifications, while suffering no damage during prolonged operation both at any fixed relative humidity and under transitions between relative humidity values lying between 5% and 95%. A non-condensing environment shall be assumed. The Grid-Eye System Assembly shall sustain neither physical nor electrical damage when subjected to the test of MIL-STD-810F, Method 507.4 for 10 days, where applicable electrical tests should be performed after 1, 5, and 10 days of cycling.

11. Built In Test (BIT)
    - The Grid-Eye System Assembly shall be capable of executing all BIT at any ambient temperature within the range from –20 °C to +49 °C.

12. Storage and Transit
    - The Grid-Eye System Assembly shall meet the storage and transit conditions for any ambient temperature in the range from -20 °C to +71 °C.

13. Thermal Shock
    - To Be Determined (TBD)

14. Operational Altitude
    - The Grid-Eye System Assembly shall not exhibit degraded performance over the entire range of AV operational flight-altitudes from 0 ft. up to 1000 ft. on a standard day.

15. Non-Operational Altitude
    - The Grid-Eye System Assembly shall meet all operational-performance specifications, in particular, suffering neither damage nor degradation of performance, following exposure in a non-operational mode to a pressure altitude of 35,000 ft., anticipated during air transport.

16. Sand and Dust
    - TBD

17. Fungus
    - The Grid-Eye System Assembly shall meet all performance specifications, while suffering neither damage nor degradation of performance, following exposure to fungus and/or adjacent fungal growth during and after a period of exposure to viable fungal spores, per MIL-STD-810F. This fungus requirement shall be verified by analysis of all potential fungus-nutrient materials used in the fabrication of the Grid-Eye System Assembly hardware.

18. Explosive
    - The Grid-Eye System Assembly shall not cause detonation of an explosive atmosphere environment, per MIL-STD-810F, Method 511.4.

19. Functional Shock
    - The sensor assembly shall be able to withstand a 6g shock load.

20. Electromagnetic Hazards
    - TBD

21. Volume Outline ICD
    - The envelope dimensions of the Grid-Eye Sensor Assembly shall meet the requirements of drawing XXXXXXX.

22. Weight
    - The weight of the Grid-Eye Sensor Assembly shall be 1 lb max. 0.5 lb. is desired.

23. Scanning Range of Grid-Eye Sensor Assembly
    - The Grid-Eye Sensor Assembly shall have the ability to scan +/- 90 degrees. General scan rate shall be 5 degrees per second. In HTM mode, the sensor assembly shall have the capability to scan at rate of 11 degrees per second.

24. Rate Sensor
    - The Grid-Eye Sensor Assembly shall have the capability of reporting rotation rate respective to the axis of rotation.

25. Power On Mode
    - At power on, the Grid-Eye Sensor Assembly shall point to zero as per the ICD XXXXXXX.

26. Power Supply
    - The Grid-Eye Sensor Assembly shall be powered by a 9 volt power supply where the voltage can be regulated for the indicated power required for the Grid-Eye Sensor and the rotating mechanism.

27. Micro-Processing Control
    - The Grid-Eye Sensor Assembly shall have an integrated micro-processing control. One recommended processor is the Arduino UNO open source micro-processor. The supplier is not limited to using the Arduino board

28. Computer Control
    - A widows based computer system is required for interfacing with the Grid-Eye System Sensor. The allowed interface between the computer and the Sensor Assembly shall be a USB cable.

29. Wireless Usage
    - The supplier shall develop a wireless communication protocol between the base computer and the Grid-Eye Sensor Assembly. The distance of operation shall be 1500 feet direct line of site. This wireless design shall allow the end user to command the Grid-Eye-Sensor Assembly in all modes of operation and allow for the saving of data on the base computer.

30. Graphical User Interface
    - Supplier shall develop a graphical user interface by way of a wireless communication protocol where the end user can operate a user friendly computer program to switch between usage modes of the sensor. All commands shall be driven through this operating interface and the interface shall have the ability to retrieve saved data files and display thermal images on a computer screen.

2.4 Compliance

1. The Grid-Eye Sensor Assembly shall meet the ESD requirements as specified in paragraph 5.7 of MIL-STD-464A.

3. Current Status of Art

3.1 Available Technology

There are about three different types of thermal sensors: Passive Infrared (non-array), Thermopile (single element) and the Grid-Eye. All three types share certain characteristics such as: a built-in lens which offers a 60° viewing angle in both horizontal and vertical directions. Both the Thermopile and the GRID-EYE are considered to be high gain models since they offer the highest temperature accuracy while the Passive Infrared sensor is considered to be a low gain model since it is available for the widest temperature range. They are equipped with a digital output via an external interface, Inter-Integrated Circuit (I^2C) which provides direct temperature values to a microcontroller without any required conversion. And among other features include selectable frame rate and operating modes for normal, sleep and stand-by operations. All of them are built to detect moving object but only the GRID-EYE and the Thermopile are able to measure temperature.

While they share so many features, the GRID-EYE offers the widest range of features when compared with single element thermopile and multiple element passive infrared sensors. Motionless object detection, movement direction and thermal image with 64 pixel resolution are unique features for the GRID-EYE infrared array sensor.

3.2 Advantages and Disadvantages on available device

- Sense people or objects in motion
- Detect changes in temperature / Temperature values output / Built-in lens (60
- Motionless detection.
- Detect movement direction: up, down, right, left, sideways
- 8 x 8 pixel array / Digital output I^2C / Direct connection to microcontroller
- Sufficiently small to conceal for surveillance purposes

- Sensitive to physical and electrical shock
- Sensitive to humidity
- Very fragile for packaging and in transporting

4. Solution Approach

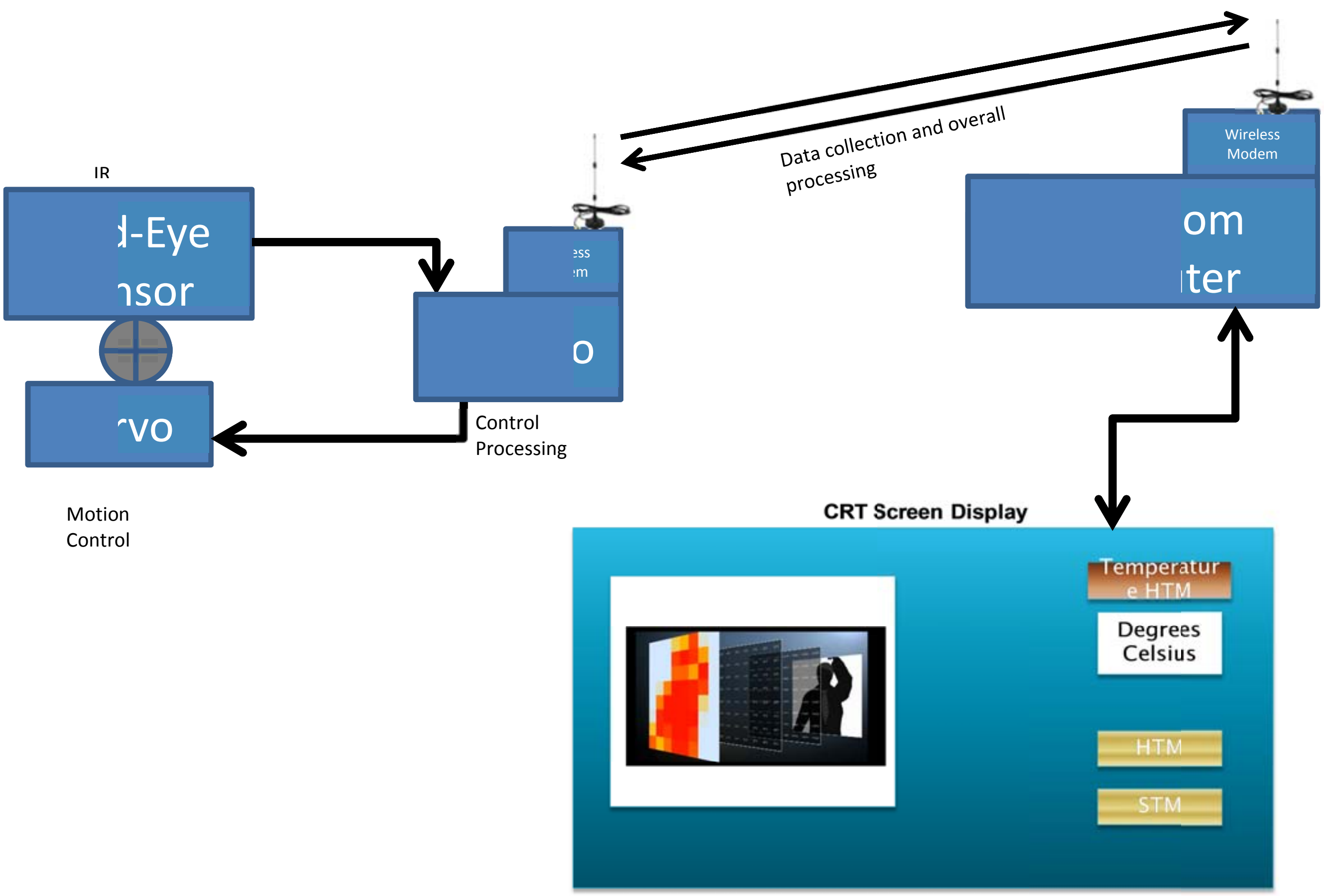
4.1 Solution Description and Expectation

Our proposed solution approach delineates the order and the way in which an input in the form of a heat signature of an object is captured by the sensor and processed within the three principal functional blocks of the system and returns an output in the form of a thermal image on a computer screen. Our system will comprise four main blocks and will be grouped as follows: Pan/Tilt Servo motor, Grid-Eye sensor, Arduino Micro Processing Board UNO and Intel Board (Microcomputer).

The Servo will be mounted upon the base of a tripod or a table and will be set to perform a 180° rotation upon the base of which the sensor will be mounted in order to rotate along with the servo. The Arduino Micro Processing board will be integrated with both the servo and the sensor as a way to establish some functional control upon both the motion of the servo and the temperature data detected by the sensor. At last, in order to project a thermal image of the sensed object, the microcomputer will be interfaced with the Arduino UNO Board as a peripheral using a compatible program that can show a graphical representation of the data as a thermal image on an integrated screen.

Our expectation is to see that our plan takes us through at least ninety percent of our proposed solution by the end of the month of February and if need be, then make necessary adjustments as we complete our project.

4.2 Primary Solution



(Block diagram of the Multi-Targeted Thermal Detection Grid-Eye System)

After the thermopile array absorbs emitted infrared radiation (IR), all 64 measurements are passed on for signal amplification. Then, amplified signals pass to the analog-to-digital converter and are referenced against a thermistor value. Finally, digital signals are compared against stored values and temperature values are output via an I^2C interface directly to the Arduino UNO board.

On one hand, the I^2C performs specific calculations that allow the mapping of specific temperature data as thermal image and on the other hand, the Arduino UNO board is conveniently equipped with both digital and analog I/O pins which make it easy to interface with an Intel microprocessor in order to provide demonstration for our design concept.

Furthermore, the Intel Board will serve as a computer system and will interface with both the microcontroller and the Grid-Eye Sensor System in order for the user to have access to the temperature data and at the same time to control the operational mode of the sensor and the motion speed and direction of the servo. A wireless communication protocol will be established as a channel of command to control the operational mode of the sensor from the end user on the base computer. This wireless design shall allow the end user to command the Grid-Eye-Sensor Assembly in all modes of operation and allow for the saving of data and the graphic representation of the thermal image on the integrated screen.

4.3 Scenarios Consideration

There are a few important considerations to make about the proposed design. In the event there are multiple objects or targets, the sensor is expected to track the one with the highest temperature once it is set to the HTM by the end user. In parallel, if two sensors are used simultaneously instead of one, depending on the manner in which they are used with respect to each other, they can be made to complement each other in the increase of the overall field of view and even its range on a lesser degree. And finally, besides the thermal image produced on the screen, the integration of a camera should avail greatly in capturing an identical image of the object of interest.

4.4 Testing and Verification Plan

We will build a prototype of the proposed design to test and demonstrate first of all the ability of the Grid-Eye sensor to detect and track an approaching single target and secondly demonstrate how the sensor can also detect multiple targets simultaneously but made to track the target with the higher temperature through the command from an end user that operates a base computer from which the mode of the sensor can be set to perform the desired task through a wireless channel.

We will show how all the temperature data is transmitted from the sensor through an interface into an open platform that is especially recommended by our client and it is the Arduino UNO microprocessor. We will also show and demonstrate an interactive graphical representation on a computer screen of live heat detection by the sensor and its tracking of a target or object with the higher temperature among many of them.

5. Tasks and Deliverables

5.1 Tasks

Each group member will be required to participate in discussion about every aspect of the project from the most fundamental to the smallest details about the role and impact of each component that comprise our system and comprehend every aspect of the project utilizing multi-discipline engineering fundamentals. All three-member team will be assigned a specific task to accomplish within a determined period of time and it will be distributed as follows:

Group Member	Tasks
Pierre Charles	Detection and tracking of objects by the sensor and the subsequent transmission of temperature data from the sensor to the Arduino Board and the coordination of the servo with the sensor
Daley Gunter	Develop wireless communication protocol that allows an end user utilizing to send command the Intel Board microprocessor to the sensor to switch to the desired mode whenever necessary.
Shaddy Abdelaal	Implementation of Control and Signal processing coordination within the system and software development.
All	Coding, Testing and building of the complete base.

5.2 Deliverables

We expect to have a working prototype of the device by the date of EECE day April 2013. The device is expected to be capable of detecting single or multiple objects present in the sensor's field of view, and tracking the object with the highest temperature once set on the HTM by the end user on the microcomputer. The end user must be capable of projecting a thermal image of that object on any proposed screen.

6. Project Management

6.1 Solution Implementation Plan

The implementation of our solution will follow a methodical study about the functions and the role of each major component and how they all interact within the system. Below is our plan for the implementation of our solution:

- Study and learn the properties and the functions of each major component of our system
- Develop block diagrams to represent the layout for communication between each and all parts
- Determine the input and output to each block diagram and the input and output to the overall system
- Examine the Control Theory and the Signal Processing relevant to the organization and order in the workings of the system
- Produce Software desirable for the implementation of Control between functional blocks of the system
- Testing and Modification if necessary

6.2 Timeline and Milestones

Objectives	**Dates**
Initial Proposal	September, 2012
Written Proposal 1	October 30, 2012
Written Proposal 2	November, 2012
Final Proposal Presentation	November, 2012
Evaluation	November, 2012
Final Proposal Presentation	November,2012
Evaluation	November, 2012
Final Written Proposal	November, 2012
Peer Evaluations	November 2012
Design Finalizations	December, 2012
Ordering Of Parts	December, 2012
Commencement of the development of the design	January, 2013
Testing of project	February, 2013
Testing of project	February, 2013
Documentation of project	March, 2013
Presentation slide	March, 2013
Final Project presentation	April, 2013

6.3 Resources and Budget

Unit	Cost
Screws	$25.00
Grid Eye Sensor	Unit Price = $35.00 (Qty 4 = $140.00)
Intel Atom Board	$0 Provided
Mounting Fixture	$500
Servos	$200
Arduino Board	$65.00
Wireless Modem	$100.00

7. Conclusion

This document presents the proposed design of a Grid-Eye sensor system that detects multiple thermal targets where the sensor assembly will have the ability to use a HTM to track the target with the highest temperature. And in the end, an end user utilizing the microcomputer shall be able to use a compatible program to produce a thermal image of the object on focus on any proposed screen.

Our system shall be capable of detecting multiple objects within the field of view of the sensor will act to track the target with the highest temperature once the sensor is set to the Hot Target Mode. The Grid-Eye Sensor Assembly shall be integrated with an Arduino UNO open source which will process both the temperature and the thermal image data from the sensor. And, an Intel Processor Board will also be required for interfacing with both the Grid-Eye Sensor and the Servo from which an end user can directly control the mode of the sensor and subsequently the speed and direction of motion of the motor through our coding schemes when the sensor is set to track an object.

In short, this proposed design has been produced in accordance with standardized communication protocols and with consideration for efficient power usage, minimal cost and product size. Our plan, as stated earlier, is to have a working prototype of the device by the end of March 2013 before the EECE day in the following month in order to have enough time to make adjustments if necessary.

8. References

1. "Arduino." *Wikipedia*. Wikimedia Foundation, 28 Oct. 2012. Web. 31 Oct. 2012. <http://en.wikipedia.org/wiki/Arduino>.

2. "Infrared Array Sensor: Grid-EYE." *Factory Automation, Components, Industrial Sensors, Laser Markers*. N.p., n.d. Web. 31 Oct. 2012. <http://pewa.panasonic.com/components/built-in-sensors/infrared-array-sensors/grid-eye/>.

3. "Panasonic Quick Clips: Grid-EYE Evaluation Kit." *Panasonic Tech Insights*. N.p., n.d. Web. 31 Oct. 2012. <http://www.pidtechinsights.com/2012/02/27/panasonic-quick-clips-grid-eye-evaluation-kit/>.

4. "Panasonic's New Grid-EYE Sensor." *Design World*. N.p., n.d. Web. 31 Oct. 2012. <http://www.designworldonline.com/panasonics-new-grid-eye-sensor/>.

5. "Passive Infrared Sensor." *Wikipedia*. Wikimedia Foundation, 25 Oct. 2012. Web. 31 Oct. 2012. <http://en.wikipedia.org/wiki/Passive_infrared_sensor>.

6. http://dkc1.digikey.com/us/en/tod/PanasonicElectricWorks/Grid-EYE_NoAudio/Grid-EYE_NoAudio.html

7. http://www.digikey.com/product-highlights/us/en/panasonic-grid-eye/2108?WT.z_Tab_Cat=New%20Products

9. Appendix

9.1 Feasibility of the project

This project has been initially determined to be feasible by NGC as a result of their expertise in this domain. However, our own study and research about the principal aspects of the project have convinced us about its feasibility as well. One of the most important functions of our proposed system is the thermal detection of a target by the Grid-Eye sensor and the advantage to this, is the fact that we do not have to design the sensor itself and in addition it comes with its own integral ability to thermally detect and track target or object. Therefore, our work will simply consist in figuring out how to transmit the temperature data into the open source Arduino UNO microprocessor and from there how to get that data and show a thermal image on a computer screen. Our research has indeed taken us through similar successful realization and thus we are confident about the feasibility of our proposed design.