Department of Electrical and Computer Engineering

Portable Perimeter Detection System: Final Proposal

Howard University
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Subject: Portable Perimeter Detection and Monitoring System – Proposal

Enclosed is The A-Team's proposal design for the implementation of a Portable Perimeter Detection and Monitoring System for the 2010/2011 Senior Design class project. Based on an extensive research into currently available portable detection systems, as well as lane sensor technologies, *The 'A-Team'* has drawn up a detailed solution to the problem posed by the PoPDaMs project. Our engineering solution approach outlines the following information:

- Primary Solution
- Scenario Considerations
- Benefits, Future Improvements, & Practicality
- Testing & Verification Plan
- Relevant Knowledge & Coursework
- Alternate Solutions

Also included in this proposal is a brief history and background of PoPDaMs, the status of PoPDaMs technologies currently available in the market, the problem statement and design requirements, and the A-Team's project management strategy.
The research for this proposal was based on information on sensor technologies and existing detection systems specifications in online sources. See the *References* section of this proposal for more information.

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Introduction

Objective

The objective of Team-A is to produce and demonstrate a system that

- Will monitor the specified perimeter
- Can differentiate between friend or foe
- Will sound an alarm if a foe is detected
- Can communicate safely and securely within the network

Background

Late at night, when visibility is limited, the anxiety of soldiers increases greatly. It is also at night that death by friendly fire is most prevalent. To protect our troops from wrongful death or even ambushes, a perimeter detection system is necessary.

Problem

Problem Definition

The challenge we have is to design a system that has proximity alarms and monitors that should be activated if soldier is approached by an enemy within the perimeter specified by the system.

Design Requirements

The constraints imposed on this project require that our proposed design must meet the following requirements:

1. <u>Overall Function</u>:
   a. Alarms should go off is a foe is detected

2. <u>Performance</u>:
   a. Should have a detection range of 15-30 feet.
   b. Should have an operating temperature of -10 - 25 degrees Celsius (14 - 77 degrees Fahrenheit).
   c. Should have night time image detection.
   d. should be able to classify the detected object as a threat or non-threat
   e. Should have wireless communication.
   f. Should be battery powered (12V DC, 100AHr).
   g. Should be portable (exact weight - TBD).

3. Compliance:
   a. PoPDaMs hardware should meet the electrical and wireless requirements as stated below:
      - IEEE electrical standards
      - United States Military Standards (if used for military applications)
   b. PoPDaMs communication or network system should be ad hoc

4. Monitoring-Communication Interface:
   The design will include one complete system with all sensor types and the ability to detect friend or foe. It will serve as a prototype of one of many backpacks in a complete network. The back pack will make use of
   a. Analog and digital data processing
   b. Data encryption and information security
   c. Portable display system
      - Monitor should display the reports of the detection
      - The system should alarm the soldiers only in the event of a foe

5. Energy, Power & Environment:
   a. Be energy efficient

6. Size:
   a. The total system should be portable and light enough to be carried by a soldier (in addition to the weight of the other required items).
   b. Exact size - TBD

Assumptions

In deciding the scope of this project, assumed that a secure communications method already exists within the United States armed forces.

Current State of the Art

Perimeter Detection Systems

At present, there are many perimeter detection systems on the market, but none that meet all of the specified requirements.

The current detection systems on the market

- Are not very rugged.
- Are portable, but not mobile. In other words, they can easily be transported from one location to the next, hence are portable, but do not operate while in motion, or while mobile.

- Generally have one sensor technology, and only process signals inherent to that particular sensor. They do not incorporate and process multiple sensor and signal types.
- Do not differentiate between friend and foe.

With respect to all the given requirements, there is currently no technology of such on the market.

Design Technologies

For each of the components that we intend using for the project, these are their current states of art.

Processor Type

The design of the Portable Perimeter Detection and Monitoring System requires the use of a central processor. The various signals from the sensors need to be evaluated and processed in a timely fashion to ensure the safety of the soldiers. Based on our needs and assessments, there are two processor types that will fit the specified needs: a microprocessor and a Field-Programmable Gate Array (FPGA) board.

Microprocessors are generally programmed for one time use at the time of manufacture and cannot be reprogrammed by the end user. They are relatively inexpensive to purchase, including design tools, but can be expensive to maintain as a new processor needs to be purchased for each new design.

FPGAs are generally purchased and programmed by the end user. They offer more flexibility in design because software can be loaded and reloaded onto the board by the user. In other words, changes can be made instantly. The initial cost of the FPGA and the software associated with the board is expensive compared to that of a microprocessor, but the ability to update the software on the board as often as needed extends the life of the technology far beyond that of the microprocessor.

Night Vision Sensors

There are currently two types of technologies used in detecting night vision. They are thermal imaging and image enhancement. Thermal imaging is great for detection especially in areas of near-absolute darkness. It can be either un-cooled or cryogenically cooled. The un-cooled type is the most common and it works at room temperature, while the cryogenically cooled type is more expensive, sophisticated, but more susceptible to damage from rugged use. Image enhancement is mostly used for night vision. It amplifies tiny amount of light, including the lower portion of infrared light.

Motion Sensors

In general, a motion detector usually contains two elements:

- A device (or sensor) that detects motion,
- A device that relays the information that movement is present, typically a light

There are two technologies being considered by the team.

1. An active motion detector, which emits optics or sound waves and measures feedback to detect motion.
    - Other active motion detectors emit ultrasonic acoustic waves to detect motion.

2. Passive Infrared (PIR) sensor, which measures infrared (IR) light radiating from objects in its field of view.

Sound Sensors

There are several technologies available for use that will serve the needs of the Portable Perimeter Detection and Monitoring System. They are as follows: Sound intensity Probe, Sound Activated Switch/Circuit.

Sound Intensity Probes consist of two microphones, separated by a pre-set distance, depending on the wavelength of the sound it is trying to detect. Intensity is determined by measuring sound pressure and acoustic velocity. As sound passes the two microphones, the differences measured across the two points are used to determine the sound intensity at the mid-point between the microphones. These probes allow us to accurately detect and isolate sounds. Unfortunately, intensity measurements are the most expensive types of measurements. So, the cost of the technology is not ideal.

A Sound Activated Switch is just what it is called, a switch that is activated when a sound is heard. These switches can be designed to only respond to sounds that fall within specific frequency ranges and connected to microphone/recorder technologies so that the sound can be captured when it is heard.

Temperature Sensors

There are two major types of temperature sensors on the market that may be of use to us: contact, and non-contact.

The contact sensors, or thermometers, measure their own temperature and require contact with the object whose temperature needs to be measured. The temperature of the object in question is determined when the temperature of the object and the thermometer reach equilibrium. Non-contact sensors make use of various methods to determine temperature. These technologies include radiation thermometer, emissivity thermometer, and fiber optic thermometer.

Initial Approach

Initial Design

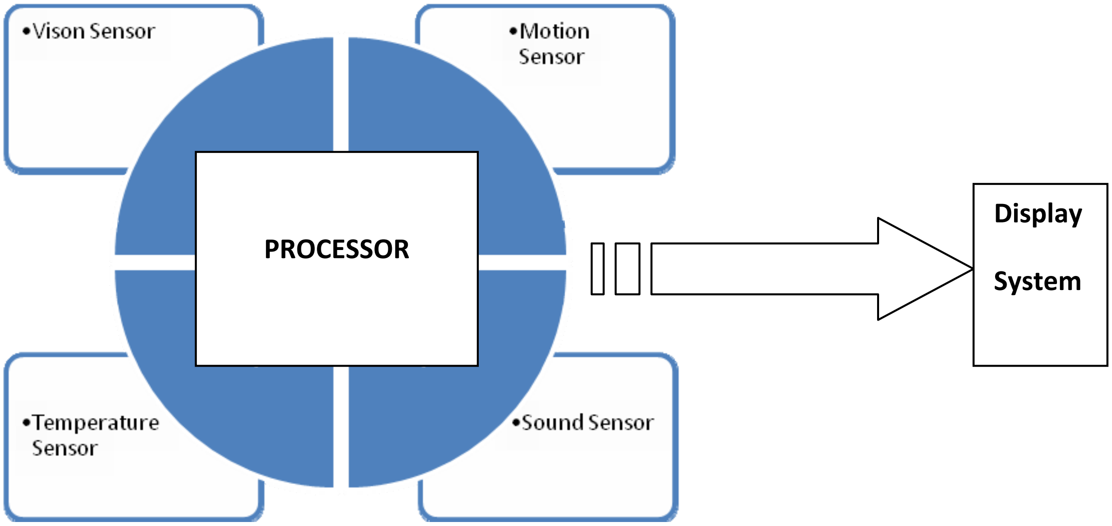

Figure 1: Initial Design

Digital System [1]

The design will make use of a digital processor to help determine friend or foe, manage the sensor technologies, and interact with the soldier. The outputs of the sensors will be processed via analog to digital conversion methods appropriate for the respective sensor and then digitally processed. The initial approach to the digital system will be similar to the following diagram:

1: Suggestion from presentation

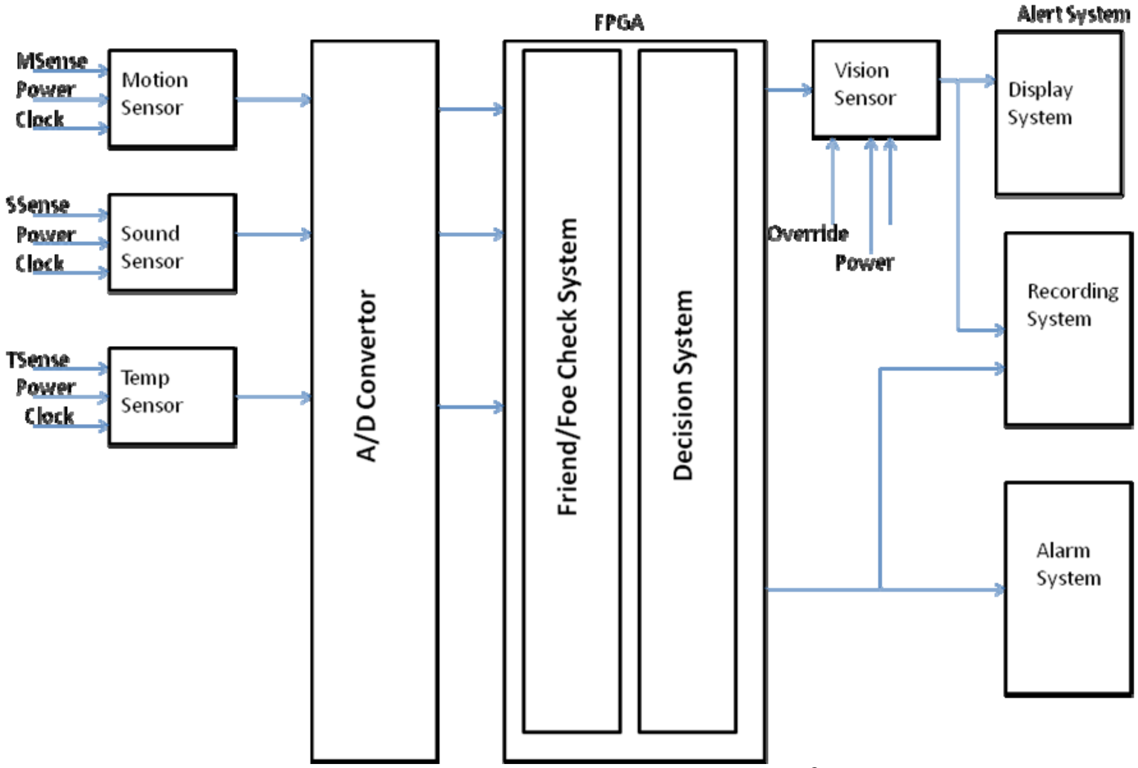

Figure 2: Digital System[2]

There will be a power system that monitors the power of the Portable Perimeter Detection and Monitoring System. It will have an LED indicator for low battery and fully charged battery states. There will also be an external monitor where the output of the vision sensors can be seen by the soldiers. Possible external monitors are laptops and cell phones.

The overall function of the system is as follows: when one sensor is tripped, all sensors will be turned on. The digital data from the sensor via the A/D will be processed in FPGA. At this point, the data from the combination of sensors will be evaluated to determine if the detected item is a threat or non-threat. In the event that the evaluation deems an object a threat, the alarm will be sounded and the vision system would be turned on. A more detailed explanation can be seen in the scenarios.

Scenario Considerations [3]

General Scenario 1: A bear enters the perimeter

If an object such as a bear enters the secured perimeter (15ft to 30ft), and it triggers on the any of the sensors, this is how the system would work:

The motion sensor: If this was the sensor triggered, it would send a signal to the A/D converter.

2, 3: Suggestion from presentation

This converts the signal to a digital signal and sends it to the FPGA. When the FPGA receives this signal, it triggers the vision sensor and it checks the signal from the sound and temperature sensors and then makes a decision. Since the bear is not classified as a threat, the FPGA returns the sensors back to their default mode.

The sound sensor: The sound sensor can only be triggered if the sound coming from the bear is in the specified foe range. If indeed it is in the foe range, the sound activated switch will be triggered and the sound will be sent to the FPGA through the A/D. The FPGA then sends it to a recording system and triggers on the vision sensor. It then uses the signal from the other sensors (excluding vision) to make a decision. The signal from the other sensors will confirm that it is not a foe and the FPGA would return the sensors to their default mode.

The temperature sensor: If the temperature of the bear is within the foe range, the temperature sensor would send a signal to FPGA via the A/D. The FPGA would turn on the vision sensor and use the signal from the other sensors (excluding vision) to make a decision. The signal from the other sensors will confirm that it is not a foe and the FPGA would return the sensors to their default mode.

<u>General Scenario 2</u>: A foe enters the perimeter

If a foe enters the perimeter, this is how the system would work:

The motion sensor: If this was the sensor triggered, it would send a signal to the A/D converter. This converts the signal to a digital signal and sends it to the FPGA. When the FPGA receives this signal, it triggers the vision sensor and it checks the signal from the sound and temperature sensors and then makes a decision. Since it is a foe, the FPGA alerts the soldier through the alert system. The solider also has a choice of seeing the image on the display to confirm the alert.

The sound sensor: If the sound activated switch will was triggered, the sound will be sent to the FPGA through the A/D. The FPGA then sends it to a recording system and triggers on the vision sensor. It then uses the signal from the other sensors (excluding vision) to make a decision. The signal from the other sensors will confirm that it is a foe and the FPGA would alert the soldier through the alert system. The solider also has a choice of seeing the image on the display to confirm the alert.

The temperature sensor: If the temperature of the foe is within the foe range, the temperature sensor would send a signal to FPGA via the A/D. The FPGA would turn on the vision sensor and use the signal from the other sensors (excluding vision) to make a decision. The signal from the other sensors will confirm that it is a foe and the FPGA would alert the soldier through the alert system. The solider also has a choice of seeing the image on the display to confirm the alert.

Below is the theory of operation of the following components in our system.

The vision sensor: There are two ways of activating the vision sensor.

1. When any of the other sensors is activated, the processor would trigger the vision sensor and it detects the image and sends it to the display unit for some amount of time before it is triggered off. The soldier can override the display time by switching it OFF/ON via a vision switch.

2. The soldier can switch ON and OFF the vision sensor at any point in time by switching it ON/OFF via the vision switch.

The Analog to Digital converter [4]*:* The signals that the sensors give out are analog signals. In order for these signals to be used by the FPGA board, they have to be converted to digital signals. This would be accomplished using an Analog to Digital (A/D) converter.

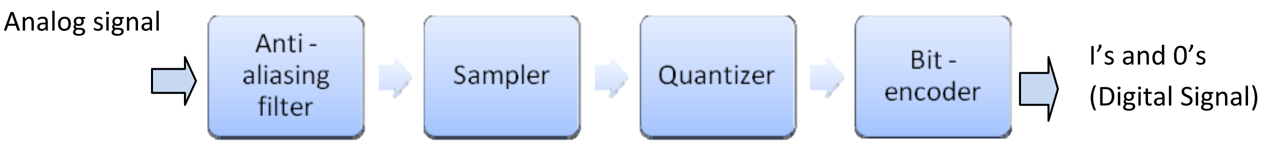

Figure 3: Block Diagram of A/D conversion

The A/D converter works on the principle of sampling and quantizing. The analog signal is processed by going through the following components:

<u>Anti – aliasing filter</u>: This is a low pass filter that makes the signal band limited. This is done to prevent aliasing when sampling.

<u>Sampler</u>: This samples the signal for modulation. Portions of the signal are taken and modulated for further processing.

<u>Quantizer</u>: The quantizer ensures that there are finite numbers of possible amplitude values for the sampled signal. This enables the signal to be converted the 1's and 0's through the bit encoder.

<u>Bit –Encoder</u>: The bit-encoder assigns a digital word to each of the quantized level.

The signal is then converted to 1's and 0's and can be processes by the FPGA board.

4: Suggestion from presentation

Alternative Solutions

1. Two systems with different sensor technologies – The systems will each communicate with a central processing unit and the central processing unit is responsible for alerting the soldiers if a threat is detected. A simple diagram outlining the idea is included below.

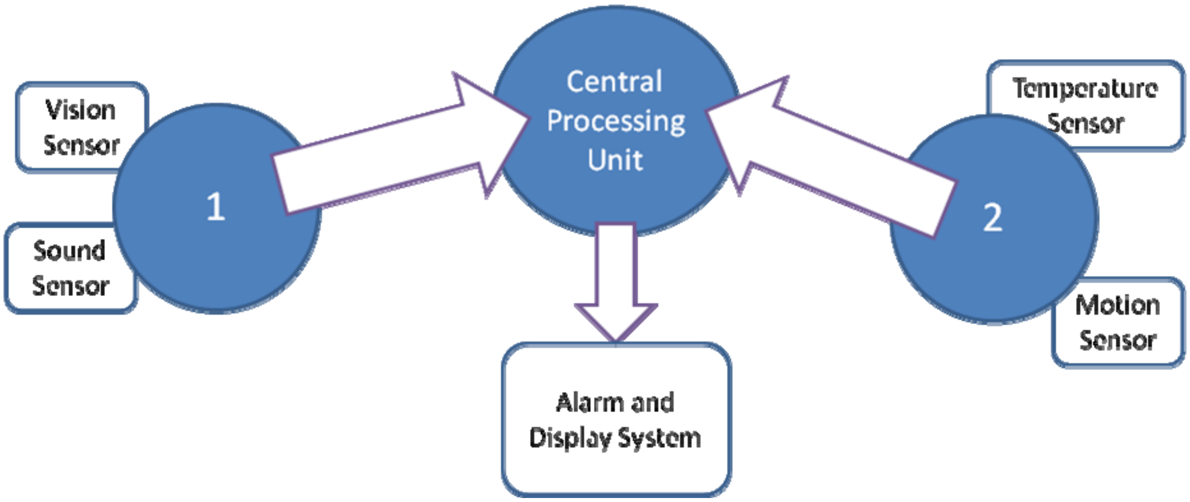

Figure 4: Alternative solution 1

2. A Network of Backpacks: Each backpack will have its own sensor technology combination and its own processing unit. When one backpack detects a threat, it will be able to communicate with the other backpacks in the network to alert them. The backpacks will then be able to alert its user. A diagram below gives a pictorial explanation of the scenario. Please note, that for simplicity only one outgoing and one incoming arrow are shown in the diagram. However, there would actually be as many outgoing and incoming arrows as there are other backpacks in the network. In this example, there are a total of 5 backpacks in the network. So, there would be 4 arrows leaving each bag, one to each of the other backpacks and four arrows coming into the bag, one from each of the other bags.

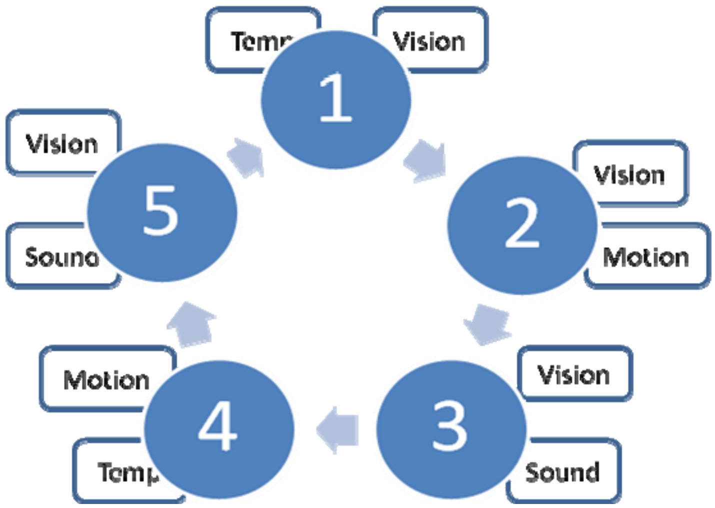

Figure 5: Alternate solution 2

Testing & Verification Plan

In order to achieve the engineering solutions, we have decided to take the following steps:

- As a team, we are to analyze each of our individual approaches and merge the solutions to a single efficient solution
- To ensure that we are moving in the right direction, we intend to meet with our advisor/sponsor and present our proposed solution. At this time, feedback will be received and any necessary revisions will be made. This step will be repeated as many times as necessary until we are given the ok to begin building.

In designing our prototype, test strategies will also be designed. It will be necessary to design a suite of tests to ensure that our components are working as expected. At each stage of the construction, the appropriate tests will be run and if the test is passed, we will move on to the next step. For example, we shall test each of the sensors as a single unit, then as a collection of units, then as a complete system of units.

Knowledge & Coursework

This design makes use of the knowledge we have already acquired and that which will need to be acquired during the design process. The design of the processing system makes use of the skills learned in Digital Systems and Advanced Digital systems design. However, the sensor technologies are entirely new to the group. We will be required to become experts in each of the sensor technologies to fully understand how to process the data from that sensor. Converting the signals to digital signals will make use of principles we learned in Signals and Systems, Communications Theory and Electronics.

Task and Deliverables

Tasks

To ensure that we accomplish the project within the limited time we have and to ensure that we all benefit from the project, we have decided to divide the labor according to each person's area of expertise. While everyone is expected to understand all aspects of the project as a whole, each person will have an area in which they specialize. This will subsequently lead to an increase in efficiency and a higher probability of success. With that said, the division of labor is as follows:

- Elijah will become an expert in the motion and temperature sensors
- Ehi is expected to understand vision and temperature sensor
- Monique will focus on the sound sensor and the digital circuit.
- As a group, we shall all work on the system integration, soldier interface and other peripherals.

Please note that in becoming experts in the sensor technologies, each person is also expected to understand the format of the sensors' outputs and the methods available to convert those signals to digital signals when needed.

Deliverables

On or before the end of March 2011, we plan to have a working prototype of our system and demonstrate its function for the spring 2011 ECE Day. In addition to working prototype, we would also provide:

- Report on PoPDaMS
- Microsoft Excel Spreadsheet of Cost/Benefit Analysis

Ethics

We shall adhere to the ethical standards of Howard University and to those set by the Institute of Electrical and Electronic Engineers, which are as follows:

1. To accept responsibility making decisions consistent with the safety, health and welfare of the public and the Howard University community, and to disclose promptly factors that might endanger the Howard University community, public, or environment;
2. To avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist
3. To be honest and realistic in stating claims or estimates based on available data
4. To reject bribery in all its forms

5. To improve the understanding of technology, its appropriate application, and potential consequences
6. To maintain and improve our technical competence and to undertake technological tasks for our internal and external advisors only if qualified by training or experience, or after full disclosure of pertinent limitations
7. To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others
8. To treat fairly all persons regardless of such factors as race, religion, gender, disability, age, or national origin
9. To avoid injuring others, their property, reputation, or employment by false or malicious action
10. To assist colleagues and fellow students in their professional development and to support them in following this code of ethics.

Project Management

Timeline and milestone

Milestone	**Scheduled Date**
Initial Proposal : Version I	November 16, 2010
Initial Proposal Presentation	November 17, 2010
Written Proposals: Version II	November 22, 2010
Written Proposal: Version III	November 30, 2010
Final Proposal Presentation	December 1, 2010
Evaluation/Selection of Design	December 2, 2010
Final Written Proposal	December 8, 2010
Peer Evaluations	December 10, 2010
Finalize Design	December 15, 2010
Ordering of components/Parts	December 20, 2010
Commencement of the development of the design	January 10, 2011
Completion of project prototype	March 24, 2011
Testing of project	March 29, 2011
Documentation of project	March 31, 2011
Presentation slide	March 31, 2011
Project Presentation	April 2011

Resources and Budget

We intend to make use of the resources around us, including our sponsor, advisor and our fellow students. If materials are available within our department, we will certainly make use of those materials as opposed to purchasing new ones. However, in the event that materials are not available, this is a tentative budget for the design.

Item	Unit Cost ($)	Quantity	Cost ($)
Backpack	60	1	60
Motion Sensor	150	1	150
Vision Sensor		1	
Temperature Sensor	130	1	130
Sound Sensor	20	1	20
FPGA	200	1	200
External Monitor		1	
Power Pack	356	1	356
ID Units	6	2	12
Miscellaneous			200
Total Cost			**1,128**

Conclusions

To reiterate, the portable perimeter detection system is needed to assist our soldiers in seeing threats they may not have otherwise seen. It will also benefit soldiers in determining if nearby objects are actually threats, or nearby fellow soldiers.

Based on our rough estimate, the annual maintenance cost is projected to be approximately $200 while the exact cost of the project is not yet known. As sensor technologies are denied or approved, the final cost will become more apparent. By March 31st 2011, we hope to have finished building the project, and have a working prototype for display on the ECE presentation day.

References

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