Middle East Technical University
Department of Computer Engineering
Fall 2011

PROJECT PROPOSAL FOR INTRUDER DETECTION SYSTEM

BEE - TECH
Çağlar Seylan _1631126
Fatih Semiz _1752476
Güner Orhan _1631050
Tuğba Demir _1630722

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1) Motivation & Purpose

Intruder Detection Systems are important for homeland security and defense applications. In recent years, there has became many advances in Seismic Footstep Detection Systems for perimeter and zone protection.

Seismic security systems have many advantages:

1. They can be hidden underground or within buildings.
2. They do not send any electromagnetic field and because of that, it is not easy to detect their presence and functions.
3. They can be put into areas where it is difficult to observe directly.

However, existing seismic systems have also some disadvantages. When there is strong changes in characteristics of seismic signals and associated noise , systems are not operate reliably. Footstep signal levels are quite low and with increasing distance from the sensor, signal levels decreases rapidly. These levels are also affected by weather and climatic factors such as rain, snow, hot weather, etc.

Seismic systems for military applications must be convenient for use with heavy environment conditions. Military systems have very strict requirements such as low power consumption (sensors use battery so it must consume low power for a long duration.), low false alarm rate.

Our purpose is to develop a new method for analyzing seismic signals. We aim to increase sensor detection range for 2 to 3 times and reduce the false alarm rate to an acceptable level. While making development , we will also consider the power consumption (it must be low) . If we achieve to eliminate (or at least reduce) the interferences caused by swaying trees, animals, vehicles, and trains,etc., we can reach the false alarm rate we desired.

2) Detailed Description of The Project

In this project, an intruder detection system based seismic sensors will be provided. The system will be put into the ground and send an alarm signal to the control center when it detects a seismic movement due to an intruder in a certain radius.

Geophone [1] will be used as the seismic sensor. A geophone is a transducer which converts seismic energy to electrical energy. Its response is proportional to the ground velocity. Thus, the more it is closer to the center of seismic activation, the higher amplitude the output will have.

The geophone will be integrated with a processor card and a wireless communication unit. When the geophone detects seismic movements, the processor will process the signal to decide whether the seismic movements is due to an intruder or not. If the cause of the seismic movements is an intruder, the wireless communication unit will send an alarm signal to the control center indicating an intruder is detected.

At the very basic, the project will consist of four parts. First part is designing an algorithm for signal processing which will be embedded into the processor card. The algorithm will determine whether the signal is due to an intruder or not. The second part is designing a software for wireless communication unit which will be the communication backbone between the detection system and the control center. The third part of the project is designing the software of the control center. The parameters for the system (e.g. threshold values for noise reduction) will be determined through this software. It will have a user-friendly GUI. We will also design a simulation environment (It will have a GUI similar to the

GUI of control software) so that we will be able to test the system in this simulator before trying the system in real environments. Since finding an appropriate place to control our system is hard, creating a simulation is an inevitable part of our project which is the fourth part.

While designing the project, we will have the following considerations:

- **The system should reduce the noise as much as possible while preserving the noiseless part of signals undistorted.**

- **The detection range should be as large as possible.**
  Our intruder detection system will have more detection range than ASELSAN's current detection system algorithm.

- **False alarm rate should be low as much as possible.**

We can achieve this enhancement by creating powerful noise reduction algorithm, so that false alarm rate will decrease.

- **The system should consume low power as much as possible.**

This enhancement is very crucial due to the difficulties on changing the batteries of the system.The processor card will have also a sleep mode for this purpose.

- **The system should classify the signals according to whether they are caused by an intruder or not.**
  Classification of the detected objects is the heart of the project. Because no one wants to give an alarm when a bird or any other animal enters the forbidden area.

At the end of the year, we will demonstrate fully developed intruder detection system with noise reduction algorithm on both simulation world and video which we would have recorded while testing our system under different noisy conditions. The system cannot provide all the features listed above. It is impossible to implement all of these features in a perfect manner. For example, if we implement complex algorithms in order to reduce the noise in a perfect manner, the processor card consumes high power. Thus, rather trying to implement perfectly all of the features listed above, we will do an optimization among them so that all of the features will be supported sufficiently good.

3) Literature Research

There are lots of ongoing projects on intruder detection systems with seismic sensors. The main purpose of these systems is to protect the border line from unauthorized entrance. There are many intrusion detection algorithms to achieve this goal. The main features that these algorithms differ from each other are;

- Detection range
- False alarm rate
- Power consumption
- Noise reduction algorithms
- Classifying the intruder

The main disadvantage of these seismic sensors is that they can detect earth movements or wind as an intruder. Therefore, algorithms must be efficient. Some of the algorithms available are:

- Looking for the regular cadence of a typical human gait.[2]
- Measuring the statistical distribution and detecting the extreme deviations from mean (Kurtosis)

According these algorithms, noise and the detection range are inversely proportional. In the real world, it is assumed that the noise level is approximately medium, which means that intrusion detection range is approximately 20 meters. Applying Kurtosis in a high noise area with a specific threshold value can result to the misdetection of the intruder, because the noise level of the area is not always the same. [4]

Another approach can be pursued. This approach is using strings of geophones for intrusion detection, and summation of the seismic signals. This contributes to the detection range. Even though all of the geophones have separate noises, only one geophone which is the closest to the walking person provides the main intruder's signal.

4) Marketing Research

Developing intrusion detection systems is a very popular area especially in military applications. We have searched various applications about intrusion detection systems in the market. Not all of them use seismic sensors. Also pressure sensors, magnetic field sensors, fiber-optic cable sensors, infrared sensors and other so many sensors are being used by some of the companies that study in this area. Also using one type of sensors is not a must. Some of the companies use more than one type of sensor in one application, or they implement applications with different type of sensors and then make comparisons between them.

Most of the products aim to detect incoming intruder. They try to accomplish low wrong alarm rates. Where wrong alarms can be occurred because of wind, rain, animals etc. There are few companies that tries to detect the classification of the intruder. Most of the companies focuses on having low wrong alarm rates and having a long battery life.
The following projects are one of the most well-known projects that took place in market:

SAND (Smart All- Terrain Networked Detectors) by ELBIT Company

SAND is an intruder detection system which is developed with seismic sensors. It both detects the intruders and also tracks them. Just because it uses seismic sensors it is a stand-alone system which tries to minimize battery usage. This technology is developed for intrusion detection on hilly, difficult to observe areas. Its advantages are being low cost and having a low false alarm rate. But it does not make intruder classification. In the figure 1 we can see a photo of the seismic sensor they use.

Figure 1 [5]

RADIOBARRIER by (POLUS EUROPE)

The RADIOBARRIER Intrusion Detection System uses different detection devices (seismic,radio wave, infra-red and magnetic) simultaneously to detect and identify the intruder. It also makes video surveillance.

It displays signals of intrusion attempts and status of the wireless sensors with the sensors coordinates linked to the terrain map. The importance of this product comes from its performance. It can make detections up to 100m range. It is also economic. You can see a snapshot below on figure 2 from the interface they use.

Figure 2 [6]

Creare Inc is also one of the most important companies in this area. They have a very strong noise reduction algorithm to decrease the false alarm rate. Moreover, they can detect the intruder with approximately 60% correctness over 350 feet (105 m) distance. With the adaptive noise cancellation (ANC) algorithm, they can detect the footsteps over 200 feet. They use off-the-shelf geophones (single-axis, 4.5 Hz geophones).

Some other important companies that have products in this area are can be listed as the following: Qual-Tron company, Dr. Frucht Systems Ltd, SELEX Galileo etc.

The major limitation of these products is the systems cannot distinguish between a human and a vehicle. Using seismic sensors with acoustic sensor may help to develop this kind of products. Also using seismic sensors in this type of applications is a plus because the sensors are behind the ground so the intruders does not know where the detection system is.

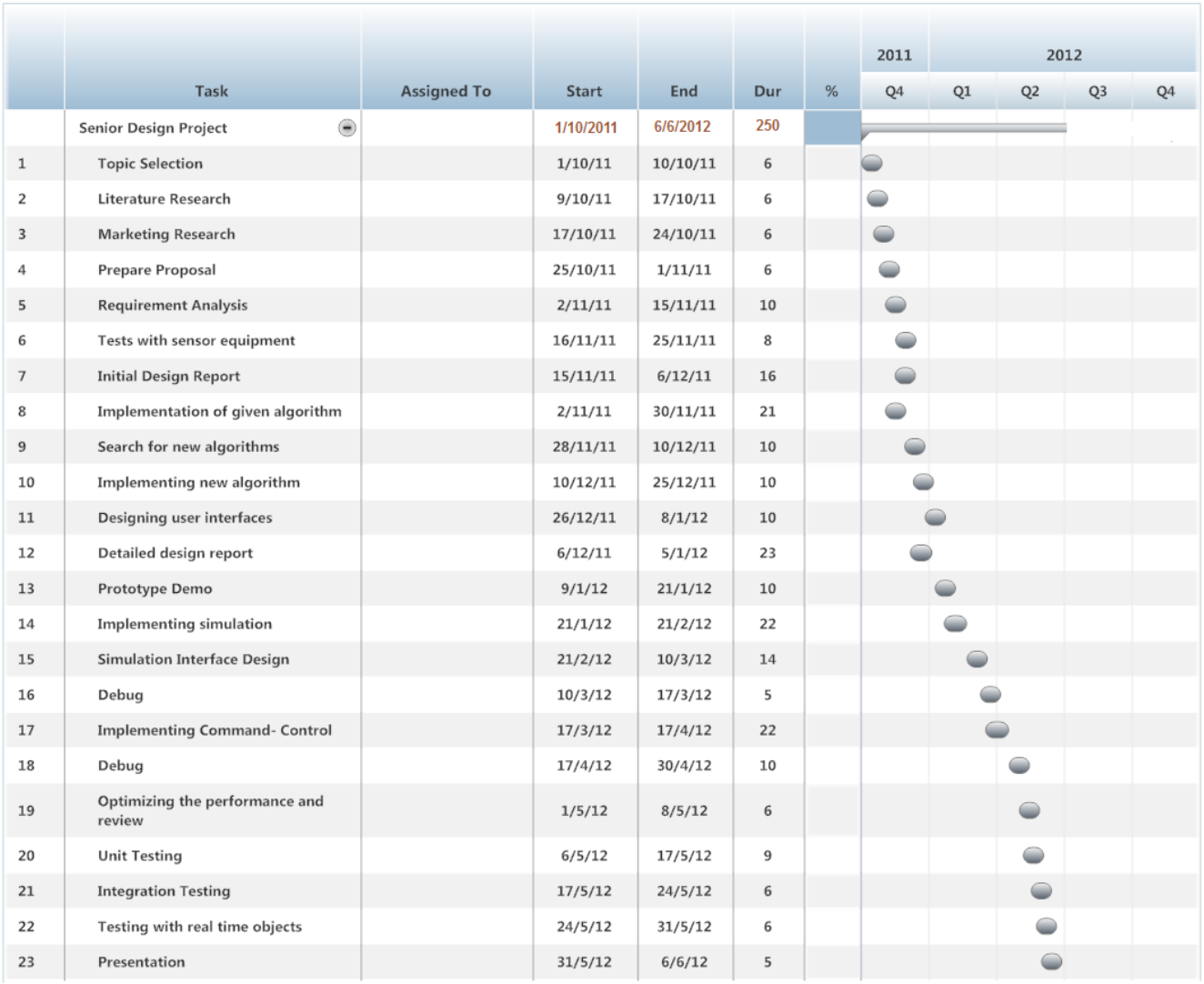
In this research area:

-using power suppliers efficiently
-having low false alarm rates
-having larger detection ranges are the objectives.

As can be seen none of the products in the market has an optimum product that satisfies these constraints. So with a new innovative approach these constraints can be handled in an optimal way.

5) Gantt Chart

The chart below shows the rough estimation about expected process deadlines.



	Task	Assigned To	Start	End	Dur	%
	Senior Design Project		1/10/2011	6/6/2012	250	
1	Topic Selection		1/10/11	10/10/11	6	
2	Literature Research		9/10/11	17/10/11	6	
3	Marketing Research		17/10/11	24/10/11	6	
4	Prepare Proposal		25/10/11	1/11/11	6	
5	Requirement Analysis		2/11/11	15/11/11	10	
6	Tests with sensor equipment		16/11/11	25/11/11	8	
7	Initial Design Report		15/11/11	6/12/11	16	
8	Implementation of given algorithm		2/11/11	30/11/11	21	
9	Search for new algorithms		28/11/11	10/12/11	10	
10	Implementing new algorithm		10/12/11	25/12/11	10	
11	Designing user interfaces		26/12/11	8/1/12	10	
12	Detailed design report		6/12/11	5/1/12	23	
13	Prototype Demo		9/1/12	21/1/12	10	
14	Implementing simulation		21/1/12	21/2/12	22	
15	Simulation Interface Design		21/2/12	10/3/12	14	
16	Debug		10/3/12	17/3/12	5	
17	Implementing Command- Control		17/3/12	17/4/12	22	
18	Debug		17/4/12	30/4/12	10	
19	Optimizing the performance and review		1/5/12	8/5/12	6	
20	Unit Testing		6/5/12	17/5/12	9	
21	Integration Testing		17/5/12	24/5/12	6	
22	Testing with real time objects		24/5/12	31/5/12	6	
23	Presentation		31/5/12	6/6/12	5	

6) References

[1] *Wikipedia, The Free Encyclopedia*. (2009, December). Retrieved October 19, 2011, from Wikipedia: http://en.wikipedia.org/wiki/Geophone

[2] Audette, W. E., Kynor, D. B., Wilbur, J. C., Gagne, J. R., & Peck, L. (2009). *Improved Intruder Detection Using Seismic Sensors and Adaptive Noise Cancellation.*

[3] Clarke, B. (2007, July 23). Retrieved October 20, 2011, from PSR-1 Seismic Intrusion Detector: http://www.prc68.com/I/PSR1.shtml

[4] Pakhomov, A., Sicignano, A., Sandy, M., & Goldburt, T. (2003). *Seismic Footstep Signal Characterization.* NY.

[5] http://www.elbitsystems.com/elbitmain/

[6] http://www.radiobarier.eu/index.php/products