Neptune

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Abstract— **Unauthorized entry into residential swimming pools is a concerning issue which in many cases can lead to property damage, injury liabilities, or even death. The Neptune system will address this issue by constantly monitoring the pool environment for signs of intrusion. Utilizing Passive Infrared (PIR) sensors and audio analysis (microphone), Neptune will determine the current risk associated with the pool. The PIR sensor will constantly monitor for people and animals that cross its field of view. The microphone will be listening to all sounds, and signal processing algorithms will be used to identify when a splash occurs. This twofold detection system will produce accurate results with a low probability of false alarms. Based upon our carefully calculated risk threshold, poolside alarms will sound and the user will receive a Multimedia Messaging Service (MMS) notification with a warning message and a picture of the pool environment if the pool is determined to be at risk.**

I. Introduction

In a day and age when security is on the forefront of every property owners' mind, one area that has remained largely unprotected and vulnerable is the backyard. The backyard poses a significantly increased liability for homeowners with a pool, as drowning ranks 5th in the leading causes of unintentional injury death in the United States and is the 1st among children aged 1-4. From 2005-2009, there were an average of 3,900 drowning deaths per year in the U.S. Approximately half of these deaths occurred in unsupervised swimming pools [1].

Pools are particularly problematic due to their ability to attract children and teenagers to break into one's yard to go swimming, otherwise known as "pool-hopping". Despite the illegality of pool-hopping, the owner may still be at fault for any injury or drowning that occurs while any child is using the pool. The legislature that governs this situation is known as the Attractive Nuisance Doctrine. It states that, "a landowner may be liable for injuries to children who trespass on land if the injury results from a hazardous object or condition on the land that is likely to attract children who are unable to appreciate the risk posed by the object or condition" [2]. Not only does the Neptune system deter people from participating in pool hopping, it also aims to alert parents in the event a child enters the pool. Both of these scenarios could lead to accidental drowning and unintentional death. Neptune directly helps to prevent the tragic fallout parents experience after a child's death, as well as aiming to curb the attractiveness of pool hopping.

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In the past, pool alarm systems have sought to protect pools by utilizing audible alarms to alert those nearby of a possible intrusion. Current designs on the market include both underwater and above water variations. Unfortunately, those located above the surface tend to cause frequent false alarms as they fail to consider false alarms from environmental stimuli. Those placed beneath the water provide enhanced reliability, but are also more expensive. The Neptune system improves upon what is currently on the market and takes intrusion detection to the next level. Upon detection, Neptune will send a text message with photo to registered phones. Most current pool monitoring solutions only alert those nearby the pool to a potential intrusion.

TABLE I
SPECIFICATIONS

Specification	Value
PIR Sensors	
Sensing Range	< 7 meters (120^{o} cone)
Weight	< 0.2 ounce
Power Consumption	< 0.5mW
Alarm System	
Sound Level	> 30 decibels
Power Consumption	< 6W
Weight	< 0.5 ounce
Microphone	
Condition	Waterproof
Weight	19.2 ounces
Frequency Response	20Hz-18kHz
MMS Messaging	
Sent Time	< 1 minute

II. Design

A. Overview

Neptune will be our solution to the problem of detecting an unauthorized entry into a residential swimming pool. To achieve this goal, we will utilize the PIR sensors to read changes in temperature in the surrounding area, providing us the earliest detection of a warm body entering the pool area. The rationale for using PIR is that it has the ability to sense humans and/or animals, while not detecting inanimate objects such as balls, rocks, and others. In addition to the sensors around the swimming pool, we also include a stationary microphone located above the water surface to constantly record the surrounding sounds. The sensitivity of both PIR sensor and microphone will be adjusted depending on the weather.

A single board computer will receive all recorded sounds coming from the microphone and begin the filtering process to eliminate unnecessary signals relating to background noise and determine whether or not a splash occurs. If our signal processing algorithms indicated a splash, the camera would take photos of the pool environment. Furthermore, we will utilize an LED to make sure that the captured pictures are recognizable even during the nighttime.

Once the motion is detected by the PIR sensor and a splash is determined in such a way that our calculated risk threshold is exceeded, the Raspberry Pi will send an MMS text message within 10 seconds as well as activate the alarm system. Due to the cost considerations and complexities involved with using cellular chip, we decided to utilize a N150 Wi-Fi Nano USB Adapter [3] as opposed to 4G/LTE to send MMS messages from Gmail account to registered phones. Shown below is the overall block diagram of the Neptune system.

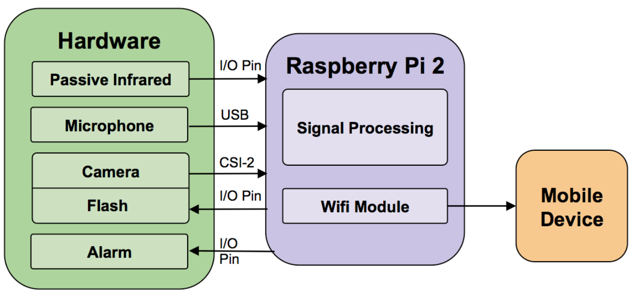

Fig. 1. Block Diagram of the Neptune System

B. *Block 1: Passive Infrared (PIR) Sensor*

The goal of the PIR sensor subsystem [4] is to detect physical, living entities by sensing temperature that enter the area immediately adjacent to the pool. So when a person or an animal is detected, we expect a high voltage signal of approximately 2.88V to be applied to the Raspberry Pi I/O, and 0V otherwise as shown in Fig. 2. We decided that a standard PIR sensor would be the simplest, least power consuming, and most cost effective way to accomplish our goals.

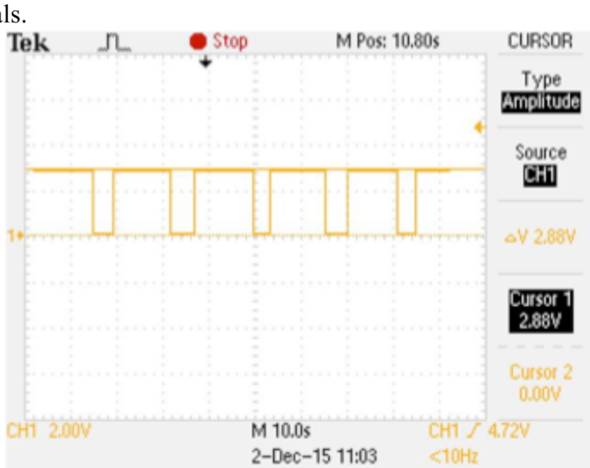

Fig. 2. Output of PIR displayed on Oscilloscope

The essential characteristics that a PIR sensor must exhibit in order to be used in our system are good range and a wide field of view. We performed an experiment in order to test these characteristics. First, we supplied 5V as an input voltage and wired the output of PIR sensor in series with a 220Ω resistor and an LED. An LED will illuminate when a person or animal is detected. This circuit was placed on a park bench approximately two feet off the ground. We then walked to several different distances on each side of the PIR sensor (x direction) and then proceeded forward (y direction) to the point where the PIR sensor detected our presence. We recorded this point and performed a series of calculations to determine the range and field of view of the sensor. A chart showing the results of this experiment is represented below.

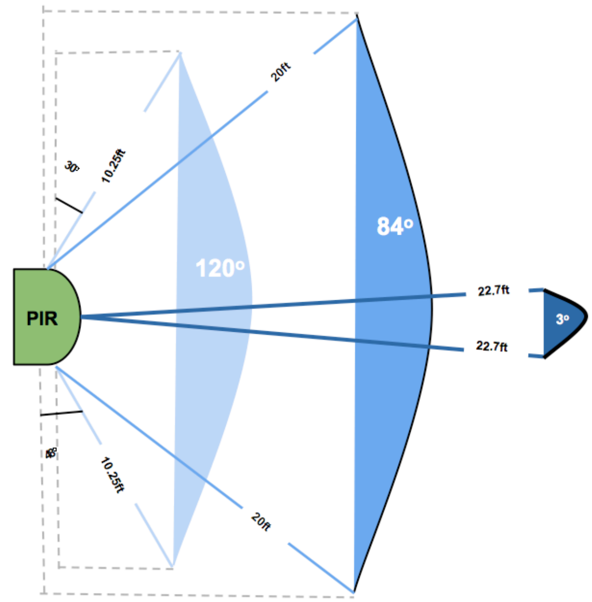

Fig. 3. PIR Sensitivity

Analyzing the results of the test shows that the PIR sensor has a 120° field of view but the range is significantly less toward the edges of this field (10 feet) as opposed to directly in front of the sensor (20 feet). PIR will detect any object within 20 ft for an 84°scope (70% of field) and any object within 10 ft for the entire 120° field of view. Knowing this information is important because we will use it to determine the number of sensors, their location, and orientation necessary to maximize our effective detection area.

C. *Block 2: Audio Analysis*

Coupled with the PIR sensor is a microphone [5] that aids in the detection of an unauthorized entry into the swimming pool area. The main purpose of this block is to determine when a drowning risk actually occurs, and then a set of mobile phone numbers which the user registered will be alerted to the threat. To achieve this goal, the microphone constantly records sounds coming from the pool environment. An analysis of the audio sample is then done to determine if it is likely that a splash occurred. Below is a spectrogram analysis of a sample splash sound in a normal pool environment.

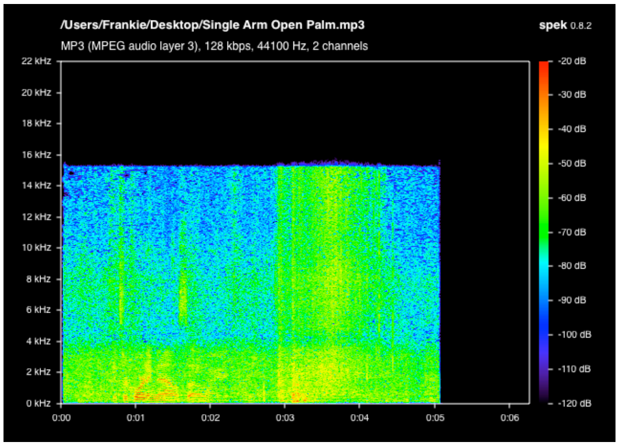

Fig. 4. Spectrogram Analysis of a sample splash sound

The audio sample used in the spectrogram was recorded at the Totman swimming pool. For this particular trial, a splash was produced by hitting the surface of the water with a single arm and open palmed hand. In this short clip, the first three seconds represent time before the splash occurred. Here, you can see that the recording device picked up spoken words between 0:01 and 0:02 seconds. This corresponds with someone instructing our team member to begin the splash. At 0:03 seconds, the swimmers' arm first made contact with the water. This is represented in the spectrogram by the sudden increase in frequency sound from 4 kHz to 15 kHz. With this information in mind, our goal is to separate splash sounds from background noise and use that with the PIR sensor to determine with reasonable certainty that there has been an unauthorized intrusion and to alert the Neptune system administrators.

D. Block 3: MMS Messaging

After the audio signal is processed and the PIR senses a human or an animal, it comes the task of relaying the information to the homeowner. We communicate by sending an MMS message from a dedicated Gmail account to the email address or phone number desired by the homeowner. Contained in the MMS message is a generic alert indicating that the Neptune system has been triggered and a picture of the pool will be attached for the homeowner to confirm the alert.

The first step in setting up the alert system is to record the user's information into the Raspberry Pi 2 Model B [6]. The Graphical User Interface (GUI) used in this system was created using Tkinter, a GUI library native to Python. The goal of establishing the interface is to make it accessibly simple for people with minimal computer experiences to operate. The GUI contains one text field for entering the phone number or email address as well as a selection field to choose the user's mobile provider. Upon the user inputting his/her information and pressing the "Update" button, the data is formatted to be read later and saved to the Raspberry Pi. The last button within the GUI is the "Log" button, which displays a list of all the alerts sent from the Raspberry Pi.

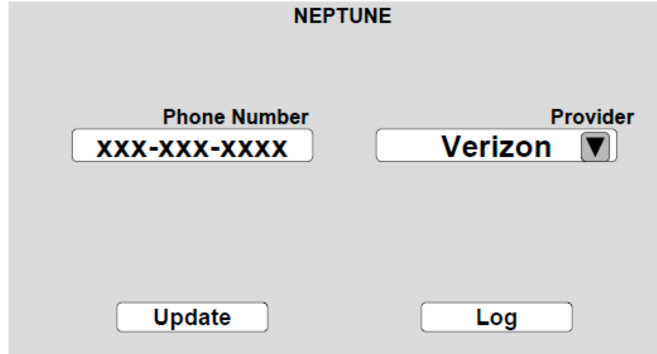

Fig. 5. Graphical User Interface

Upon detecting an unauthorized entry, Neptune retrieves the data which the user saved as well as the picture captured at the corresponding time to the alert. Neptune then connects to the Gmail servers through a Wi-Fi connection and logs into the assigned Gmail account. After compiling the message from its pieces: the owner's information, the body consisting of the generic alert and the picture, Neptune sends the message to the user; thus completing the alert process. If an error is encountered at any point in the messaging process, Neptune would still save the alert and error message into the log, and then proceed to activate the alarm system.

E. Block 4: Alarm System

Besides sending an MMS message to the homeowner, Neptune will also activate an audible alarm located poolside to alert those nearby. Given all the electronic parts in the Senior Design Project lab and Marcus 5, we were able to design an alarm that sounds up to 32 dB. To do this, we supplied 12V to our circuit as well as used a 90Ω speaker and a 10mm LED. The complete PSPICE schematic of our Neptune alarm system is shown in Fig. 6. What drives the speaker and LED are the complementary feedback pair known as a Sziklai Pair and a frequency generator circuit.

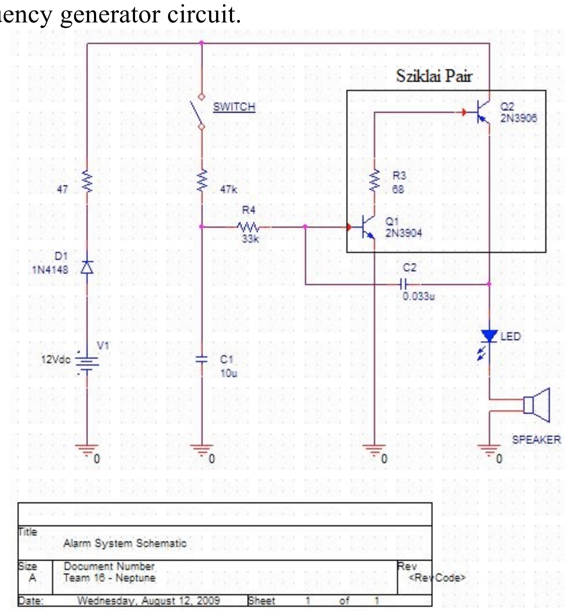

Fig. 6. Neptune Alarm System PSPICE Schematic

The Sziklai Pair is the cascaded combination of 2N3906 (PNP) [7] and 2N3904 (NPN) [8] transistors to provide a higher current gain of β^2. The Base of this pair will be driven by a frequency generator circuit consisting of a series of C1, R4, and C2. We utilized the momentary push-button switch to activate the alarm so that once the switch is on, the two capacitors will be charged and the Sziklai Pair will be in the "active" mode. The response time of the switch is controlled by 10μF capacitor (C1) while the sound wave of the speaker is generated by a 3.3nF capacitor (C2).

III. Project Management

TABLE II
MDR DELIVERABLES

MDR Deliverables	Status
Characterize various splash sounds	Complete
Send MMS message from Raspberry Pi 2 to cell phone	Complete
Demonstrate a working PIR sensor	Complete
Build and test an alarm prototype	Complete

Our MDR goals are outlined in the above table. Based on feedback from our Preliminary Design Review, our MDR deliverables were altered to better align with a redesigned project. As such, they were changed to reflect the shift from a system driven by sonar detection to one that utilizes a microphone and PIR sensor to detect potential intrusion in a swimming pool. This has also impacted the course of project through FDR in April. As shown in Appendix, our Gantt chart includes the next actions we intend on taking primarily involve integrating our current subsystems to create a working prototype of the overall Neptune system. We also plan to work with our chosen camera to be able to photograph the intrusion and relay that photo to a mobile device. In addition to all of these integrations, our power supply must be built, designed, and verified in order to market Neptune as a standalone system.

Each member of our team brings a particular set of skills; enabling our group to arrange the workload in order to reach our goals. Hang and Frankie share similar expertise in regards to hardware, electronics, circuit design, and signal processing. Therefore, Hang will be focusing on alarm system circuitry and power systems while Frankie will implement signal processing required for audio analysis. Greg and Scott have a greater affinity for software, having programming experience in a variety of different environments and utilizing multiple coding languages. Scott is focusing on the software associated with the camera system as well as ensuring the PIR sensors are operational. Greg is concentrating his efforts on the Raspberry Pi in addition to implementing cell phone communication.

As each of us started working on our particular subsystems, we all ran into situations where we needed to ask the group for assistance. Thanks to the friendly and helpful team dynamic we have established, there is no hesitation among any of our members to reach out when they get stuck. Team 16 looks out for one another and is determined to deliver a system that solves the issue we are trying to address. Our goals would be unreachable without strong communication among our members. We make the most of our time during weekly team and advisor meetings, making sure all issues and questions are addressed as well as laying out our plan for the next week. We also utilize group chat, where each of us can be in immediate contact at times we are not meeting.

IV. Conclusion

After presenting the MDR deliverables to our faculty evaluators, Professor Vouvakis and Professor Parente, we successfully demonstrated the functionality of four subsystems. Moving forward to CDR, our goal is to integrate the subsystems in order to deliver a complete operating system by the end of February. To do this, we established a well-planned schedule which includes every member's responsibilities as shown in the Gantt chart. [Appendix] Although each of us is in charge of individual subsystems, we will assist and verify each other's portions periodically to ensure that our results are capable of integrating.

The first task we will concentrate on is integrating the microphone and our single board computer so that we are able to receive the recorded sound on the Raspberry Pi. Then, we will analyze the audio input by applying our signal processing algorithms to determine whether or not a splash occurs. Thus, our goal is to demonstrate more experiments on different objects dropped into the swimming pool to identify the proper frequency responses and decibel levels for particular splashes by mid-February.

Since our "risk threshold" is calculated based upon a certain splash and PIR output voltage, our next task is combining the PIR sensor and Raspberry Pi. We will utilize Raspberry Pi Camera [9] to capture photos; hence, they provide the homeowners an overview of the pool environment.

We understand that our single board computer will not supply enough power for the alarm system, which would make it infeasible to integrate the alarm and Raspberry Pi. To tackle this issue, we will utilize a buck converter [10] to reduce the power outlet (120 volts) to 12V, and then generate 5V from 12V using a voltage regulator. This will accomplish the goal of driving both our alarm system and Raspberry Pi successfully.

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First and foremost, we would like to thank our faculty advisor, Professor Holcomb for his support and guidance throughout the first half of our SDP project. Secondly, we want to thank our evaluators Professor Parente and Professor Vouvakis for their honest and valuable feedback. Lastly, we want to give thanks to Professor Hollot and Francis Caron, who both work to make this course a possibility.

APPENDIX

Fig. 7. Team 16 Gantt chart for 2016

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