WORCESTER POLYTECHNIC INSTITUTE

Intelligent Audio Systems

IQP E-Term 2011

An Interactive Qualifying Project Report submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE
In partial fulfillment of the requirements for the
Degree of Bachelor of Science
By:

Naumaan Ansari, Kush Patel, Thomas Womersley

8/7/2011

Project Number: FB02
Division: 48- Humanistic Studies of Technology
Project Advisor: Bianchi, Fredrick W.

Abstract

Interactive systems are designed to get their users involved. This project is designed to gather and analyze interactions of a trash can interactive system. A new interactive trash can is designed to produce sounds when trash is tossed in. The reaction of the person interacting with the trash can is recorded on video. It is anticipated to see different reactions by different people based on the sounds played and to be analyzed to understand which sounds invoke different emotions as well as reactions.

Table of Contents

Introduction

There has been much research conducted on human behavior. One way to research this behavior, is to put people in a situation that forces them to react in a certain way. For example, imagine having a trash can that makes sounds when you throw things away. What kind of reaction would this invoke? Will it be positive or negative? Can this reaction lead people to throw more trash away? The intention of this IQP is to place a human being in an environment that will modify their behavior in such a way that may make them more inclined to throw trash away. The projects overall goal is to have this reaction lead to a higher interest in throwing trash away. In addition, through careful analysis of behavior, it may be possible to gather large amounts of data to detect emerging patterns.

A trash can was designed to utilize microprocessors and sensors to detect the activity and behavior of people and to alter their expectations. For example, when the power button to turn a computer on is pressed, there are certain things the user expects. The computer should turn on, or not, depending on if it is working or plugged in. The user doesn't expect it to spontaneously combust or start screaming. The same goes for a trash can. When a piece of trash is thrown into it, it is expected to simply take the trash. However, what if the trash can began making noises? What would you do then? These questions were addressed while working on the project. When a person places a piece of trash inside of the can, the trash can will begin making noises, and the noises will vary depending on the location of the trash can.

One of the supporting ideas surrounding this project is a theory called Fun Theory[1]. This theory is one that attempts to make ordinary activities more fun. In this project, throwing out trash is made fun by having the trash can be interactive. By making it fun, the desired outcome is to increase the amount of trash thrown out. By making the trash can fun, there may be a change in the behavior from the people using it. This change in behavior is the goal of the project.

[1] (Volkswagon, 2009)

Background

Effect of Technology on Society

From the first wheel to the completion of the atom bomb, technology has always had great implications on society, both good and bad. The atom bomb was one of the world's greatest technological achievements, and also one of the most devastating. Debating the ethics of technology seems to be moot, since its advancement is inevitable. The question, then, shouldn't be whether or not technology affects society, but how can it affect society in a positive way. The interactive trash can experiment is designed to "trick" people into doing the right thing, such as simply throwing away your trash. This has great implications from an ethical standpoint. This project tries to modify the behavior of people in a positive way, but it can be argued that the manipulation of behavior is unethical due to the lack of free will in the situation. This is probably true. The project is basically a commercial in which the goal is to manipulate the "viewer" to do buy the product, or in this case, throw some trash away.

Theories

This project looked at several aspects of human-sound interactions to understand and explain the different actions and reactions provoked by sound. There are many theories that help explain human behavior. In this project, Emergence, Nudge theory, and Fun Theory were used to explore the behavior provoked by the interactive trash can.

Emergence

The theory of emergence explains how collections of simple systems and objects can lead to complex systems and designs, or phenomena.[2] Simply put, as stated by Greek philosopher Aristotle, “the whole is more than the sum of its parts.” Patterns emerge from seemingly insignificant events or data. Emergence is relative to the project in a number of ways, including the patterns that may arise from the data gathered by the interactive trash can. Although this project focuses on building the device and not on the analysis of data, it is important to note the potential relevance of the accumulated data. Patterns of emergence are found naturally throughout nature. Many philosophers believe that these same patterns can be derived from many applications and activities including business, economics, science, and the arts[3]. These patterns can establish naturally occurring behaviors in the human population[4].

An example is given by a PBS documentary, NOVA. The documentary shows how a school of fish seem to all move in a coordinated fashion, even when there are hundreds. This movement isn’t done by following a leader, but rather, by following a set of rules embedded within the fish’s conscious. These rules include following the fish in front, and feeling any predators that might approach. The current trash can project is attempting to find similar patterns in the actions of human beings. When the trash can is placed into an environment, the collected data may reveal some emerging patterns. These patterns are considered to be keys to

[2] (Wikipedia, 2011)

[3] (Wikipedia, 2011)
[4] (Haan, 2006)

unlocking certain aspects of human evolution[5]. Emergence is a new philosophy behind human interactions and human performance as well as explaining evolution.

Nudge Theory

Nudge theory[6], a recent discovery that has won two Nobel prizes in economics, explains actions of people when they are faced with decisions. Nudge theory states: though people maybe rational beings, many of their decisions are not. In *Nudge: Improving Decisions About Health, Wealth, and Happiness*, authors Thaler and Sunstein explain how small nudges in life can drastically change the decisions and actions of people for the better and can thus improve the world. In Marcel Cote's article on nudge theory, he explains the simple effects of making objects the "standard" or "default" which the general public generally turns to when faced with a complex decision or choice. Service providers have exploited this by "nudging" the general purchase certain products and use specific tools and services which become more beneficial to the service and product supplier. Commercials are the simplest forms of nudges that are targeted to a specific crowd based on the time they are played and in relation to which show they are interrupting. For example, during the Superbowl, there are several commercials about football products that target and nudge the viewers to purchase the products to support their favorite teams. However, the ideas presented by Thaler and Sunstein look at the effects that a nudge can be used to generate better behaviors and habits among people.[7] One of the simplest and implemented nudges was drawing an image of a bee in a urinal; this was tested in

---

[5] (Haan, 2006)

[6] (Nudge(book), 2011)

[7] (Cote, 2010)

Amsterdam's Schiphol Airport and was extremely effective in nudging men to pee at the target location that reduced spillage by 80%.[8]

As described in Nudge, people have two systems of thought: an automatic system and a reflective system. The automatic system refers to the instinctive responses that do not involve thinking whereas the reflective system is conscious and action or path is deliberately chosen. Given that there is a significant difference between these two systems of thought, people make “the wrong decision” at times because of biases, heuristics, and fallacies which are cause by anchoring, availability heuristics, representative heuristics, status quo bias, or herd mentality. Anchoring happens when people base their decisions or answers based on a preexisting condition or on information which would result in an incorrect decision or answer. Anchoring is a prime reason why people have different answers to the same question base on their environment, experiences, and education. Availability and representative heuristics occur when people attempt to predict the frequency based on their own calculations and understandings. These choices or decisions generally occur when people are attempting to understand something based solely on their knowledge or the limited information that is provided. The status quo bias occurs when people pursue their course of action based on what has traditionally been done; children might follow in the footsteps of their parents and select the same career. Herd mentality is similar in the sense that a person’s decision is based on the general selection, but it is generally based on the actions of others. A group of friends might go skydiving and though one of them might be scared, he or she will jump with them to fit in or

[8] (Cote, 2010)

possibly because of peer pressure. Understanding why people make the decisions they make is very beneficial to understanding human-sound interaction[9].

[9] (Thaler & Sustein, 2008)

Understanding Human & Sound Interaction

Sound is so predominant in society and is one of the common interfaces for human interaction with others as well as with their environment. Human interaction with sound has been researched to understand not only the effects on people's behavior, but also on how people are affected biologically and physiologically by sound.

Infrasound

Human beings can hear sound in the range of 20Hz to 20 KHz. Although this is the range of human hearing, this range is not limited to all human beings. It is possible to hear sounds with a frequency as low as 1Hz. Sounds below the frequency of 1Hz are known as infrasound. For humans to be able to hear infrasound there has to be significant sound pressure, measured in decibels. Although the assumption is that the ear is the primary organ used for hearing a sound, it is very possible that infrasound may be felt as vibrations in different parts of the body[10].

It is very common to hear the theory that animals have a "sixth sense" when it comes to predicting disasters. An example is the 2004 earthquake in the Indian Ocean[11]. Animals seemed to vacate that area before the earthquake occurred. Scientists believed that these animals could sense the infrasonic waves through the earth, and therefore responded accordingly.

[10] (Davies)
[11] (PBS, 2008)

According to an article written by MSNBC, British scientists discovered that humans can also have similar reactions to infrasound. Everyone at one point has felt a shiver down their spine or random sensations in their body that they can't explain. These scientists suggest, through experimentation, that "infrasound can produce a range of bizarre effects in people including anxiety, extreme sorrow, and chills." One of the scientists in charge of the project, Professor Richard Wiseman of the University of Hertfordshire, explained how various forms of music were played for a group of people. Some of the pieces were interlaced with infrasound. More than 20 percent of people had more unusual reactions when infrasound was present, although they did not know which pieces had the infrasound. According to the article, these experiences included feeling uneasy, or sorrowful, getting chills down the spine or nervous feelings of revulsion or fear. Wise said, "These results suggest that low frequency sound can cause people to have unusual experiences even though they cannot consciously detect infrasound."[12]

Existing Intelligent & Interactive Systems

Interactive systems are some of the most popular inventions of all time including such as Nintendo Wii because they stimulate human senses and invoke behaviors and reactions. Other more subtle systems such as the Bottle Bank Arcade or the Deepest Bin Trash can[13] only have simple designs yet they are able to change human behavior to properly dispose of trash or recycle bottles. Interactive systems in general effect human behavior and interaction in their

[12] (The Associated Press, 2003)

[13] (Volkswagon, 2009)

environment and those reactions can be observed as data to understand and further develop systems that can nudge human behavior.

Fun Theory

Peoples' behaviors, actions, and reactions are partially a reflection of their environment. Fun theory, an initiative by Volkswagen, has principles similar to those in Nudge Theory in that they attempt to influence decisions and actions of people for the better. The Fun Theory award is given to a project in recognition for those who design different objects, systems, and environments that change people's behavior for the better. Fun theory focuses more specifically on the action of people more than their choices, and how they can be changed to do good, such as tossing trash properly or obeying speed limits. For example, people generally ignore the effects of speed and may litter, but if these actions became slightly more fun or interesting, people tend to pay more attention to them, correct their own actions, and influence others' actions.[14]

[14] (Volkswagon, 2009)

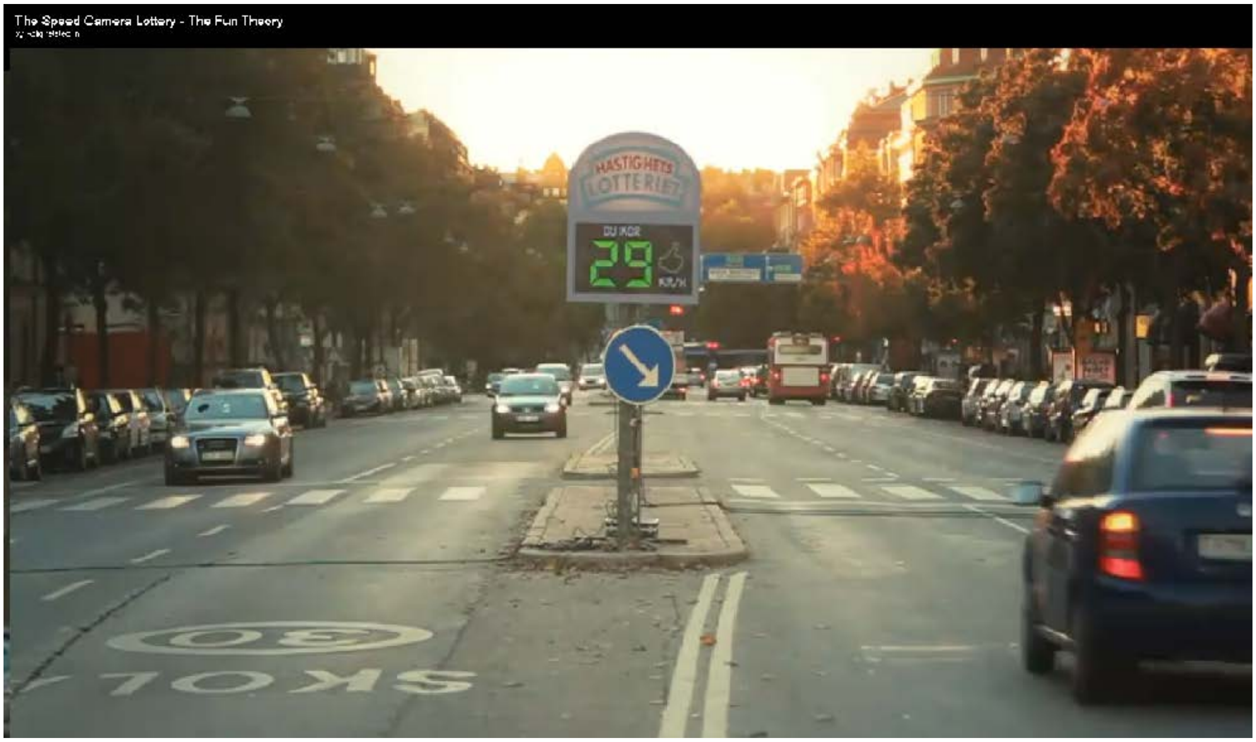

Figure 1: Speed Camera Lottery

The Speed Camera Lottery is one of the recent candidates that has been awarded the fun theory award because it is a smart way to encourage drivers to obey the speed limit. The system is set up at a busy intersection and has a visual display showing the speeds of all the drivers at pass by. Those drivers that are speeding get fined and those that are not get entered into a lottery to win some of the money that is received from the fines. This encourages people to not only avoid getting fined, but also give them an opportunity to be rewarded for their good driving behaviors. Before the system was run, the average speed of the intersection was 32 km/h and then during the experiment the average speed was 25km/h which is a 22% speed reduction; a phenomenal outcome for a simple game added to everyone’s daily lives.

Another one of the winners, the World’s Deepest Bin[15], was an extraordinary design that encouraged people to throw away trash in the trash bin instead of polluting the environment. The system was a simple trash can with some sensors that detected the trash

[15] (Volkswagon, 2009)

going in and then speakers was play a sound which create the illusion that the trash can is much deeper than it actually is.

Figure 2: Fun Trash Can

People became curious as well as enjoyed the sound interaction of this system and thus tossed their trash as well as picking up other trash in the park and tossed that. This creates the incentive for people throw trash away properly as well as cleaning up the environment. This trash bin collected 41kg more than the normal trash can nearby totaling to 72kg of trash. [16]

Many great interactive systems and environments have been design in attempt of winning the Fun Theory award and the trash can design is one of the few useable designs for creating an interactive audio system. Interactive systems such as an audio emitting trash can can provoke better behaviors in people and it is a part of the objective of this project to get positive reactions out of people.

[16] (Volkswagon, 2009)

Sonic Warfare

It is important to note that although sound has been used in the past to affect behavior in a positive manner, it has also been used as a tool of negativity. This is easier described as sonic warfare. Sonic warfare isn't what it sounds like. Yes, there has been sound that can harm others, but sonic warfare typically has to do with any sound that can be thought of as ill suited; gunfire, loud machinery, loud music, speeches. According to Steve Goodman, a lecturer at the University of East London, sound warfare can be used in multiple fashions. It is not simply limited to using high frequencies to cause harm, but also, the speeches by Hitler are classified as a form of sonic warfare. According to Goodman, "Sonic warfare then, is the use of force, both seductive and violent, abstract and physical, via a range of acoustic machines (biotechnical, social, cultural, artistic, conceptual), to modulate the physical, affective, and libidinal dynamics of populations, of bodies, of crowds."[17] By this definition, the interactive trash can built for this project can be theoretically described as sonic warfare, because although our goal is to simply influence behavior, we are also tarrying to manipulate the system (people) to gather data.

Alex Davies, a student who wrote his thesis at the University of Wales, has similar views on sonic warfare, but approaches it from a different angle. He believes that sonic warfare is more related to psychotropic warfare, or warfare of the mind. "It is the human condition to try and find answers for inexplicable events of phenomena. Sonic weapons are often embraced in this capacity, as they are not only often imperceptible to the ear in their operation, but also are capable of extensive physical and behavioral control. As a result, sonic violence has also

[17] (Goodman, 2010)

become a prevalent theme in the area of conspiracy theorists and ‘mind control’ victims”[18] says Davies.

Objective

The interactive trash can presents a new form of human and sound interactions which can lead to mental stimulations which may produce different actions, reactions, and behaviors. Implementing this interactive system in public locations may have several benefits from promoting better behaviors, actions, and decisions. This IQP, as stated in the introduction, is attempting to force a reaction out of someone interacting with this trash can. This reaction, or behavior, is the key to the project. If someone throws away more trash due to the sounds coming out of the trash can, the project could be considered a success. If the opposite occurs (or no change at all) it doesn’t necessarily mean it has produced a negative outcome. It is simply a result that needs further study.

[18] (Davies)

Methodology

As already discussed, the trash can designed for this project is used to try to “convince” people to throw away more trash. Littering is a known problem in many populous areas of the world. The goal of designing the trash can is to make it so that the sound coming out of it forces people to react in such a way that makes them throw away more trash. The factors necessary to accomplish this is the devices used to create the sound, sensors, program for the sensor, the design of the trash can itself, and the sounds themselves.

The trash can system designed for this project consists of some very high tech equipment. Devices such as a computer, motion sensor, speaker system, and audio interface were utilized to bring the trash can to life. Each component plays an important role in the objective of the project. Since the trash can’s objective is to invoke a reaction out of someone using it, the components must be discreet. As a result, a base was constructed to place under the trash can so that all the various components and wires can be hidden. The base must also be discreet as to not draw attention from the trash can itself. This task is difficult given that the base had to be big enough to hold all the devices, which are quite large when, put together. To remedy this, the base was shaped to fit the trash can as closely as possible. The result was a large hexagonal base that will be explained later.

Components

Each trash can component was chosen after careful analysis and consideration.

Sensor

The MoveOn sensor[19], as shown in figure 3, from infusionsystems.com was initially utilized in this project. This sensor is a basic motion sensor used to capture the motion of a heat emitting object. It enabled the trash to detect trash being thrown in. Once the trash is detected, a signal is sent to a computer to play one of the various sounds being used for this design.

Figure 3: MoveOn Sensor

Another sensor, called the Light sensor[20], as shown in figure 4, was also considered. The sensor itself has an invisible line draw horizontally across from its tip, and any object that passes through it will trigger the sensor. This type of sensor is very useful when the trash is being thrown into the trash can because it detects only the trash, and not the people throwing it away. An illustration is show in figure 5. On the left, there is a side view of the octagonal trash can. The small rectangle is the sensor, inside of the head of the trash can, while the red line is the invisible line that picks up detection. The right picture is a top view.

[19] InfusionSystems.com
[20] InfusionSystems.com

Figure 4: Light Sensor

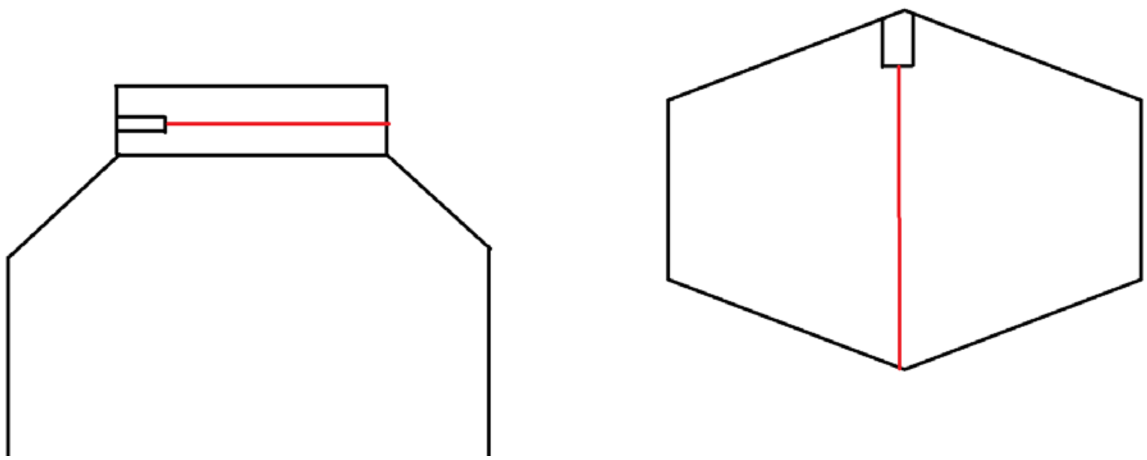

Figure 5: Light Sensor Illustration

A third sensor was also considered. The third sensor is a Bend sensor[21], as shown in figure 6. The Bend sensor is triggered with the slightest motion of the sensor. The possible implementation for this sensor is to place it on the trash bag itself, and when people throw away trash, the bag would move causing the sensor to trigger.

Figure 6: Bend Sensor

[21] InfusionSystems.com

At the end of the process, the Light sensor from Infusion Systems was decided as the most suitable sensor for this project. The reason that it was the ideal sensor is that it would allow for the most reliable trigger.

As stated above the other possible sensors that could be utilized were a motion sensor and a bending sensor. The motion sensor was originally the sensor that was going to be utilized. In preliminary testing, the motion sensor worked perfectly. In further testing, it was discovered that the success in the preliminary testing proved to be a coincidence. The available motion sensor only sensed the motion of an object with a heat signature. This caused a problem in sensing the trash that was thrown away because the only way that the trash can would be triggered, would be if the person that threw away the trash and put their hand into the trash can. Therefore this sensor was inadequate for the purposes of this project.

The bending sensor, which triggered through the sensing of vibration, was then tested preliminarily. In these early tests, the sensor proved to be effective. The bending sensor was attached to the trash bag so that when the trash was thrown away, the bag would move and send a vibration up the bag to the bendy sensor. This sensor configuration was thought to be a good solution for the project, but further testing revealed that when the trash bag began to fill, the bendy sensor became ineffective. This sensor configuration was also ineffective when the trash that was thrown out was light, such as any scrap piece of paper.

These two sensors were the only two sensors that were immediately available. The desired light beam and light sensor could be obtained, but not in a very timely manner. Through the use of the other sensors, the concept of the trash can was proven and the functionality of the computer program was also verified. Without the correct sensor, the testing of the trash can could not continue.

Mac Computer

A medium size iMac computer, as shown in figure 7, was placed in to the base of the exoskeleton of the trash can. The computer specifications include 2GB of RAM, and a Dual Core Intel processor with 1.7GhZ clock speed. The purpose of this computer is to gather and store the data being collected by the sensors.

Figure 7: IMac[22]

The computer utilized for this project is quite obtrusive. It is very large and very heavy. It is the sole reason that this project requires a base to house everything in. The only reason this is being used is due to its convenience and availability. If the project ever went to the real world, there are many other options to explore. Some of these options include tablet computers, embedded systems, or even cellular devices. Embedded systems are simpler versions of

[22] (apple_desktop_06)

computers. They can handle a limited number of tasks. The only thing that requires controlling in the project are the sensor, and speakers. The embedded system could quite handily control these objects. The problem arises when it is necessary to gather data. This would require more complicated microprocessors, as well as external peripherals. This essentially becomes a computer. Tablets and cellular devices are mini computers. They can handle most of the tasks, though not as efficiently as a full computer. If the right programs were compatible, tablets could be the best way to go due to their simplistic and minimal design, along with their complex functions.

HP USB Mini Speakers

When choosing speakers, there are a lot of things to consider. The lab utilized to build the trash can has quite a few speakers of its own, but were too big for the scope of this project. Instead, it was necessary to buy the smallest and thinnest speakers possible. There were a few criteria the speakers needed to meet. The speakers needed be loud enough to hear through the base of the trash can, but small enough to fit inside. They also needed to reach a decibel range of around 70 decibels. The reason for this is because 70 decibels is louder than a human being speaking at normal levels, but quieter than a lawnmower[23]. Since the speakers are volume controlled through the computer, the frequency does not matter as much. The intention of the speakers is to garner attention, not to be obnoxious while doing it. They were easily stored into the exoskeleton of the trash can. The speakers were placed into the exoskeleton for several reasons. It is required that the trash can itself be easily removed from the exoskeleton as to not be bothersome to janitors who discard the trash. Also, when people realize that the trash can

[23] (howstuffworks, 2011)

has a speaker system, as well as a computer, it may provoke possible intentions of stealing. This is counter measured by the exoskeleton of the trash can being bolted to the ground and surrounded by as much secure material as possible. The speakers were purchased from Wal-Mart.

Figure 8: Speakers

Video Camera

A video camera was used to record the people using the trash can. The video camera is a simple HD camera that was placed inside of a backpack and pointed towards the location of the trash can. It was be angled so that it can pick up the reactions of the people utilizing the trash can. The camera was also angled to try and pick up the reactions of the surrounding people to see if they have a behavioral change due to the sounds coming from the trash can.

Mechanical Design

When the design process began many different trash cans were considered as the suitable trash can for this project. At the end of the selection process a small trash can was decided on for the trash receptacle, as shown in the following Figure (Figure 9)

Figure 9: Trash Can

During the design process several design constraints became apparent. One constraint is that in some way the intelligent trash can needed to house a motion sensor, computer and speakers. All of these things needed to be contained within in the trash can in such a way that anyone using the trash can was unable to tell that these things were contained inside the trash can. The reason that these components needed to be hidden is so that users of the trash can will be unsuspecting of the trash can when using it. This allows for the trash can to be more inconspicuous.

The first iteration of the design (illustrated in Figure 10) was created as a two tier design. The trash can would be inserted into a shell constructed out of two by four posts covered by plywood. The shell and the trash can would then be attached to a base that would house the computer and speakers. The outer shell would allow for the wire from the sensor to by run up to the top of the trash can so as to be placed in the optimal position, at the top of the trash can, to sense the motion of the trash. This design though had a major flaw that made it unusable. Due to the chosen materials (wood), it was very heavy.

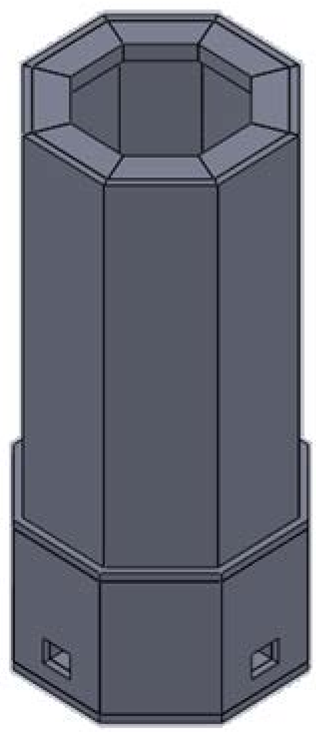

Figure 10 Trash Can on top of base

In order to correct the problem of how heavy the original design it had to be brought back to the drawing board. Using the original trash can as the focal point a new design emerged. The new design incorporated components of the initial design. The components that were kept in the final design were the base and the removable top level (illustrated below in Figure 11). The difference in the top level in this design is that it was shortened to cover only about 5 inches of the bottom of the base. The top therefore allows the trash can to sit inside of it and become part of the base (illustrated in Figure 12). This top level remained removable to allow for easy access to the compartment in the base. The base itself has the dimensions 29 inches from one side to the opposing side and a height of 11.25 inches. The final design remains constructed out of wood, but because it is smaller and uses less material it is not as heavy as the original design.

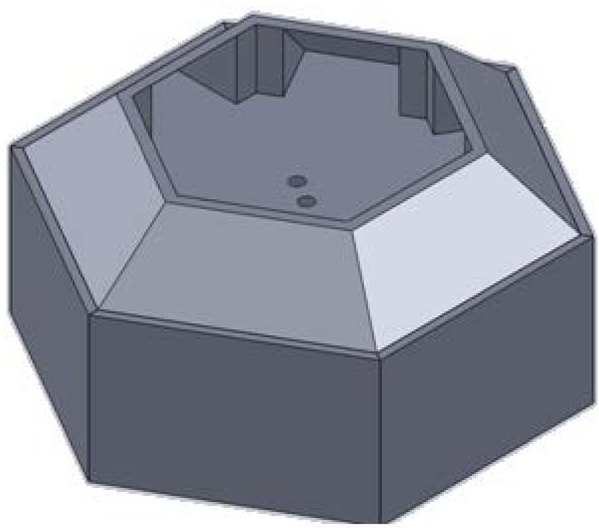

Figure 11 Final Base Design

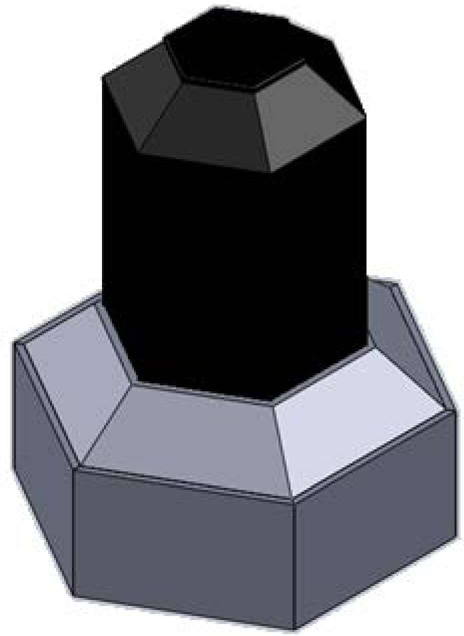

Figure 12 Trash Can On top of base

In the final design the upper shell for the trash can was removed. This meant that the wire from the sensor had to be run up through the bottom of the trash can. Then the sensor would be attached to the top of the trash can out of sight from users of the trash can. The placement of the sensor is illustrated below (Figure 13) by a cross sectional sketch of the trash can and base. In Figure 14 a picture of the move on sensor shows that the white globe of the sensor is how it senses the motion.

Figure 13: Move On Sensor

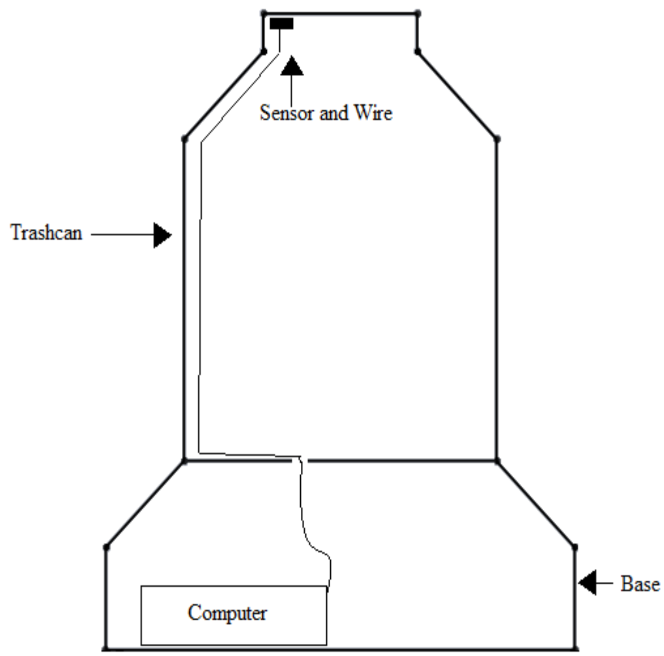

Figure 14: Cross Sectional Sketch

This final design iteration proves to be the most suited for the goals of the project. It is lighter than that of the original and creates a compartment for the electronics to be hidden from the eye. It allows for a very seamless integration of the trash can and the base. This is good so that the trash can is not very different from any other trash can. The reason that this is good is that it should be as inconspicuous as possible so that it does not receive and unintended attention because of the way it looks. The idea behind this project is to get people to use the trash can as if it is another trash can, be surprised by it, and then to want to use it more. If the trash can were to have some outrageous design it would take away from this goal and skew any data that is collected from the trash can. Therefore the final design corrects all the flaws that the original design contained, and allows for a very ordinary looking trash can.

Implementation and Location

After building the base and setting up the sensor for sensing the trash the, plan of actions was as follows. First, a suitable location for the testing of the intelligent trash can needed to be found. After considering several locations, the Campus Center cafeteria was decided upon.

The Campus Center was the best choice for the test site because it met several criteria. These criteria included the following; a high human traffic area, high possibility of trash, ease of access, and probability of gaining access to the area. The food court in the Campus Center satisfied the high human traffic by being a place that many frequented for lunch and other food related activities. It satisfied the trash criterion by allowing for all of the food wrappers, cups, dirty napkins, etc. The Campus Center food court is very easy to get in and out of, and the trash can could easily be installed. Finally, many IQP projects have been tested and displayed with in the Campus Center over the year, which satisfies the final criterion.

The next step was to determine the exact location. The main consideration for the exact location was that an outlet needed to be nearby in order to power the computer and the sensor. Another consideration was how frequently the exact location would be frequented by people with trash to throw out. This was analyzed through observation over several days. During this observation period there were several spots that met these criteria. The optimal spot was determined to be next to the cash register and the water cooler.

The first step of testing was to put the trash can into the Campus Center without it being activated to allow for the public to acclimate to the presence of the new trash can. The next step was to turn the trash can on and allow people to interact with it for a couple of days. During both of these steps video was taken without the people, that interact with the trash can, knowing. This allowed for the people to react genuinely to the trash can. The video allowed for a proof of concept for the entire project. The video also allowed for people to observe the effect of the intelligent trash can.

Sounds

A large variety in sound selections is important to be able to determine which sounds could provoke different behaviors and invoke different emotions. The human hearing range spans from 20Hz to 20,000Hz which enables people to hear many different sounds in nature. The interactive trash can emits the sounds from the base creating an illusion to the person that the sound it being omitted from inside the trash can. The first interaction, because of the unexpected playback of sound, can result in surprised or fear reaction because of the unexpected sounds. Some sounds could possibly startle the people interacting with the trash can which may result in them not tossing trash into it again, but it is important to observe these reactions as well. The sound choice is random during these interactions so some sound might be more familiar to them than others and this will also vary the reactions.

- Food Noises
    - Burp
    - Cookie Monster
    - Munching / chewing

A selection of trash thrown away in public locations such as a train station, a college campus center, or an airport, is food remains. Hearing these sounds relating to food could result in interesting behaviors and reaction because they may believe that the sounds omitted from the trash can are related to the trash even though they are not. Other reactions might nudge people to "feed" the trash can some more as it may be perceived that the trash can is hungry. Though the World's Deepest Bin had an infinite dropping sound, people attempted to fill the trash can. Similarly, these sounds can attempt to promote the “feeding” of the trash can resulting in people looking to acquire some trash to throw away.

- Animal Sounds
    - Birds
    - Lion Roar
    - Elephant Trumpet
    - Dog bark

People interact with all kinds of animals from house pets such as dogs and cats to exotic animals at the zoo. Some animals sounds might be ignored based on the location of the trash can; if the trash can was placed outside, people might ignore a light bird chirp because it people hear birds all the time in nature. Other animal sounds could startle or incite fear such as a lion’s roar or elephant’s trumpet because they elephants are more of an exotic animal and only seen in zoos or jungles. Several different reactions can occur with different animal sounds because there is such as wide distinctive variety, and people might ignore it, or be too frightened to put trash in it again. It is important to determine which sorts of sound that appear to be threatening or frightening to observe what sounds incite this behavior.

- People/Manmade Object Sounds
    - Applause
    - “Thank you”
    - Famous quotes
    - Arcade Sound

- Vehicle (Cars / Trains / Machines / etc.…)
- Cellphones

Mankind has created so many everyday inventions that omit different sounds such as the TW, videogames, cars, or cellphones. The trash can however, is generally a soundless object and it would be interesting to observe reaction people would have to hear manmade sounds being omitted from a trash can. Some sounds such as an applause or a “thank you” might encourage people to throw trash away again because they are praised. Also, the information or statements relayed in these sounds could be informational. In places such as schools, the trash can can relay an interesting fact or in an airport it could inform the public about a specific flight arrival or delay in departure.

- Music
  - Classical
  - Pop
  - Rock
  - Hip Hop
  - Jazz
  - R&B
  - International

Many people listen to music all the time; in their car, subways, elevators, during their exercise and calls on hold. The tastes of different genres of music vary from person to person and thus it is important to incorporate a large variety and selection of music to observe different reaction from enjoyment to disgust. People generally prefer certain types of music; someone might enjoy hip-hop and rap while hating classical and jazz and someone else might be the complete opposite. The genre of music played by the trash can can affect people in certain ways from provoking anger to soothing and comforting them[24]. Because this interactive system is designed to observe how people are provoked, it is important to test all possible sound to obtain all different reactions. People could also be introduced to different kinds of genres they have never heard before and enjoy them. The data of the different reaction to different music is important for several aspects because it can judge what the general public of that area enjoys and thus radio stations can modify their sound selections as well as other places can play different kinds of music such as elevators or train stations.[25]

- Other
    - No Sound
    - Infrasound

Overtime, people will become familiar with the sound producing trash can. If at times the trash can did not produce a sound on purpose, it can create different reactions by people. We could cause people to become sad, and others to judge them because their trash tossing did not return a sound. People could also become curious and try to analyze the trash can to see if different size and weights of the trash deposited would trigger with different sounds. Research studies have shown that sound beyond the hearing spectrum can physiologically

[24] (O'Donnell, 1999)
[25] (Olson, 1996)

affect people[26]. It would be interesting to continue researching the effects these infrasounds would have on people in a public environment. In order to understand human behaviors and ultimately understand how people interact and react to sounds, the sound emitting trash can would have to play a great selection of different sounds.

[26] (O'Donnell, 1999)

Software

MaxMSP[27] software provides a platform to create programs that enable the computer to interact with sensors allowing the computer to be an autonomous, interactive system. Max has a custom function that connects to a midi system and can parse the data returned from the sensor into useful values. Another function, fluidsynth[28], enables the playback of an instrument sounds stored in a sound font file. MaxMSP's feature enables the software to be exported as an independent program which allows for any computer to run it.

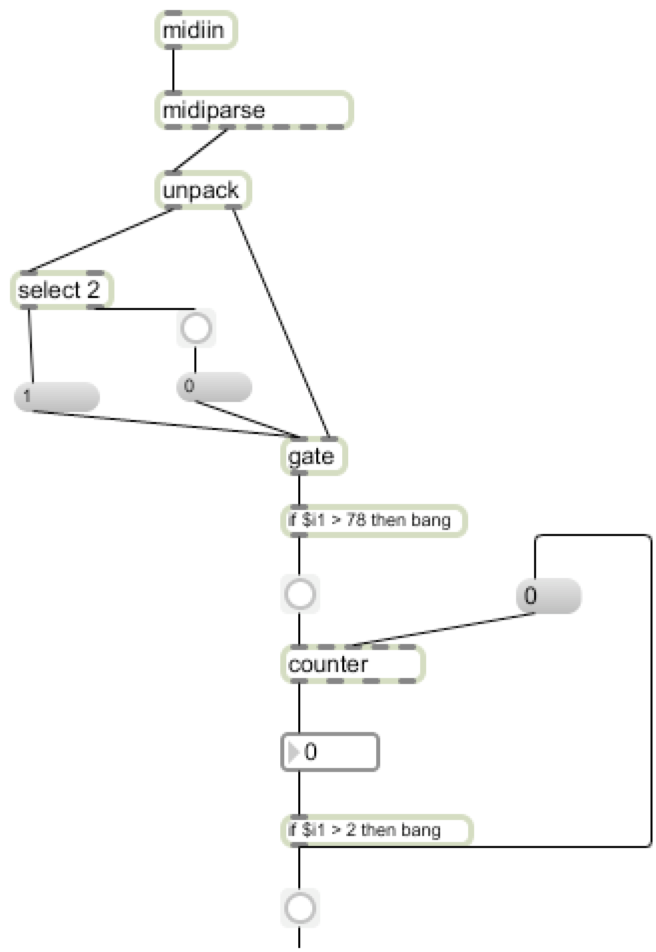

Figure 15: Sensor Connection Portion

[27] (Cycling '74, 2011)
[28] (Cycling '74, 2011)

The program is design to work with a BendMicro[29] sensor as the trigger which returns data that is analyzed by Max and outputs a variable range of values. When garbage is thrown into the trash can, multiple values above 78 will trigger the counter. Once the counter reaches 3 counts, it will trigger the next portion of the program as well as resetting the counter that will be ready for the next trigger.

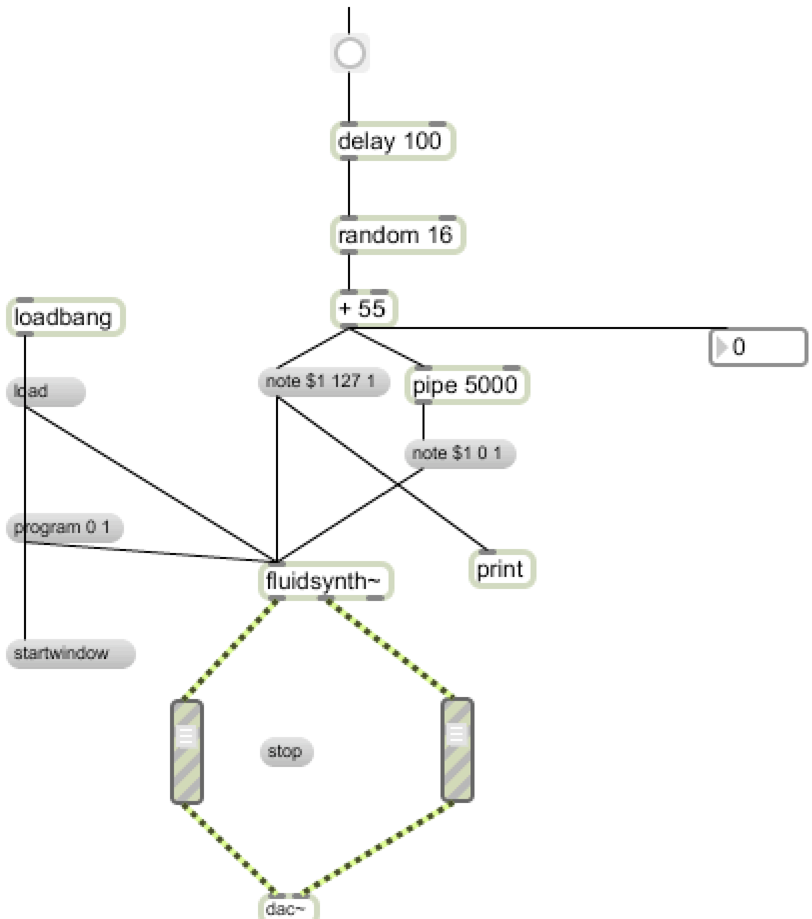

Figure 16: Sound Playback Portion

Polyphontics[30] can create instruments with custom sounds and save them in sound font formats which can be called by fluidsynth in MaxMSP[31]. The 16 sounds are loaded into the

[29] See page 17 for more details on BendMicro sensor
[30] (Sonic Amigos, 2011)
[31] (Cycling '74, 2011)

Polyphontics and assigned to different keynotes on a keyboard ranging from 55-70 and then the instrument is exported as sound font file to be called by fluidsynth in Max. Once the above portion of the program "bangs", triggers this half, the program calls a random variable from 0-15 and adds 55 to that value which results in a random value from 55-70. This determines which key is to be played on the keyboard thus indefinitely determining which sound will be played.

Simple modifications can change this program to be function for different sensors, sounds, and diverse environments. The sensor connection part of this program can become functional for any sensor by modifying the range that the values are returned. For example, if the MoveOn[32] sensor is implemented, the value ranged is lowered from 78 to 18 and the counter limit is changed from 3 to 5. If different sounds need to be played, then a new instrument can be created in Polyphontics and the program only needs to change the range of the notes to be played as well as which sound font file to open. The entire program is designed to be modular and simple for future expansion and development as this project would evolve.

Final Components / Modifications

As stated in the methodology, a few sensors were under consideration for the trash can. The chosen sensor for the project was a light sensor that put an invisible beam across the opening of the trash can that triggered when trash passed through it. In testing the trash can a more simplified approach was taken because the accessibility to the light sensor was limited.

[32] See Page 16 for more details on MoveOn sensor

In order to simulate the appropriate sensor, a Wii remote was connected to the Mac computer via Bluetooth. This, along with a free software and ITunes, allowed for the trash can to be manually triggered when a person placed trash into the trash can. This further allowed for the concept of the intelligent trash can to be proven.

Results

The projects final phase required experimentation. This experimentation was done within the Campus Center at WPI to simulate a more public, crowded area. The overall results of the experiment are explained here.

Reactions

Now that the trash can was functional, the original plan of action for the testing of the trash can was to be followed. The trash can was placed in the testing environment, disconnected, and therefore was just a normal trash can allowing for a control test. The control test was used to allow people that frequent the Campus Center cafeteria to acclimate to the new trash can. A fair amount of people used the trash can during the control test. Some were curious about the difference in appearance from the normally seen trash cans in the Campus Center, but most were not phased by the difference. The control testing yielded a half full trash bag. In the subsequent testing, the trash can was fully connected and manually triggered. In a fully operational test one and a half trash bags were filled. The increase in trash volume from the control test was quite astonishing.

During all of the testing, a video of the interactions with the trash can was taken inconspicuously. During the control testing, the video is very uneventful. The main purpose for the control video is to establish that the trash can would be used in its current location, and that the appearance of the trash can would not bias any person to throw or not throw trash away. During the testing of the fully functional trash can, the video is much more enlightening.

Reactions to the trash can emitting sound were different for each individual. Some reactions were of pure astonishment, while others were of curiosity. There were also a couple of ways that people became aware of the intelligent trash can. For some, they discovered it when they used the trash can. Others discovered it when other people used the trash can and were just a bystander in the situation. The reactions in these different roles also varied. For example, one bystander did a double take when the trash can emitted a sound. Another bystander continued to walk away while looking back with a baffled expression.

The most interesting reactions came from a group of children that used the trash can. Early in the morning, a group of about 30 children, who are part of a WPI summer camp, came to the cafeteria. When one child used the trash can, they all began to do the same. It started a very large chain reaction amongst them. The children would actively look for something to throw out so that they could hear new sounds. Many of these reactions can be seen on the video.

It is interesting that the children had the biggest reaction to the intelligent trash can. The difference in reaction between the adults and the children raises the question of why? This is a puzzling question, but one that has an answer backed up by research. The answer to this question is that children are much more curious of their surrounding environment than adults are. According to research done at Purdue University, children are very aware of unfamiliar objects in their immediate environment[33]. Furthermore this awareness leads to investigation of the foreign object. This explains why the children all became so infatuated with the trash

[33] Smock, Charles. "Children's Reactions to Novelty: An Experimental Study of "Curiosity Motivation"."Child Development. 33.3 (1962): 631-642. Print

can once it began to make sound. When the intelligent trash can made sound, it became an unfamiliar object in its environment.

Further Research & Development

This project could be the beginning of something much bigger. The original idea of the project was to design an intelligent audio system in order to detect patterns in humans. Although this idea evolved into a more specific task, they are similarly related. The reactions that were received from people using the trash can seem to be something that can be further developed.

As stated already, children seemed to be the most excited about the trash can. Future MQPs or IQPs could expand on this idea. When this project was originally designed, it was aimed at everyone inside the cafeteria. If the age group was narrowed down, the results may have been much more interesting. If the trash can was placed into a school, playground, or park, the results would be much easier to dissect. This project could possibly be a type of early intervention for children. Children's minds are sponges[34]. That is why when someone is learning how to play an instrument, or learning a new language, the best time to teach them is when their brain is still developing. Since the trash can project is a subliminal way of forcing people to throw away trash, it may work on children to the point that they will continue their trash throwing efforts as adults.

Over the course of the project, many problems were encountered. For the future, proper sensors should be used. This enables a much easier use of the trash can. The Light sensor is the best sensor to utilize for the trash can. Not only is it the easiest to set up because of the invisible laser, but it's also the safest route considering no other sensor activates on non-

[34] (Fridays Child Montessori Preschool)

heat motion. Utilizing the light sensor also improves upon data gathering. Since the Wii remote was used instead of the sensor, there was only visual data that was received. If the light sensor is utilized, there could very well be more data gathered through the sensors programing in the computer. By using this data, it is possible to derive patterns such as frequency of trash being thrown away, amount of trash being thrown away, time between trash being thrown away, and how each sound affects the frequency of trash being thrown away.

Instead of videotaping from a distance, proper video cameras could be installed inside of the trash can itself to get a more personal reaction. More specifically, the video cameras could be placed near the head of the trash can, as shown in figure 17. This enables the camera to see all the facial reactions of the users, as well as all of the background reactions behind the user.

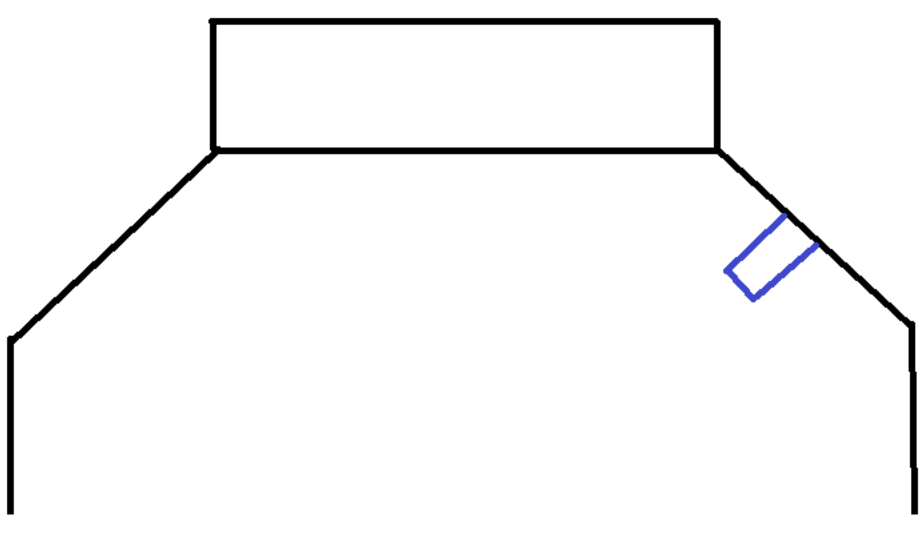

Figure 17: Video Camera Placement

An alternate interactive system was designed at New York University that combined motion tracking software to a spotlight that shined on random persons and followed them as they moved.[35] Though this system did not attempt to promote any behavior, it was designed to observe different reactions people would have to a “stalking” spotlight. Implementing this type of system would enhance this project. Although the spotlight method would not be utilized, similar software that was used to analyze the data could be. The students designed software that analyzed the movement expressions of the people walking around. If the software could be modified to analyze the facial expressions of the people caught on camera, the results would be interesting.

[35] (Han)

Conclusion

Overall, the results of this project were more than satisfactory. Although there were obstacles that needed to be overcome throughout the project, each challenge presented was a way of improvement for the trash can itself. The results indicate that the intelligent trash can makes people want to throw out more trash. The results also show that the trash can works as a form of behavior modification. By making the trash can more interesting to throw out trash, makes people want to use the trash can more. This proves that through the use of a sound emitting trash can people can be in essence forced to throw out more trash.

Appendix A: Authorship

Section	Author
Abstract	Patel
Introduction	Womersley, Ansari
Background	Ansari, Patel, Womersley
Objective	Patel
Methodology	Ansari, Patel, Womersley
Results	Womersley, Ansari
Analysis	Womersley
Further Research & Development	Ansari
Conclusion	Ansari

BACKGROUND	Author
Effects of Technology on Society	Ansari
Theories	Ansari, Patel
Understanding Human & Sound Interaction	Ansari, Patel, Womersley
Infrasound	Ansari
Existing Intelligent & Interactive Systems	Ansari, Patel

Methodology	Author
Components	Ansari
Mechanical Design	Womersley
Implementation & Location	Womersley
Sounds	Patel
Software	Patel
Final Components/Modifications	Womersley

Works Cited

Hearing range. (2011, June 28). Retrieved July 1, 2011, from Wikipedia: http://en.wikipedia.org/wiki/Hearing_range#Effects_of_high_frequency_limit

http://infusionsystems.com/catalog/index.php/cPath/24. (2011). Retrieved from Infusionsystems.com.

http://infusionsystems.com/catalog/index.php/cPath/24. (2011). Retrieved from infusionsystems.com.

Nudge(book). (2011, May 17). Retrieved May 25, 2011, from Wikipedia: http://en.wikipedia.org/wiki/Nudge_%28book%29

Abdallah, S., & Plumbley, M. (2009). Information dynamics: patterns of expectation and surprise in the perception of music. *Connection Science*, 89-117.

apple_desktop_06. (n.d.). Retrieved July 20, 2011, from http://img.tomshardware.com/us/2007/09/06/should_you_buy_a_new_mac_mini_imac_or_mac_pro/apple_desktops_06.jpg

Charles, S. (1962). Children. *Children's Reactions to Novelty: An Experimental Study of "Curiosity Motivation*, 631-642.

Cote, M. (2010). Nudge Theory. *CA Magazine*, 56.

Cycling '74. (2011). Retrieved July 15, 2011, from Cycling 74: http://cycling74.com/

Davies, A. (n.d.). *Acoustic Trauma : Bioeffects of Sound.* Wales: University of Wales.

Fridays Child Montessori Preschool. (n.d.). *Children's Minds Are Like Sponges*. Retrieved July 8, 2011, from Fridays Child Montessori: http://fridayschildmontessorigoldcoast.qld.edu.au/childrens-minds-are-like-sponges

Goldsmiths College. (2009). *Intelligent Sound and Music Systems*. Retrieved May 22, 2011, from isms intelligent sound and music systems: http://www.doc.gold.ac.uk/isms/?page=ISMS Home

Goodman, S. (2010). *Sonic Warfare: Sound, Affect, and the Ecology of Fear.* Cambridge, MA: Massachusetts Institute of Technology.

Haan, J. (2006). How Emergence Arises. *Ecological Complexity Volume 3 Issue 4*, 293-301.

Han, J. Y. (n.d.). *Motion Tracking*. Retrieved June 28, 2011, from Jeff Han: http://cs.nyu.edu/~jhan/tracking/index.html

howstuffworks. (2011). *What is a decibel, and how is it measured?* Retrieved July 18, 2011, from howstuffworks: http://www.howstuffworks.com/question124.htm

Marcus T. Pearce, M. H. (March 2010). Unsupervised statistical learning underpins computational, behavioral, and naural manifestations of musical expectations. *NeuroImage*, 302-313.

O'Donnell, L. (1999). *Music and the Brain*. Retrieved July 1, 2011, from Brain & Mind: http://www.cerebromente.org.br/n15/mente/musica.html

Olson, K. D. (1996, February 22). *The Effects of Music on the Mind Beyond Soothing the Savage Beast*. Retrieved July 1, 2011, from Reverse Spins: http://www.reversespins.com/effectsofmusic.html

Partners In Rhyme Inc. (2011). Retrieved June 18, 2011, from Partners In Rhyme: http://www.partnersinrhyme.com/soundfx/human.shtml

PBS. (2008, July 1). *Can Animals Predict Disaster? Tall Tales or True?* Retrieved May 25, 2011, from PBS: http://www.pbs.org/wnet/nature/episodes/can-animals-predict-disaster/tall-tales-or-true/131/

Saenz, A., & Stephens, R. (1986). Noise Polution. In G. Jansen, & E. Gros, *Non-auditory Effects ofNoise: Physiological and Psycological Effects* (pp. 225-248). John Wiley & Sons Ltd.

Sin-Lyul Lee, C. C.-M. (2005). *Intelligent Sound Field Tuning System for Home Theater Systems.* IEEE.

Soames, J. (1999). Noise Sensitivity as a factor influencing human reaction to noise. *Noise Health*, 57-68.

Sonic Amigos. (2011). *PolyPhontics*. Retrieved July 15, 2011, from SonicAmigos: http://sonicamigos.com/polyphontics/

Thaler, R. H., & Sustein, C. R. (2008). *Nudge: Improving Decisions About Health, Wealth and Happiness.* New York: Penguin Group.

The Associated Press. (2003, September 7). *Infrasound linked to spooky effects* . Retrieved May 25, 2011, from msnbc: http://www.msnbc.msn.com/id/3077192/

Volkswagon. (2009). *The Fun Theory*. Retrieved May 25, 2011, from thefuntheory.com: http://www.thefuntheory.com/

Wikipedia. (2011, May 21). *Emergence*. Retrieved May 25, 2011, from Wikipedia: http://en.wikipedia.org/wiki/Emergence