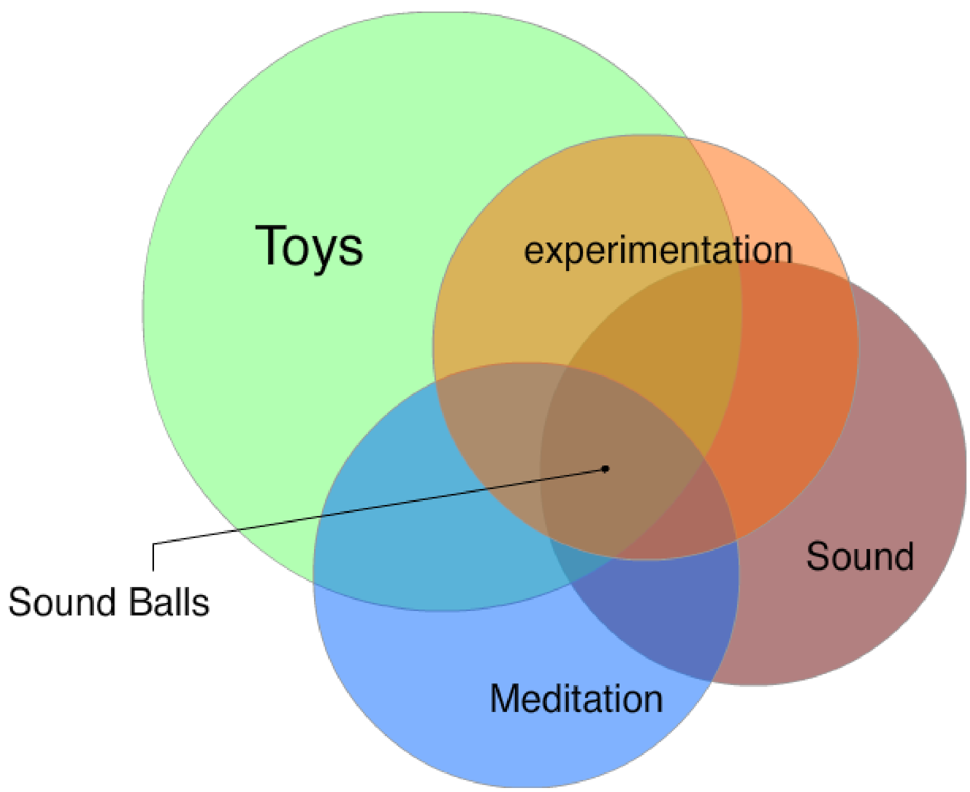
# Sound Balls

Andy Wallace

**Overview**

Sound Balls is an exploration of how people can create sound using a set of smart balls. I set out to create a non traditional method of sound generation the blends digital and non-digital elements in the form of a new audio toy. By manipulating a set of smart balls, users convert real world action into a fluid sound-scape that affords play and exploration as users learn the rules of the system while interacting with it. The balls themselves have unique attributes in both their hardware and the way the information from them is converted into sound, and the system as a whole has two unique modes of interaction: Free Form and Singing Bowl. The information is gathered from each ball by an implanted micro-controller and sent wirelessly to a computer where it is interpreted in order to create the sound.

**Domains**




Sound Balls occupies several domains, but it can largely be reduced to four distinct domains: Sound, Toys, Exploration, and Meditation.

*Sound*

Most obviously, Sound Balls is a system of sound generation. While not necessarily an instrument, the creation of sound is essential to the project. Within this domain, procedural digital sound is the primary focus. All of the audio generated by the project are the result of synths created in SuperCollider. Sonically, There is an emphasis on combining both digital and non digital sounds. In the Free Form mode, digital bleeps and noise filters are complimented by crisp chimes inspired by Chinese baoding balls and the Singing Bowl mode obviously draws from classic Tibetan singing bowls.

*Toys*

Although Sound Balls is not targeted specifically at children, play is a huge part of the intended experience. Unlike most instruments, it should be rewarding to a user who has never touched it before and more importantly it should be fun. Interacting with it should be exciting and magical. In much the same way that children's toys often aim to to create an imaginary space and imbue objects with importance or narrative value, Sound Balls should transform a set of normal looking balls into an unexpected and novel sonic experience.

*Exploration*

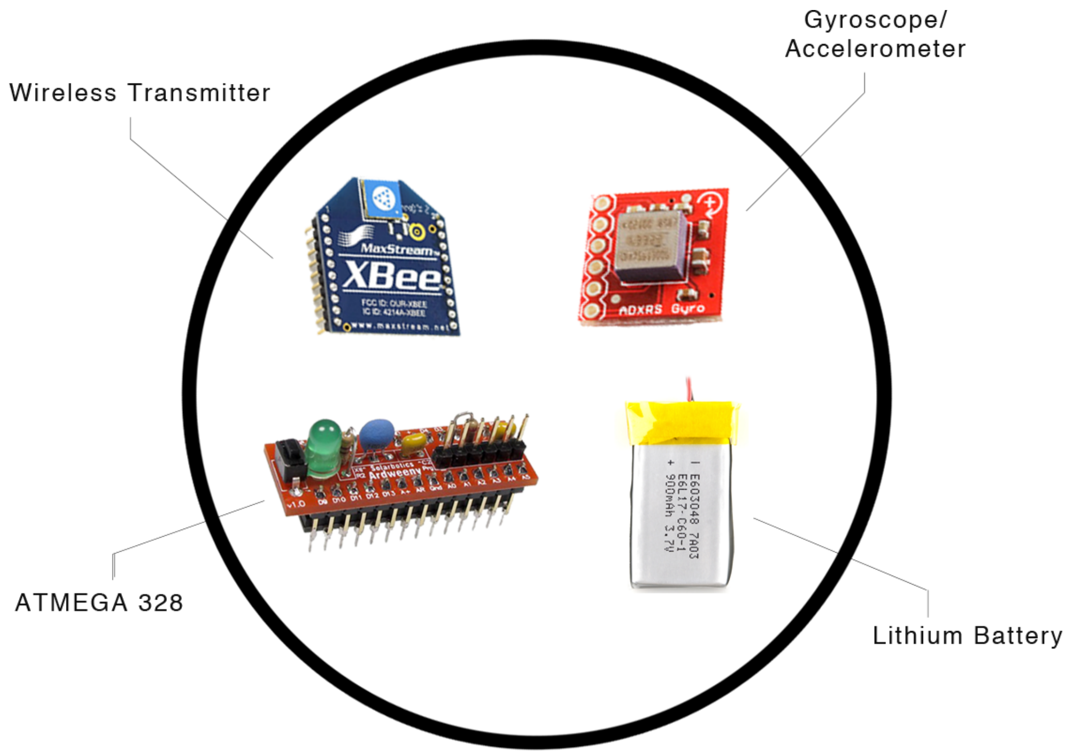
The method by which the sound is made and controlled is deliberately left somewhat opaque. Any interaction with the balls will create sound, but it may take some time to glean exactly what the rules are. The system should be complex enough to reward users for experimenting and learning exactly how it works with greater control over the sounds being produced. This kind of exploration shares a lot with the toys domain in that they both rely heavily on play. Toys don't have exact rules, and in environments that are interesting exploration can be extremely fun.

*Meditation*

Although it was not my original intent, there is a strong meditative element to the Singing Bowl mode of the toy. Not at all unlike the traditional instrument the mode is based on, it seems to promote concentration and alignment with the sound being produced. This may be something of a misnomer, as I don't believe the mode encourages personal reflection to any strong degree (although it certainly could for the right user), but it does seems to focus the users attention in a unique way, strongly locking the connection between their actions and the sounds being created. Out of the four domains this is probably the least connected, although the link to sound is undeniable, as the ability of sound to assist in the creation these sorts of mental states has been undeniably shown.

**Summary**

Sound Balls is an audio toy that uses five smart balls to create sounds. Largely intended for more than one user, the combination of different sound being generated should create an interesting sound-scape for the users that can be controlled more carefully once they have some experience with the system. The target audience is broad, comprised of anybody who might be interested in a novel acoustic experience. Although musicians are more likely to understand comprehend the system more quickly, there is no skill level that must be cleared to start using it, as any interaction should produce interesting sound, unlike most instruments.




Overview of the components inside each ball

Each ball is equipped with an ATMEGA 328 micro-controller, an xBee wireless transmitter, a small lithium rechargeable battery and either a gyroscope or accelerometer to track its movement. This information is passed to an Arduino base station also equipped with an xBee which communicates to an openFrameworks app using the computers serial connection. The openFrameworks app interprets the raw incoming data from the balls depending on the mode it is in and sends Open Sound Control messages to a SuperCollider program that generates the sounds. This process will be invisible to users, though, who will simply see a set of balls that make sound.

Although a skilled user can use Sound Balls more effectively, it is not really an instrument. There is always an element of randomness to it, and while the action can be directed, it can never be completely controlled. Having an element of the unknown is important to the experience as the little surprises that come from interacting the with the system are part of what makes it fun. It is an audio generation platform but it is also a toy, and play is a distinct part of the interaction.

Users would most likely encounter Sound Balls in a gallery setting, where it is on display and viewers are invited to play with it. It could certainly be placed in other settings, but the group nature of it as well as the relative cost of having the full set-up make it unlikely to be a consumer item. When encountered in this setting, people will have to work with each other to determine it's exact set of rules, if they are interested in controlling it, otherwise they will simply move the balls around and enjoy the resulting sonic environment.

While I believe it is beneficial to include some minimal instruction (this ball works well when rolled, this ball controls the sound of the other balls etc), keeping this to a minimum is important to me, as part of the pleasure of an unusual medium is the exploration of exactly what it can do. This was one of the most interesting elements of the test groups I ran when prototyping. Almost without fail, a few minutes into playing with the balls the relative cacophony of everybody throwing the balls around would stop when somebody would say “Wait, stop moving those. Let’s see what happens when I just do this...” and from there each ball would be inspected in order to glean its own sonic qualities before play resumed in a much more directed way.

**Precedents**

Because so many of the works included here obviously involve audio to some degree and cannot be properly be described by written words alone, for most I will provide the URL of a video that I feel demonstrates the project.

Scrapple by Golan Levin
Video: [http://vimeo.com/2379389](http://vimeo.com/2379389)

Scrapple is a sequencer that utilizes physical objects to make sound. Any object can be laid on a long table with a projector and camera mounted above it, and will be interpreted as a specific tone based on its proximity to the top of the table when the play head passes over it. The play head will continue to loop over the table, allowing the sound to modified by moving the object or built upon by adding more and more objects to it.

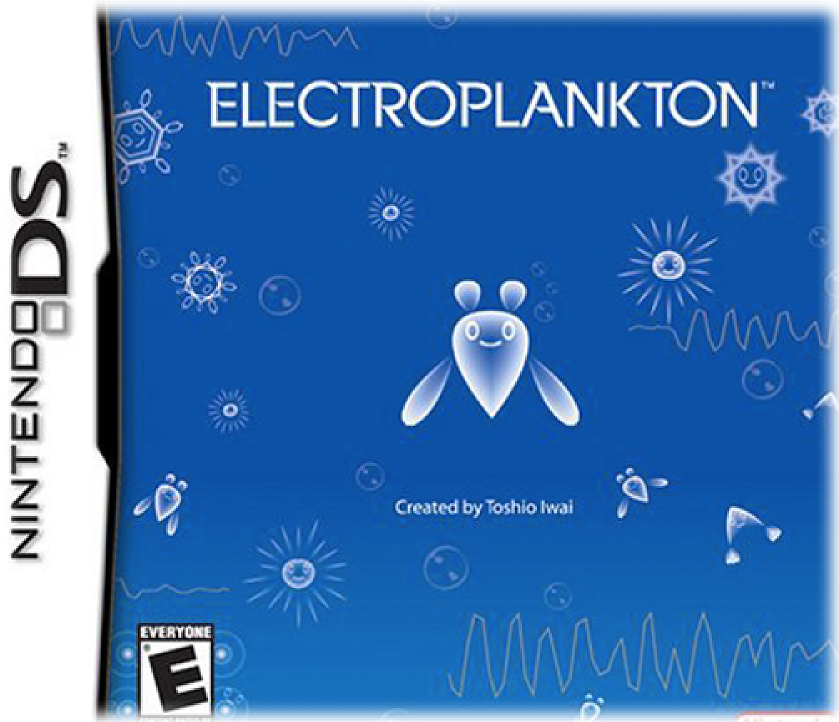
I liked the way that Scrapple invites everyday object to be imbued with musical potential. Any object can be added to the table and will have distinct sonic qualities based on its shape. While Sound Balls clearly requires a specific set of objects, they deliberately do not appear digital as I wanted to capture this feeling of normal objects transforming into sonic beings. The Scrapple instillation also does a great job of encouraging and rewarding exploration. By having the play-head clearly go over the table in loops, users can tell exactly when a sound is being made, and are then able to adjust just that part of their creation to see how it can be modified. This was an element I hoped to incorporate into my own work.

RhythmSynthesis by Ryan Raffa
Video: http://vimeo.com/22783883

RhythmSynthesis is another sequencer created by Ryan Raffa as his thesis project for Parson's MFADT program in 2011. It also utilizes computer vision to create sounds base on objects placed on a surface, but behaves very differently from Scrapple. In RhythmSynthesis, colored shapes are applied to a light box and create sound as an invisible play-head passes over them. The sounds that are produced are affected by the color, size and shape of the object that are being passed over. The custom cut shapes can be combined to make new shapes of different sizes.

This project is more mysterious in its interaction than Scrapple, and as a result feels a little more magical. People interact with it without full knowledge of what they are doing, and while this can make it a bit harder to get a firm understanding of its workings, it allows for unexpected results, and because it is created in such a way that truly unpleasant sounds are difficult to create this kind of blind experimentation can have enticing results. The interaction in Sound Balls is definitely somewhat opaque, but I have hopefully created something like Raffa's project, where any interaction will create something interesting, and those who take the time to get really understand the system can utilize it to create very deliberate sounds.

Electroplankton by Toshio Iwai
Video: http://www.youtube.com/watch?v=d3v6npP8OZk

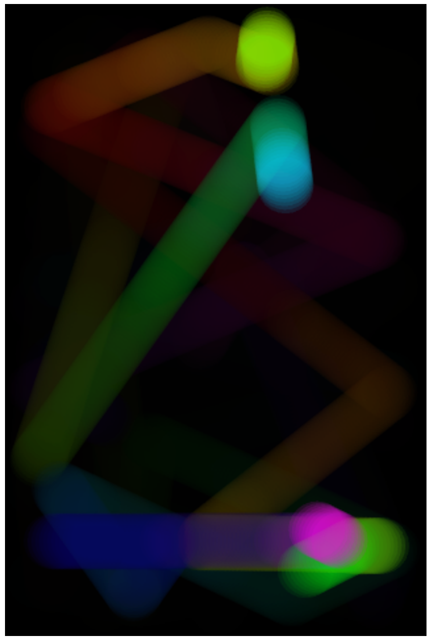



This collection of music toys released for the Nintendo DS provides a great gallery of unique musical interfaces. Making great use of the DS's stylus interface, the project was a surprise when it came out as it is one of the few non-games released for Nintendo's handheld system but managed to gain a fair amount of critical success (scoring a 76 on review aggregator GameRankings.com) and has become an example of the potential of the system for uses besides gaming.

Electroplankton explores many non-traditional scenarios for music generation, which was obviously something I sought to do with my own project. Iwai is also very interested in the blending of digital and non-digital instruments and has explored this in his other projects. His approach toward generating sound using the setup of a toy had a great impact on my thinking of how to go about crafting the interaction of Sound Balls.

Balls by Ioitic

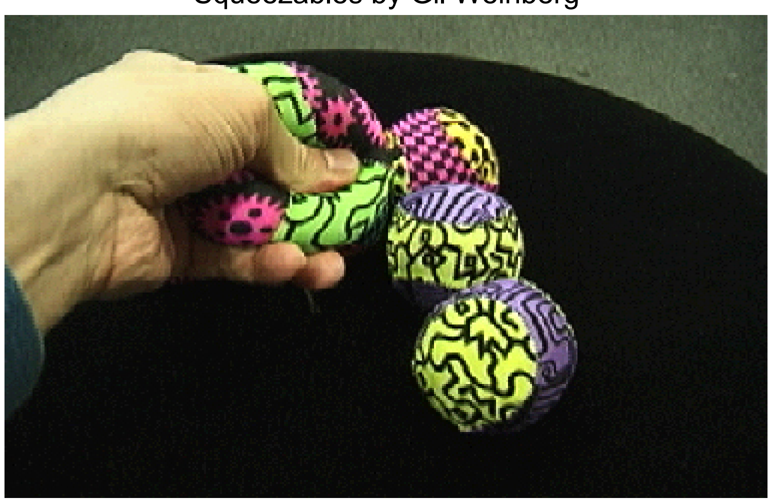
Video: http://www.youtube.com/watch?v=CuOviP0vzGQ



This somewhat simple iPhone app fills the screen with a set of balls that bounce around and make noise. The user can select from a variety of sound sets for the app to draw from and can customize the sounds created utilizing a number of sliders. Although individual balls can be dragged and released, the app functions just as well on its own, ensuring that the balls never stop moving.

Although this app is entirely digital, the nature of having balls bounce into each other to make sounds bares resemblance to my project, especially in its early phases. While the application is very fun and relaxing to play with at first, I found that it grew old quickly as there was not much an advanced user could do to control the sound. In my own project, I wanted to make sure that once the system was understood to some extent, this knowledge could be used to exercise better control over the sounds being made instead of exhausting its potential.

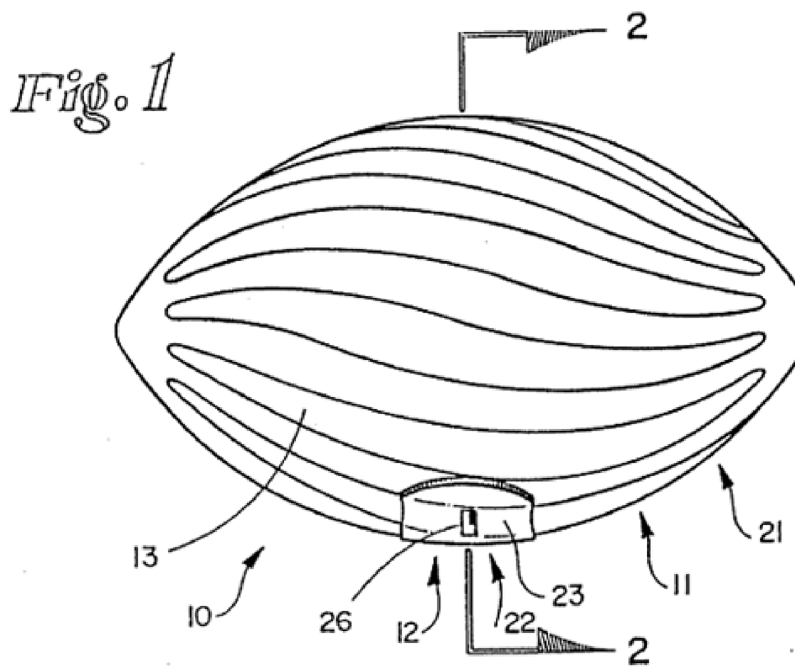
Squeezables by Gil Weinberg



Squeezables was a MIDI instrument consisting of a set of gel balls that could be squeezed or pulls to create different sounds. Certain balls created the rhythm while other balls provided the melody or adjusted things like tempo, and many of the balls were affected by what was happening to their neighbors. The balls were all mounted on a podium and a piece composed specifically for them was presented at Ars Electronica in 2000. They were created as part of a larger project based on inventing new instruments.

Besides the obvious fact that this project uses balls to create sound, Squeezables was relevant to me, because Weinberg specifically aimed his instruments to have appeal and be usable by people of a wide range of skill levels, and for his performance, included both accomplished musicians and relative novices. Unlike the Sound Balls, Squeezables are actual instruments intended to play music, so he sought to do this by having instruments of varied complexity for the different players to use. In my own work, I wanted to create toys that allow varied levels of control to different types of users.

Whistling Football
Randall H. Moorman




This patent (#5253866) was immediately obvious to me when I stumbled across it as the whistling football put out by Nerf during my childhood. The product is fairly simple: a small whistle placed on the side of the ball has air pass over it when it is thrown, creating a sound without greatly reducing the ball's ability to sail through the air.

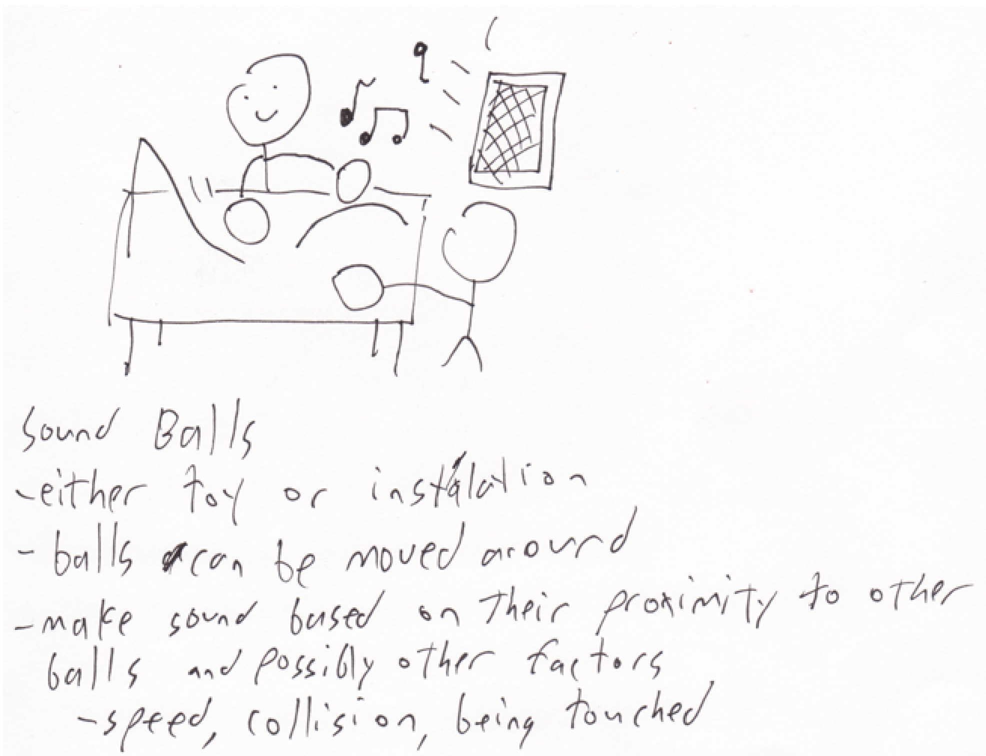
While not bearing any especially strong resemblance to my project, this was worth noting for me as a reminder that there is an interest in the synesthetic connection between action and sound outside the digital realm. These toys are popular for a reason: connecting what a person does with an object to a sound makes it more interesting and adds a new dynamic to what may be a familiar object.

Singing Bowls

By far the oldest of the references I am making, these ancient Tibetian instruments are used both ceremonially and recreationally to create a strong resonance that appear to come from outside of the object. This sound is produced as a slow build up as a wooden instrument is moved around the edges of the bowl. I have always been fascinated by singing bowls and the unique sound they can make.

While the Singing Bowl mode of Sound Balls, and the type of user experience it creates pays obvious homage to this instrument, I drew upon them in other ways as well. In Sound Balls, the sound does not emanate from the balls themselves, but from a potentially distant speaker. Connecting the direct action happening to the balls with the separate sound coming out of the speaker needed to be considered. Singing Bowls are a great example of how action and sound can be tied together when the physical origin of the sound alone may not be helpful.

**Iterative Design Process**

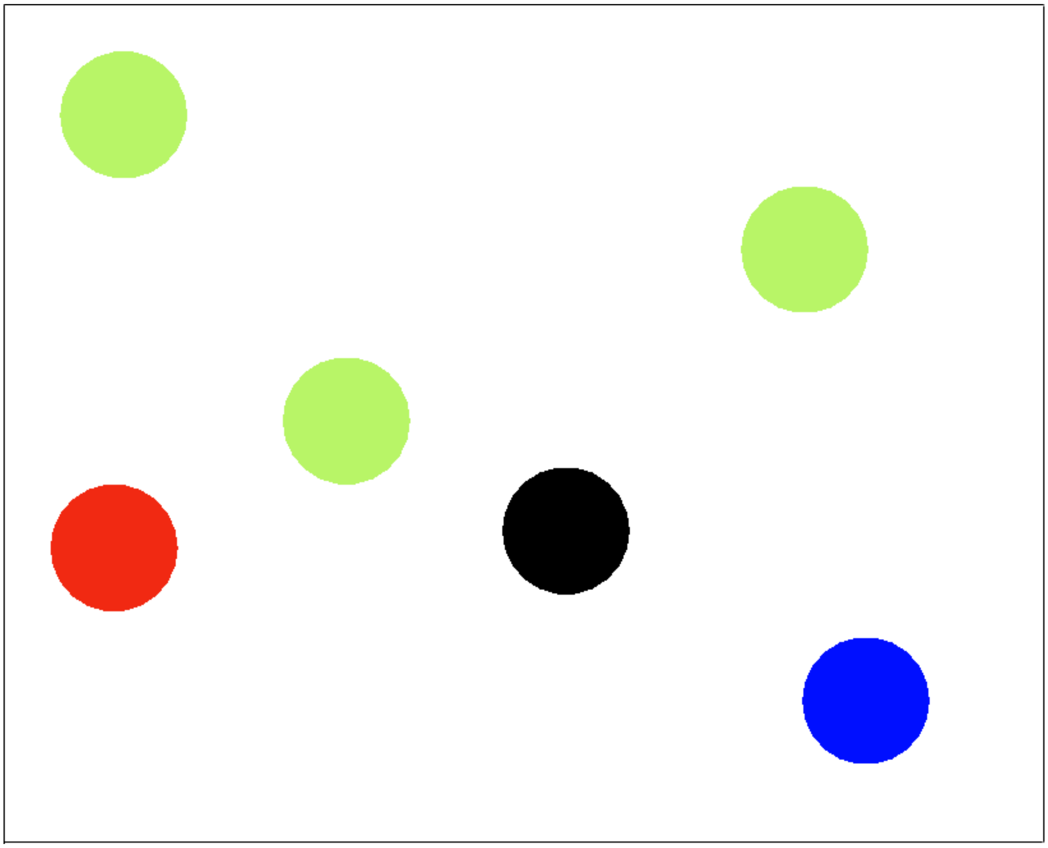


Original sketch proposal for Sound Balls

*Inception*

While brainstorming for possible project ideas, I had several sketches that involved some kind of smart ball that made sound. The two most promising to me were a ball pit toy that played something of a game of hide and seek, hiding among the non-special balls in the pit, and set of balls which would eventually become the Sound Balls. Obviously, this was the topic I decided to pursue.

*Digital Prototype*

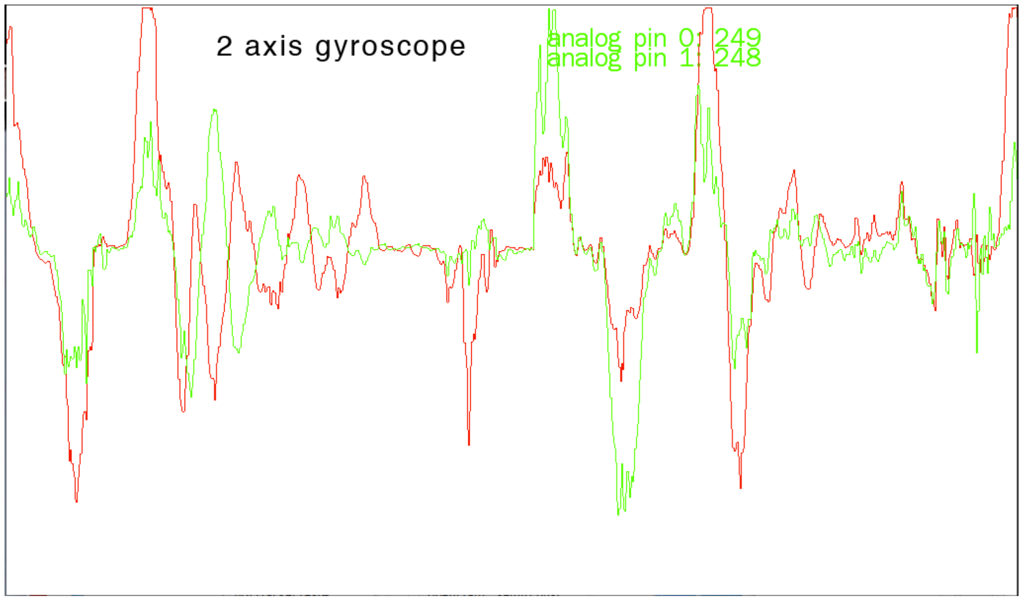


I first created an openFrameworks sketch that roughly simulated the interaction of the balls. As in the final iteration, It made sounds by communicating with SuperCollider. It was important to me to use an external program for sound geenration as I have never been pleased with the sounds that openFrameworks is capable of generating on its own. The balls could be dragged around with the mouse and made sounds when they were moved or collided with each other.

In this version, all of the balls generated sound using identical rules. Volume was determined by the speed of the ball and the pitch was determined by the ball's distance from the other balls. Originally, I wanted to use the distance between the balls as a major factor in determining their sound.

This prototype did a good job of testing the basic interaction and sound generation, but it did not allow for any group play, and obviously did not even come close to replicating the feel of manipulating physical balls. I did take some steps toward implementing an OpenCV version to track bocce balls, but this did not really mimic the actual use either as it required that the balls stay within range of the camera and not be obscured. The type of interaction needed to use the camera was very dissimilar to the way people wound up manipulating the final project.

*Physical Testing*



Data from testing the gyroscope

The next step was to work with actual hardware. I did not worry about getting the wireless transmitting working at this point, but simply wanted to see which sensors most accurately gave me information about the ball's movement. The primary sensors I was working with were a gyroscope and an accelerometer. I hollowed out a styrofoam ball and inserted the sensor by itself into the ball, tethered with wires to an Arduino attached to my computer that tracked the data coming in a simple Processing sketch.

From these initial tests, it became clear that the gyroscope gave readings that could be easily interpreted to give a good approximation of the ball's velocity. Having the unit tethered, though made it difficult to work with and test accurately, so getting it wireless and self contained became the next goal.

*Connecting to openFrameworks*

This implementation prototype focused on how information could be transferred wirelessly from a ball to the computer. It also incorporated openFrameworks into the process instead of depending on Processing, which would have been unable to computational laod that I knew the final project would require. Once it was up and running, an individual ball could send the following information to the computer:  ID number, velocity, distance from other balls, and if a collision occurred.

This data was all delivered as ints of either 1 or 2 byte length. The smaller pieces of information could be sent as a single byte (the collision flag, could have been reduced to a single bit, but for consistency in transmission, I found it useful to send everything as a collection of one or more bytes). The base station received the individual bytes and rebuilt them into ints where appropriate. All of the communication was done through xBees connected to Arduinos.

I originally had a lot of trouble using OF's serial communication as my computer was crashing every time I tried to connect the two devices. This turned out to be because the Arduino was sending out information constantly, flooding the serial port. Putting brief pause between transmissions largely solved it, and finally have the OF application actively request information from the base station when it needed it became the solution that I used for the rest of the project.

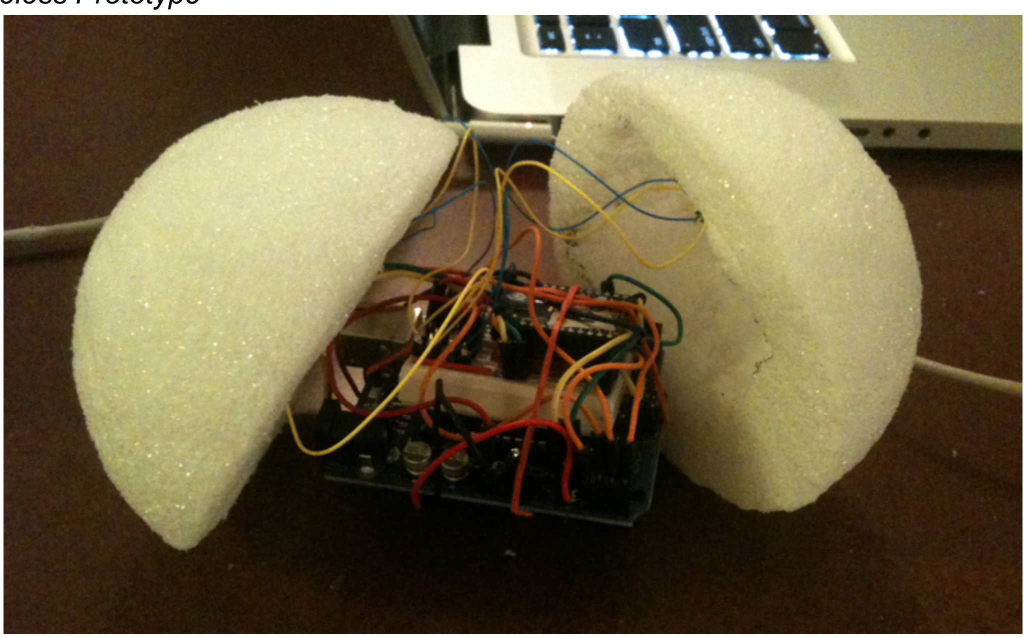
In this prototype, the ball did a lot of processing internally. There was code running on the Arduino that analyzed the data coming in and determined if there had been a collision as well as doing the calculations on the gyro data to determine the speed. I originally thought that this would cut down on processing time by having the each ball manage itself, however, the amount of calculation that needed to be done was not nearly enough to tax the computer, and the difficulty of having to open up the ball any time the methods being used needed to change made this unwieldy. Almost immediately, I opted to have the balls send their raw data with all calculations being done on my computer.

*Sensor Testing*

Although I was pleased with how the gyroscope handled determining the speed, I wanted the balls to be able to determine their distance as well. I outfitted the ball with a set of IR receivers and emitters, so that each ball could sense the others. However, I found that this method was very unreliable, requiring  the LEDs to line up almost exactly with the receivers as well as being very affected by the ambient light in the room.

I also began brainstorming alternate behaviors for balls as well as alternate sensors to interact with. I tested several sensors, including tilt switches, rang finders and photo-resisters. Although some of these gave good information about what was happening to the ball, I abandoned them early on as their interaction they afforded limited in some cases and awkward. Since it seemed that the gyros might be the only sensors used in the balls, I started thinking about ways that the sound could be controlled with just the one sensor.

*First Wireless Prototype*



This was the first functional prototype that came close to emulating the behavior I hoped to see in the finalized version. It consisted of two units, encased in Styrofoam and powered by a 9 volt battery, each using a gyroscope to read the balls motion. The balls made whine sounds that grew louder when moved and changed their pitch based on the speed of the other ball. While I obviously wanted more balls in the final version, this was a way to test out my original idea of having all balls affect the sound of other balls.

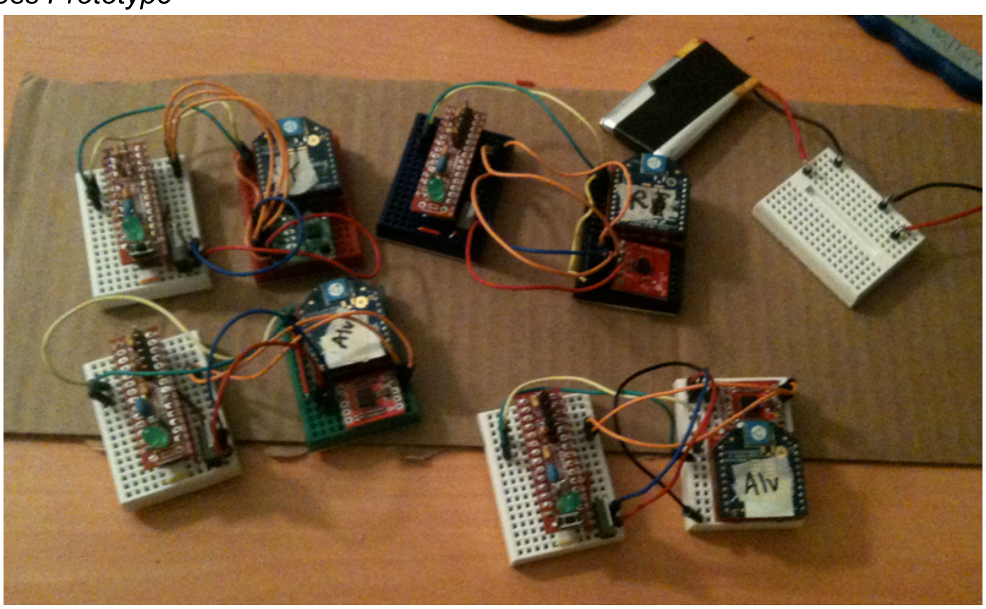
This prototype also featured some basic collision detection that I had created by analyzing graphs of the data coming in from the gyroscope. In this iteration, though, the collision detection was extremely spotty, missing many actual collisions and frequently firing when a collision had not occurred. This was a problem that continued to be an issue right up until the final iteration, although it was improved upon with each subsequent prototype.

The issue combined with the fact that the balls were always generating sound caused most testers to be very unsure of what their involvement really was in the sound creation. For most, there was relatively little causal link between their actions and the resulting sound. I also found that although I had designed the balls to be rolled, this was far from the only action that users attempted with it. Nearly everybody picked the balls up and swung them around, which registers very little on the gyroscope. Other actions people did was spin the ball, tap it against things, and sliding them along a surface. Most of these did little to affect the sound.

In terms of the sound, it was interesting, but somewhat creepy. The two sounds often combined to make dissonant noises that turned some suers off to it. This definitely needed to be addressed, because I did want to create an object that was fun to use, and abrasive of foreboding sounds did not facilitate this, even if they were interesting.

One thing that this test really showed was how fun it is to have multiple people interact with the balls. Even with just the two balls, having two people play with them resulted in much more interesting sound, and generally more fun for the testers as they got to play off of what the other person was doing.

*2nd Wireless Prototype*



Internal components of the balls

In this version the hardware, code, and sound were all upgraded. The balls now used Ardweenies, the extremely small Arduino clone put out by Solarbotics, and were powered by rechargeable lithium batteries. Because the batteries were rechargeable, this allowed me much more freedom when testing because there was no imperative to turn the ball off when it was not being used (which took some time as there was no on/off switch at this point and turning it off required opening up the ball). Instead I could keep it sealed all day and just recharge it over night.

I also implemented two balls that used the accelerometer instead of the gyroscope to allows some of the balls to be moved around in the air. I created two new behaviors for these balls, the control ball, which made sound based on its position along three axes as well as affecting the pitch of the two gyro balls. I played with several sounds for the second accelerometer ball, but settled on what became the origin of the Singing Bowl mode: the ball would know if it was being moved at all, and as long as it was, it would cause a tone to grow louder, slowly increasing the volume and the detune to create a resonant sound. As the ball was moved two more tones would eventually join in, and when the ball stopped, the sounds would burst in a loud chime. If the ball was left alone, it would repeat this cycle from start to finish until a user moved it again. I intended this to provide a background track for the other sounds.

When I began testing these four balls, one of the accelerometer balls died almost immediately, so I had to switch back and forth between the control ball and singing ball behaviors for testers. The singing bowl ball was very well received, but there were problems with the control ball. Having it make sound in addition to controlling the two gyro ball sounds made it confusing to use. Testers did not sense the change they were applying to the other balls because of the sound being directly generated by using the control ball. I decided to give up on the idea of having every ball affect the sound of the others as well as making its own noise as this just seemed to spawn confusion. With this test, I tried just muting the control ball and immediately, the results were much better.

The other problem was that the sounds of the two gyroscope balls were too similar. Although they occupied different ranges, there was not enough difference in their sounds to really tell them apart. For this reason, in later iterations I had one occupy a very low range of frequencies (roughly between E3 and E4), and the other occupy a very high one (C5 to G6). This gave the balls much more unique sounds and allowed them to be easily distinguished from each other.

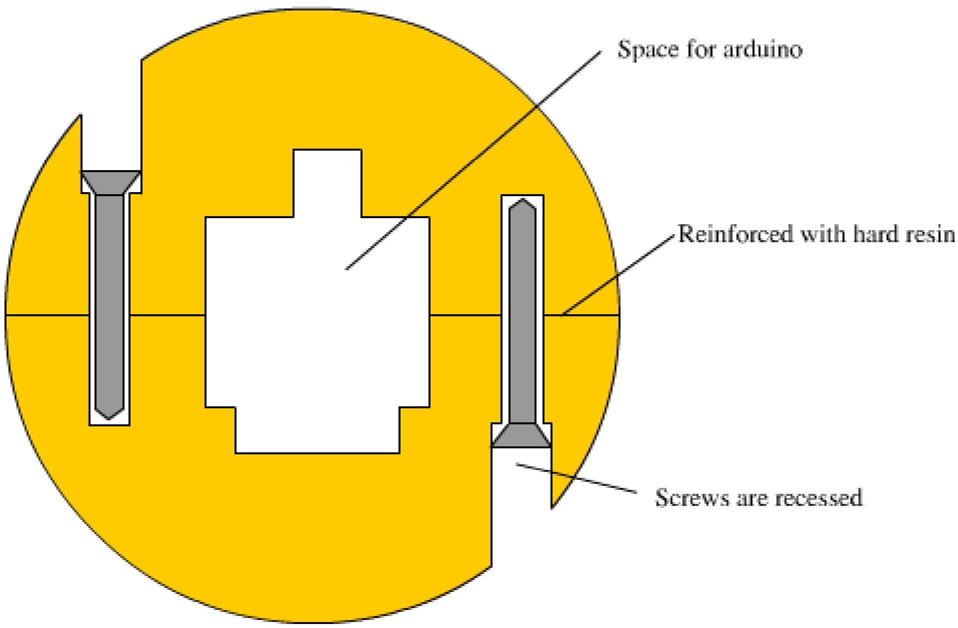
During the testing of this prototype, several users mentioned that they would like to see the ball some how indicate its use, especially in regard to what the control ball was doing to the other balls. This is why, in the final version, the control ball has stripes that correspond to the colors of the balls it affects and which are aligned along the axis that the internal accelerometer uses for that ball.

The casing for each ball also changed as I started using a more durable styrofoam than what I had been using. This type of foam, purchased fromwww.plasteelcorp.com, was denser than what I had previously used and took considerably more force to break. Additionally, although I did not use it for any of the balls I was using, I tested out a hardening resin on an extra ball and found that it worked nicely for creating a paint-able, hard shell for each ball without blocking the xBee signal at all.

*3rd Wireless prototype*

This prototype nearly finalized the hardware end of the balls, of which there were now 5.

Each ball now had on/off switches as well as JST ports to charge the batteries. Additionally, each ball was held together with two screws, allowing it to be semi-permanently sealed. In this version, one ball was covered in the hard resin and was painted. Instead of the onboard processing used earlier, in this version each ball transmits just an ID number, and the 2 values from the gyroscope or the 3 values form the accelerometer depending on which ball it is.




In terms of the code I continued to improve the collision detection as well as creating a way of sensing if either of the accelerometer balls had been spun. Part of what allowed this to was implementing a recording system into the openFrameworks code that saved all of the incoming ball data to an XML file that could be replayed without requiring me to actually move the balls around to test them. When testing out the balls, if a collision did not fire when it should have, I could tweak the code and then replay the exact same incoming data to see if the changes worked.

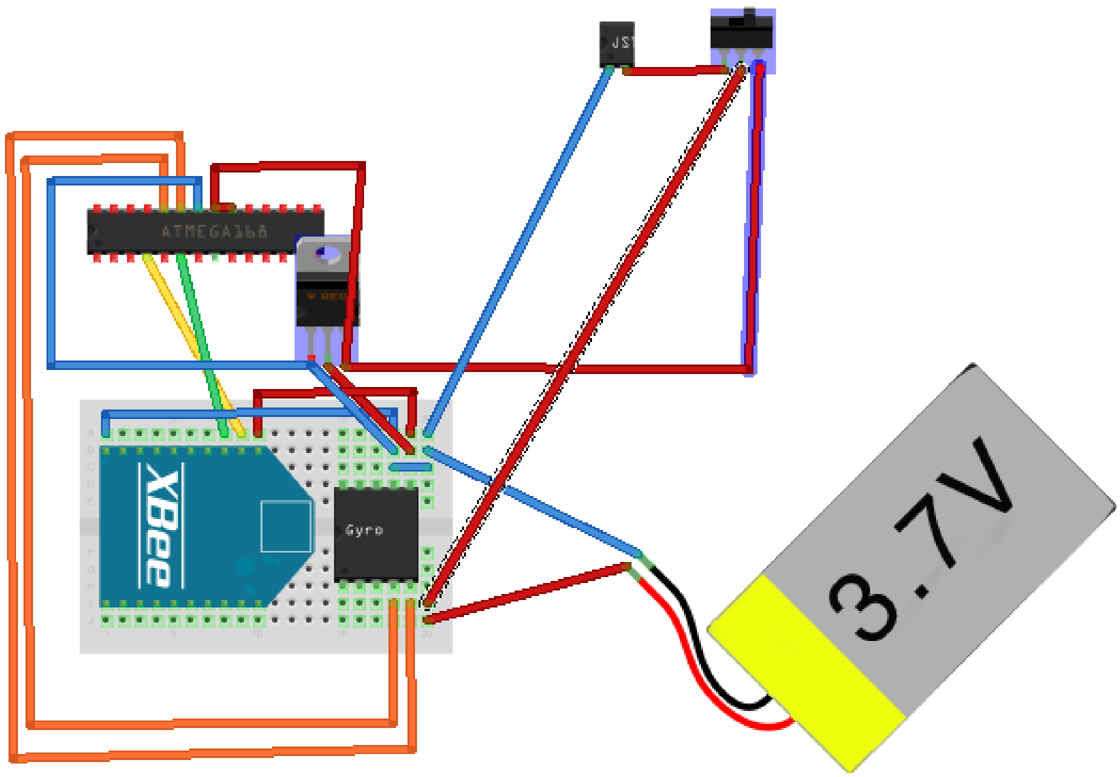
The sounds went through some large changes, including the Singing Bowls as their own mode, and some new behaviors for the balls in the original mode. The response to the Singing Bowl ball had been very good, but it just didn't fit with the sounds of the other mode, and because it was not immediate (the sound had to grow as the user kept moving the ball) it was often neglected in favor of the balls that made sounds as soon as they were moved. So instead of forcing it in a mode that didn't work, I decided to branch it off into two separate modes. In the new Singing Bowl mode, all of the balls were singing bowls, with just one tone (as opposed to the three the single Singing Bowl Ball had previously. They also did not repeat their last action if left still, because there was no longer a need to create a backing track, as they were the main focus of the mode.

This left a gap in the free form mode, which needed to be filled. I reworked the sounds originally made by the control ball (which was now silent) to be more controlled by user action and less random on the whole and applied these to what had been the Singing Bowl Ball. This prototype also featured one more gyro ball, bringing the total up to 3. Originally, I thought I would have it function like the other two, occupying the range in between them, but this made it sound far too much like the other two, and I found myself in the problem I had been in before where the chime balls were not distinct from each other. To solve this, I created an entirely new sound for the ball. It creates two tones, which are adjusted by the control ball and are run through a noise filter, the strength of which is also determined by the control ball. After a lot of experimentation and tweaking the values, I was pleased with the sound, that was unique within the set of balls without sounding completely unrelated.

*Final Prototype*

The final prototype was fairly similar to the last prototype, just more polished. At this point, all of the balls had the resin applied to them and were painted. When sanding down the balls, before painting them, I decided not to sand them completely smooth as I liked the wavy texture that resulted from sanding them down only partially. I also was able to increase the transmission rate by roughly 50% which allowed the balls to function with less delay as well as making the collision detection more accurate.

In testing the final version, I found that different groups of people reacted very strongly to the different modes. The majority of testers found the Free Form Mode difficult to grasp and preferred the Singing Bowl Mode as it had a fairly visceral reaction for most people. When testing the Sound Balls with a group of audio engineers, though, it was the exact opposite. They found the Sing Bowl Mode to be somewhat static and really enjoyed the Free Form Mode. They seemed to take great pleasure experimenting with the balls and really getting a feel for how each ball worked. This sort of experimentation was good to see, as this was an aspect of the toy that I wanted to encourage.




Wiring of the ball

**Evaluation**

In creating Sound Balls, my main goals were to create something that was fun, creates interesting sound, and feels magical.

First and foremost, Sound Balls is a toy, and it should be fun. One consideration though, is its ability to be fun for beginners without becoming boring as soon as the system is understood or has been interacted with for a little while. This can be a difficult balance to strike, as making something that offers strong reward for advance users can be intimidating to people who are new to it,

Obviously, as a sound toy, it should make audio that is interesting and engaging. My goal was not to create an instrument, so being able to make music was not a high priority, but creating a worthwhile sound scape was. Furthermore, just about any interacting with the balls should create something of value, with more advanced users being able to exercise better control over the sounds being created.

The last goal is somewhat more opaque, but it is important that interaction with the Sound Balls feel magical to the user. Using physical object to create digital sound is novel and the objects should feel as though they are imbued with a special quality that can't quite be explained. Although there is obviously technology running behind the scenes, creating an object that allows the user to suspend disbelief was important to me.

*Strengths*

The Sound Balls are definitely fun when first played with. Testers consistently smiled and laughed as they interacted with them, and they were eager to keep playing once they started. In this regard, they succeed. The fact that people want to keep playing with also helped the issue of having a skill curve: the initial interactions tend to be somewhat random, but people interacting with the balls, people tend to stop and test out each ball to get a feel for the behavior of each ball.

Also successful was the response many people had to the Singing Bowls. Much more so than the Free Form Mode, this interaction easily allowed testers to suspend disbelief int terms of the sounds being produced. When using this mode, the connection between action and sound became complete for most people. The other mode does this to some extent, and most people do regard them with some wonder when they first start playing, but the Singing Bowls really exemplify this magical feeling.

*Weaknesses*

Even with the various tweaks, the Free Form mode is still somewhat stochastic and difficult to glean. Although the sound engineers did much better with it, and I do want a system that is not completely obvious as first glance, it is still too hard. For most people, there is a randomness to the sounds, and even once they understand the basic rules of the system most people hit a wall fairly quickly.

Although I expanded the number of gestures that could be recognized over the course of project, there are still motions that many users do that either don’t register, or in some cases, cause false collisions. The fact that these gestures go unnoticed by the system, or worse confuse it, breaks the illusion that these are magical and fluid toys, and highlight the underlying technology in a bad way.

The biggest issue, though is the lack of control in Free Form Mode. While users have fun interacting with them, few felt like they could really have tight control over the sound. The accelerometer ball is particularly bad in this area. The motions applied to it will make good sounds, but they can be difficult to recreate or expand on.

**Future Directions**

Moving forward with this project, one of the biggest things to continue with is to increase the number of gestures recognized by the system. Different users do many different things with the balls and for the experience to really be immersive, as many of these actions as possible should create sounds for the different balls. Part of this too is creating sounds that reinforce the different gestures. By having different action produce significantly different sounds, the feel of users control will increase.

Another direction to move in is working on the physical appearance of the balls to hint somewhat at their intended use. Even if more gestures are recognized, some balls are better than others at sensing certain things depending on the hardware inside of them. Right now, the Control Ball does this to some extent, with the colors on the ball corresponding to the balls it affects, but it would be good to create a system that marks which balls should be rolled versus which balls respond well to being picked up and moved around.

During my critique, one of my critics mentioned the material I was using. I had decided on the styrofoam with a hardened shell mostly for durability; I had to make sure that the balls could survive a lot of abuse as they were intended to be tossed around and hit into other objects. This was fine for creating a prototype of the project, but material consideration would be important if this is going to continue. One of the things brought up in the critique was the potential of using a material that would allow the balls to bounce, which could add a lot of interesting interaction to the experience.

As it was something that I found caused problems for the project, the Free Form Mode could use more tweaking to allow a greater sense of control and causality for the people interacting with it. While it does not fail entirely, and some audiences tap into this mode very well, I think it could have broader appeal. While I want to preserve a sense of exploration, I do think that it should be somewhat more accessible.

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All code for this project can be found at
[andymasteroffish.com/soundballs](andymasteroffish.com/soundballs) or
[a.parsons.edu/~walla368/spring2011/soundballs/](a.parsons.edu/~walla368/spring2011/soundballs/)