Redesigning a Gaming Controller
First Semester Report
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Abstract

The idea of redesigning a video game controller for the physically handicapped came about when a man with Muscular Dystrophy, approached CSU with such a request. He, and people with similar conditions, are not able to engage in any but passive entertainment. Watching TV and reading can get very boring; there is a need for those with limited movement to be able to engage in more active forms of entertainment, such as playing video games.

We began this project by exploring existing technologies. There is a great deal of assistive technology already in use. However, this technology is used for assisting those with handicaps in communication, learning, and other such practical means. We did find some controllers which could be used for gaming. The problem with these is that they are very expensive, and often specialized for those with no movement below the neck. A controller designed for those with limited movement does not seem to exist, much less one which is fairly affordable.

We have examined much of the existing technology for assisting those who are physically handicapped in daily activities, and have come up with several designs for modifying video game controllers. Our first designs are relatively simple; we will retrofit existing controllers for ease of use. Other designs involve more advanced technology, such as that used in optical mice, as well as touchscreens. There is quite a bit of work to do with these designs in the coming semester, as well as in future years.
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
<td>i</td>
</tr>
<tr>
<td>Abstract</td>
<td>ii</td>
</tr>
<tr>
<td>Table of Contents</td>
<td>iii</td>
</tr>
<tr>
<td>List of Figures and Tables</td>
<td>iv</td>
</tr>
<tr>
<td>I. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>II. Reasons for Pursuing the Project</td>
<td>1</td>
</tr>
<tr>
<td>III. Existing Technologies</td>
<td>3</td>
</tr>
<tr>
<td>IV. Current Designs</td>
<td>6</td>
</tr>
<tr>
<td>1. Push Button Retrofit</td>
<td>6</td>
</tr>
<tr>
<td>2. Radial Array Retrofit</td>
<td>8</td>
</tr>
<tr>
<td>3. Other Designs for Pursuit</td>
<td>8</td>
</tr>
<tr>
<td>V. Conclusions and Future Work</td>
<td>9</td>
</tr>
<tr>
<td>1. Design plans for next semester</td>
<td>9</td>
</tr>
<tr>
<td>2. Testing</td>
<td>10</td>
</tr>
<tr>
<td>3. Advanced Designs</td>
<td>10</td>
</tr>
<tr>
<td>4. Conclusions</td>
<td>12</td>
</tr>
<tr>
<td>References</td>
<td>12</td>
</tr>
<tr>
<td>Bibliography</td>
<td>13</td>
</tr>
<tr>
<td>Appendix A – Budget</td>
<td>A</td>
</tr>
<tr>
<td>Appendix B – Testing Plans</td>
<td>B</td>
</tr>
<tr>
<td>Appendix C - Design Constraints</td>
<td>C</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>D</td>
</tr>
</tbody>
</table>
List of Tables

Table A.1  Table of First Semester Budget

List of Figures

Figure 3.1  Sip and puff device
Figure 3.2  N64 controller for one switch games
Figure 3.3  Team Xtreme Module & example of use
Figure 3.4  Limited Dexterity Controller
Figure 3.5  Sip & Puff Xbox 360 controller
Figure 3.6  First B-Type Controller
Figure 3.7  Ben Heck’s Controller
Figure 3.8  Emotiv Systems Controller
Figure 4.1  Push Button Array
Figure 4.2  Initial testing device
Figure 4.3  Radial Array
Figure 4.4  Spacial Grid
Figure 4.5  Texture Grid
Figure 5.1: Illustration of a 4-way mode rocker algorithm
Figure 5.2: Illustration of 2-D scroll mode algorithm
Figure 5.3: Capacitor Array
Figure 5.4: Touch screen
Figure A.1  Chart of First Semester Budget
Chapter I – Introduction

Redesigning a gaming controller began with a man with Muscular Dystrophy, who has effectively become our client, approaching CSU with the idea of creating a controller that he, and people with similar conditions, could use to play video games. With this beginning, we set off to explore current technologies and possible implementations of this idea.

As we explored the possibilities, we found that we had to define our scope to something smaller than just a video game controller for the handicapped. Since the initiator of the project has Muscular Dystrophy, we decided to define our initial user base as those with physical disabilities that still allow for some movement. We decided against designing games for those with cognitive disabilities or with no movement capabilities at all, at least initially, simply because we cannot cover every possible angle in only one year.

Exploring current technologies lead us to many interesting discoveries, and a greater knowledge of what is available for assisting disabled individuals in day to day life. We were even able to find a few, highly expensive gaming devices. However, none of these devices seemed to target the user base that we had decided to work on.

Through further research, we have developed several ideas for how to design and implement a gaming controller for the physically handicapped. Several of these designs are quite simple and involve mostly mechanical alterations. We are also examining more advanced technology for other designs. Each design that we come up with will require extensive testing before we know if, or how well, each one works for our targeted clients.

In chapter 2, we will further examine the reasons for starting and pursuing this project. In chapter 3, we take a close look at the existing technologies for assisting disabled individuals. Then, in chapter 4, we explore the designs that have been proposed for construction and testing. Finally, in the chapter 5 we look at possible routes for the more distant future, and the conclusions that have been drawn from our project so far.

Chapter II – Project Catalysts

Our group was approached by a man with Muscular Dystrophy to redesign a gaming controller to fit his mobility needs. His journey through life has been long and difficult and marked with pain, suffering and debilitation:

- Born with Werdnig-Hoffman’s Disease, a form of Muscular Dystrophy (MD), and life expectancy of less than two years.
- At age of 12, once again, given less than two years to live because of scoliosis, a side effect of MD. Endured months of painful operations which he had only a 10% chance of surviving.
- Has always been confined to a wheelchair with no use of his legs, arms or hands. [1]

Despite the odds, our client has persevered and is now seeking more active forms of entertainment besides reading and watching TV. As capable and compassionate engineers, we accepted the task of “redesigning a gaming controller” for someone with limited mobility.

Before we could go to the drawing board we needed to understand the limits of mobility that he has as well as others with muscular dystrophy. We did some research on MD and first answered what the disease actually is so we could develop some design constraints. The muscular dystrophies (MD) are a group of more than 30 genetic diseases characterized by progressive weakness and degeneration of the skeletal muscles that control movement. Some forms of MD are seen in infancy or childhood, while others may not appear until middle age or later. The disorders differ in terms of the distribution
and extent of muscle weakness (some forms of MD also affect cardiac muscle), age of onset, rate of progression, and pattern of inheritance. The important factor is that the muscles are constantly in degeneration, which in turn puts limits on our design. [2]

In the primary stages of the project we are just focusing on limitations in mobility. Our client and others with muscular dystrophy have the same cognitive skills of able-bodied individuals. It is for this reason that we are only focusing on the hardware of the gaming controller and not altering the clock or speed of the software. Also, many concerned with affordability and does not want to fork out hundreds of dollars for a gaming controller. It is for this reason that we have chosen to retrofit an existing controller to fit our client's mobility needs.

We have begun further research by visiting local facilities in Fort Collins and meeting with patients and workers to develop a range of motion to develop our design constraints. Foothills Gateway and Respite Care are working with us in conjunction with the university’s Occupational Therapy Program to develop testing methods with our future designs. Testing and methods are further explained in the appendices.

Chapter III – Current Technologies

In order to get an idea of what we might do with our project, we began to research current technologies available for disabled people both in gaming and in everyday life. We needed to figure out in what direction to go with our gaming controller, so the first thing we did was to go to the Occupational Therapy department at CSU. Within this department, there are many assistive technologies being used to help disabled students operate computers by using a mouse head tracker. “A head tracker is an alternative for the computer mouse that allows people with head control to control a computer. A dot is placed at the forehead or an eyeglass and the head tracker uses the reflections of infrared light to calculate the position of the head.” [3]

![Figure 3.1: Sip and puff device](http://www.enablingdevices.com)

Other devices we discovered that might be useful are the sip & puff controls, shown in figure 3.1. This switching device activates two functions with only one tube. Sipping is one function and puffing another function. These devices usually come with something to be attached to the wheelchair since it is a device designed for a quadriplegic person. There were plenty of other switching devices but most of them were either too expensive or not applicable to our design constraints.

When we visited with one of the members of the assistive technology team at CSU, we gathered a lot of information on how disabled use computers. With this information we were better equipped to decide what we can actually use in our project. We also got a better idea of the range of motion for the disabled people we are targeting, though further testing must ensue. We also received booklets and magazines about the most recent assistive technology out there. There are several companies that provide entertainment for disabled children but they are very small children and since we are dealing more with an age range from 10 to 60, those toys were not applicable to our application either. Enabling Devices was one of the major distributor of such toys and tools that we used to further our understanding.
Once the assistive technologies were explored we needed to find out what else already existed out there regarding gaming controllers for the disabled. We made several discoveries, including Ben Heckendorn’s one handed controller, limited dexterity controllers, and much more. One of the first discoveries we made was a Nintendo 64 controller, shown in figure 3.2, with multiple buttons and multiple joysticks so the player could choose were to place their hand on the controller. These types of controllers were developed for single switch games. Single switch games are games that have been programmed or reprogrammed to only function on a single switch input. These games are specifically designed by companies such as One-Switch, for the disabled to use.

![Figure 3.2: N64 controller for one switch games](http://game-accessibility.com/index.php?pagefile=motoric)

The next discovery was a module, shown in figure 3.3, that could be defined by the user as to what kind of button you want to use for whatever action defined by the software. “The Player can use their own switches, up to 5 of them with Team Xtreme for N64. Each switch can be individually setup to control any key you find on a regular game controller.”[4] This was a good idea but since the price and our constraints with our client weren’t met by this device we had to move on and find something that was more suitable for us. We also found limited dexterity controllers that are just spread more apart than usual and uses a large joystick as well as large buttons spread apart, as shown in figure 3.4.

![Figure 3.4: Limited Dexterity Controller](http://rjcooper.com/game-controller/index.html)

![Figure 3.3: Team Xtreme Module & example of use](http://www.pathwaysdg.com/tx_desc.htm)

The next finding was a sip & puff controller using the assistive technologies mentioned earlier. It operates on the principal of sip & puff being two functions and then also adding lip buttons to the device, shown in figure 3.5. As you can see it has three sip & puff straws and attached to it an Xbox 360 controller. There are also 4 lip switches attached which are not very visible in the picture. Then there is a sip & puff straw attached to the side used for the start and select functions of the controller. So all in all it takes care of the 12 functions that are required in an Xbox 360 controller. Now the problem with this technology is the price and how easy this device is actually to use. For our application the device was way too expensive, more than $250, which is not very marketable at that price.
One of the ideas suggested to us by our client, was to make whatever controller we did design capable of being taken apart and rearranged in some shape or form. So we found another existing controller that employed this idea besides the Nintendo Wii. It was actually one of the world’s first controllers of this type and is usually referred to as a B-Type controller, shown in figure 3.6. “The GlideFX uses a ‘Trackball’ to manage movement that is normally controlled by the right analog stick. Separate left right controls and adjustable Sensitivity settings” [5] are some features of this controller. It was designed for the Playstation 2.

Another suggestion given to us by our client was to investigate further into Ben Heckendorn’s doings, since he had made a one handed Xbox 360 controller, shown in figure 3.7. Ben Heckendorn is the creator of many portable video game modifications and is also an independent film maker. The controller he designed is a very basic but good idea and functions simply by resting one hand on the controller and then being able to do all the same things that you usually do with two hands with only one hand, shown in figure 3.7 b. This design, however, was not applicable to our client since he has muscular dystrophy and has different needs then just a one-handed controller. This idea, however, helped us understand the fact that you could always just combine certain things into one and with that simplify a controller.

Our client had beaten Mario 64 on the Nintendo DS. This gave us an idea about touchscreen technology, which we would have liked to pursue further but due to limited funding we were not very confident that anything could be done with the touchscreens in just one semester so it is being saved as a future pursuit. touchscreens are very capable to be used by the disabled as he has demonstrated, and
so the Nintendo DS is the only main stream device that utilizes touchscreen technology.

One of the most promising discoveries we made was a gaming controller of the future. It is a controller that uses the brains voltage differences to enable actions, shown in figure 3.8. The company currently designing such a device is called Emotiv systems. Their mission statement on their website stated “Our mission is to create the ultimate interface for the next-generation of man-machine interaction, by evolving the interaction between human beings and electronic devices beyond the limits of conscious interface.”[6] A lot of the semester was spent trying to contact them to try to collaborate and test their product on the disabled bodies we had in mind.

![Figure 3.8: Emotiv Systems Controller](http://cache.kotaku.com/assets/resources/2007/03/brainingame.jpg)

We called multiple times and wrote emails waiting for a response when finally we were able to arrange a phone conference so we could further our understanding of their project. We were told that it works based on Electroencephalography (EEG), which “is the neurophysiologic measurement of the electrical activity of the brain by recording from electrodes placed on the scalp or, in special cases, subdurally or in the cerebral cortex. Electrical currents are not measured, but rather voltage differences between different parts of the brain.”[7]

So before the actual phone call we set up some questions to ask such as the test range of the subjects and the outputs provided but for patent law reasons he was not able to give us much information about their product except that a variety of people would be able to use it including disabled people. We were informed that the information he can give us is very limited and so all we learned was the basics. The controller price is supposed to be within consumer range and available within the next 5 years. Emotiv also mentioned that as soon as they were able to release more information they might want to collaborate and help our project.

The functions of the controller were described to have three separate forms: expressive, affective, and cognitive. The expressive form of the controller is meant to control the facial characteristics of the gaming character by reading what facial expression you are making. The affective form of the controller is a measurement of your emotions, so it can read emotions and then translate them to actions or also emotions that the game character is affected by. The third and final form is the cognitive form, which is just using conscious intent to have certain actions accomplished. You can think push and the action push applied by the computer. The cognitive side so far has 12 functions. A push and pull function along with the 2D directions such as up, down, left, right; on top of that it has 6
3D rotational commands that can be used to look around with the gaming character. The device is still being heavily tested and not ready for commercial use yet but hopefully will be soon. It definitely is a project possibility for future endeavors into this subject.

So from this information we went ahead and started to develop our own plan. We considered all previous ideas regarding gaming controllers for the disabled and tried to come up with the best possible solution without exceeding our given budget which was a little hard to do with only $50 a person. We also got ideas about using technologies that have not yet been employed in gaming applications which will be mentioned a little further in the report about our design plans.

Chapter IV – Current Designs

1. Push Button Array

Our basic idea for the construction of a button pressing device came from a jury rigged handheld system – a Nintendo DS - used by the founder of our project. He had a ball on top of the buttons that he would lean his hand on in order to press one of them. Our idea is similar, but on a larger scale. First, we are making our design modular, so that there are two sets of buttons that can be placed at the most convenient locations for the user. Second, we have a half sphere cut from a large ball mounted so that it can be leaned on in various directions to press one of eight buttons beneath it. This is like moving a joy stick up, down, left, right, or along one of the diagonals in order to press a button. We have found switches that are rather small, and easy to press. We will mount each of them spaced equally around a circle beneath the half sphere, with the sphere mounted atop a rotating point in the middle of the circle. For the second set of controls, we will use the original controller, mounting the other half of the large rubber ball onto the joystick which is already part of the Game Cube controller. This will allow for directional control as far or near the buttons as needed.

Figure 4.1: The circle of buttons under the half sphere are pressed by the plane of the bottom leaning on top of one of the eight buttons.

We have constructed a device to test this idea, with eight buttons connected to LEDs. It has the half sphere mounted atop a Game Cube controller's directional joy stick – which provides the rotating point as well as a centering force. The device was used to see if it is possible to press a button in each of the four directions, and how difficult the design is to use. We found this initial test board to be too flimsy to survive extended testing. Also, the half sphere was mounted too high, indicating that the joystick it is mounted on needs to be inset into a piece of wood to allow it to be closer to the top of the
buttons. Creating a more usable testing device will be a top priority for the near future.

Figure 4.2: The push button method for pressing switches is shown here. The half sphere is tilted until it presses one of the buttons.

2. Radial Array

When meeting with Mr. Brian Misek, from Avago, he suggested a second type of mechanical device which we plan to pursue in the coming semester. We will create an array of buttons arranged radially to a disk – probably made of wood. These buttons will be pressed by the edge of the disk being pressed up against them. A small ball on top will provide an easy method for moving the disk. We will explore means of making the disk slide easily, such as ball bearings or mounting it on a joystick from a broken controller.

Figure 4.3: The disk's edge will be used to press one of the eight buttons arranged radially around it.

3. Other Designs for pursuit

In addition to the simpler retrofit designs, we have considered quite a few options involving more advanced technology. We have begun looking closely into those involving Optical Mouse technology. We are attempting to get a development kit for an optical mouse for use next semester. If we are successful in this, we can begin to pursue this technology in a few different directions.

Our first idea is to track the movement of a mouse, mapping it against a programmed grid. When the mouse entered a new zone, a new command could be issued. This grid could be a traditional
3x3 square grid, with the center being a zone where no command is issued, or it could be radial grid, similar to the spokes of an old wagon wheel – again with the center being a zone where no command is given.

**Figure 4.4:** The Spacial Grid will detect where the mouse is by keeping track of its movement with an X-Y coordinate system. Each “zone” will issue a different command to the console.

The second option with optical mouse technology is to take advantage of their image processing capabilities. We found out that a mouse takes a picture of what it is on top of, and determines how it has been moved by taking another picture and comparing them. Since there is already this image processing capable devices, we theorized that a mouse could be programmed to read a texture or color that it is on, and determine if it is in one of 9 zones on a defined mouse pad. Basically, we are going to see if a “mouse pad” with 9 distinct colors or patterns would allow for a different command for each zone to be issued to the console. The zones would be laid out in a similar way to the spatial zones of the previous optical mouse design idea.

**Figure 4.5:** The texture map will allow the mouse to detect where it is by the texture or color it is on top of. Each texture will relate to a different command being issued to the console.
Chapter V – Conclusions and future work

1. Design plans for next semester

The major design plans for next semester are two fold. The first is to construct and test the two retrofit designs, the second is to begin exploration of the optical mouse technology based designs. The retrofit designs have been completed, and the next step is to construct the controllers themselves. These controllers need to undergo extensive testing in order to tune the exact dimensions and parts for optimal usability. The optical mouse designs are very rough, and will require a significant amount of coding in order to make them work. This will be an assignment for one or more of the group members beginning next semester.

2. Testing

In order to determine which design or designs will work best to allow handicapped individuals to play video games, we will need to test each of them extensively. We have begun partnering with the Assitive Technologies department at CSU for this purpose. We are building boxes with our button pressing techniques, with the buttons wired to LEDs instead of to a controller. These testing boxes will be similar to the testing device that has already been constructed, but they will be more durable and will not have the problems which have been identified in that device. These boxes will be given to a Graduate Occupational Therapy student, and she will determine if potential clients can press each of the buttons, and how easily. Feedback from this testing will be used to tune a final product. Any other devices we build will be tested in a similar fashion.

3. Advanced Designs

In the future, this project could pursue a number of designs involving more advanced technology. These include emotiv, touchscreens, a sliding conductive plate, and a capacitive array.

When examining emotiv, we were very excited by the possibilities of that technology. Just the concept of controlling a computer with your mind is amazing, and when someone is actually working on, and has a prototype of a device that does just that, one can't help but wish to play with it. However, there were two factors in our decision not to use this technology. The first was that it would take a lot of programming, which we do not have time for this year, to translate the emotiv signals into something that a gaming machine can understand. The second, and more important reason, is that the technology is not at a stage where the developers are comfortable with having students work on it. While this option ought to be kept in mind for future teams, it cannot be pursued at this time.

Another advanced design we examined to help build our new gaming controller is a Mobile Navigation Interface IC for Slider Mechanical Module from Avago Technologies. This device is called the AMRI-2000 and “can provide a mouse-like cursor control interface, analog joystick cursor control, four-way or eight-way switch functionality, as well as scroll-wheel emulation.”[8] This device would be especially useful for our gaming controller design by its functionality and customization that it offers. The operating system can change modes and “dynamically reconfigured to provide the best user navigation experience for any active application.”[8] Unfortunately this product is not currently out on the market and would be out of the manufacturing budget we have speculated.
The capacitive array uses similar technology to that of a touch screen without the screen while using much less power and space. Costs are greatly reduced as well as one component can be used instead of four. Possible design capabilities could be used for future gaming controller buttons, however due to the small size of the arrays they might not be best fit for physically disabled gamers. [9]

Finally a touch screen could be utilized for advanced designs and programmed with special software to function as a gaming control. Currently touch screen overlays are out on the market but the costs are way out of our manufacturing range. [10]
4. Conclusions

After much careful consideration of design constraints and existing technologies, we have decided that the most reliable and affordable option for redesigning a gaming controller would be to retrofit an existing one. Currently able-bodied individuals would expect to pay about $15-$50 for a gaming controller depending on the gaming console. The price range for a gaming controller for physically disabled individuals ranges from $300-$500 of sip and puff technology. There are currently different gaming controllers for physically disabled individuals at cheaper prices, however they do not work as well as our intended design and users complain about not getting their bang for their buck.

Our redesigned gaming controller will not only meet the desired specifications, but it will be quite affordable as well. The retrofit design upon completion will enable someone with limited mobility to play as any other able-bodied person. This will be achieved at a price range of $60-$80. The consumer will be quite satisfied and the design will be able to cross over to most gaming consoles (besides the Nintendo Wii).

Throughout our research we have learned that physically disabled individuals, especially those with muscular dystrophy, live very boring lives. While able-bodied individuals have the freedom to play sports and be active, consumers have targeted them as their main audience for video-games. One would think that in our current state of technological affairs there would be more of a market for individuals who cannot perform such active tasks. After working with our client and others with similar limited mobility we feel compassion as capable engineers and are compelled to bring them an affordable, reliable, working product.

References

Bibliography


Appendix A – Budget
We began this semester with the standard budget for Senior design, $50 for each student per semester. This amounted to $150 for our first semester. We have spent $55 thus far, with a donation of one controller to our project. Our budget for the year, with the amounts spent is summarized by the following table:

<table>
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<td>Parts</td>
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<td>$25.00</td>
</tr>
<tr>
<td>Software</td>
<td>$50.00</td>
<td>$0.00</td>
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Table A.1: A summary of our first semester budget

In specific, we have purchased 8 LEDs, 9 easy press push button switches, 2 spools of 20 gage wire, 8 AAA batteries, and two bags of rubber balls. We have had one controller donated to us, and have used another broken controller that a team member owned.

This leaves us with $245 for use next semester, plus any donations we receive. With a few donations, we ought to be able to acquire a few needed materials for continuing the project, such as wood for building the chassis of the testing devices, a Game Cube console, and more switches and LEDs.

If the project costs were to be fully covered, including paying for time and donations, the cost so far would be significantly higher. The time spent has been akin to a side project of a full time job, amounting to about 6 hours of work per week for three people. Most of this work as been done in research, with little going to construction this semester. Material costs would be close to $85, adding $15 for each of the controllers that were acquired for free. The material and time cost for one retrofit design controller will be 1 original controller ($15), a couple of hours of work, plus 8 buttons, wire, and some wood for casing($25 in parts). This amounts to a single controller costing only $40 in parts to build. Since the weight of the controller is not significantly more than that of a standard controller, I would assume the the cost of shipping and distribution would be similar. In the end, a final product would most likely cost between $60 and $80, once the costs of labor and profit are added. This is a very reasonable price, considering that the alternatives cost upwards of $200-$300 each.
Appendix B – Testing Plans

In order to test our various designs, we will need subjects with muscular dystrophy and other degenerative diseases that limit motion as well as subjects with other disabilities that would inhibit the dexterity needed to use a standard gaming controller. Ideally, we would want at least 10 subjects to test each design, and for each to spend a significant amount of time on each one.

The data we need from these tests is basically if the subjects were able to light up each of the LEDs consistently, how easy it was to light up each LED, and if using the device for an extended period of time made it easier to use. Data should be collected on a scale of 1 to 10 for each of these areas, with 10 being perfect and 1 being completely unusable. Any comments on how the design could be improved will be appreciated and taken into consideration in future designs.

Once the data and feedback have been collected, we will collect the data into a table, analyze it and create a better design based on these results. Once improved designs have been constructed, further similar testing will be required.
Appendix C – Design Constraints

- Affordable
- User has some motion in hands or feet
- User has little or no cognitive disabilities
- Design is usable enough to play video games
Acknowledgments

We would like to thank Lance Carr for originating this project, and for working with our group on several occasions to get us started. Also, Walt Grady from HP gave us many pointers and a lot of excellent advice on our project. Brian Misek from Avago also came in and discussed several more technologically advanced ways for us to design a gaming controller, including the optical mouse technology and the radial array method of retrofitting. Finally, we would like to thank our advisor, Dr. Olivera Notaros for all of the direction that she has given us over the semester, for keeping us on track and for pushing us to the point we have arrived at.

We would also like to thank Buy Back Games of Fort Collins for donating a Game Cube controller.