CHAPTER 11
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INTERACTIVE GAME FOR CHILD

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INTRODUCTION

The goal of this project is to create a custom handheld game for our client, a nine year old child with severe visual limitations as well as some motor limitations. The creation of a handheld game provides both educational and physical benefits to the client. A lower emphasis on visual cues helps to develop other senses such as touch and hearing. The ability for our client to participate in an activity, that other children his age enjoy, will also facilitate interaction with peers.

SUMMARY OF IMPACT

The design consists of a small handheld gaming device that provides three different games and tactile, audio and video cues to our client (Figs 11.1 and 11.2). The device is entirely unique from electronics to software to casing for the customer. The customer has been using the device for two months, as of the end of the academic year, and after subjecting it to numerous “drop tests”, his mother reported that it was still working and that he loved it.

TECHNICAL DESCRIPTION

The design of the handheld gaming device is grouped into three separate categories: hardware, software, and casing. Hardware design consists of microcontroller selection, audio and video output, power, tactile feedback, and printed circuit board (PCB) design. The microcontroller is capable of controlling elements of the hardware subsystems while also running the game software. It is also responsible for interfacing to an external display to provide graphic images to the user. This involves generating game graphics and appropriately sending them to the display device. The Parallax Propeller is used in this design due to its availability of open-source code for applications such as

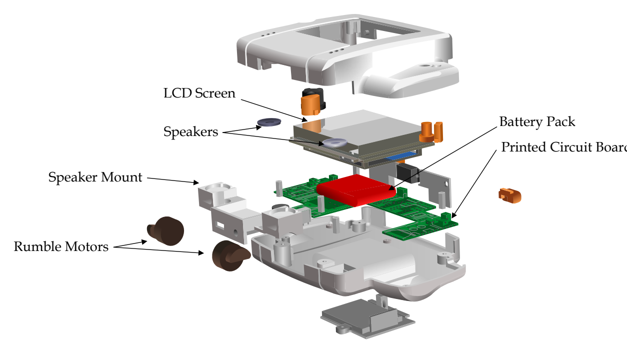

Fig.11.1. Custom designed handheld gaming device.

graphics and audio, its packaging simplicity (44 pin LQFP), the ability to generate NTSC and VGA video signals, and an available development board.

The customer receives feedback from the handheld device through audio, video, and tactile feedback. The audio subsystem consists of an all-in-one audio amplifier system (National Semiconductor LM436) and Kobitone 235-CE221-RO 8Ω, 1.1W speaker. For a display, a 4” LCD with a brightness of 220 nit is used. Tactile feedback is provided using two tactile feedback motors taken from an Xbox 360 controller, driven with separate fixed frequencies and variable duty cycle PWM signals that are fed to the gate of power MOSFETs. Each motor has independently controlled variable speed.

In order to integrate the electrical subsystems into a compact package, a custom PCB is included in the design. The PCB has a custom shape that allows for maximum layout area inside the enclosure while providing a cutout for the battery. In addition, the shape allows a single PCB to hold all of the subsystems including the user interface buttons. To avoid noise and EMI issues, the propeller, power and audio circuitry are all confined to different areas of the board. Large grounding planes are placed around and between these subsystems to provide additional shielding. The printed circuit board is shown in Fig. 11.3.

The system is powered by a 7.2V 700mAh NiMH battery back, which provides 1.5 hours of use between charges. In addition to the selection of a NiMH battery pack, DC/DC converters provide the required 12V to the LCD and 3.3V to all other subsystems. To increase the voltage to 12V, a MAX618 converter is used. To decrease the voltage 3.3V, a MAX1685 was used. Low drop out linear regulators are avoided in this design due to their inefficiencies and because a battery capacity of less than 12V was desired for weight reasons. The entire system is protected from faults by a 1.1A PTC placed on the PCB near the battery interface.

Three games are designed to provide entertainment for the customer: Simon, Avoidance, and Maze (Fig. 11.4 shows screenshots from Maze and Avoidance). Each game consists of varying levels of difficulty and focuses on audio and tactile cues. Many of the features of these games originate from prototype sessions with the client to observe his interests. The first prototype session introduced the customer to the vibration modules and ensured his comfort with the vibration feedback. The second and third sessions involved the client playing simplified versions of the games where his interactions were gauged and adjusted to fit his level of play. Game play is achieved by data transfer from a removable SD cartridge, one for each game.

The driving force behind the development of the Simon game is the desire to introduce our client to video games and the intended interface of the handheld. This game is a very simple and a common game for children, requiring the user to mimic a sequence of colors. After the first prototyping session, it was determined that an easier level needed to be provided to first familiarize the user with video games. Once the user adapted to the rules of the game, the level of difficulty would be increased.

The Avoidance game focuses on the player, represented by a triangle, avoiding a square that moves down the screen. To alert the player to move the triangle, the hand held vibrates. Another feature of the game is to retrieve bonus items. The bonus items are represented by circles that also move down the screen along with the square. When they are touched by the triangle, the score is increased and a sound is played. When the player hits the square a life is lost and when all the lives are gone, the game is over. A different sound effect is played to signify an obstacle being hit in order to show the user this is an undesired action.

Fig.11.2. Prototype of the device.

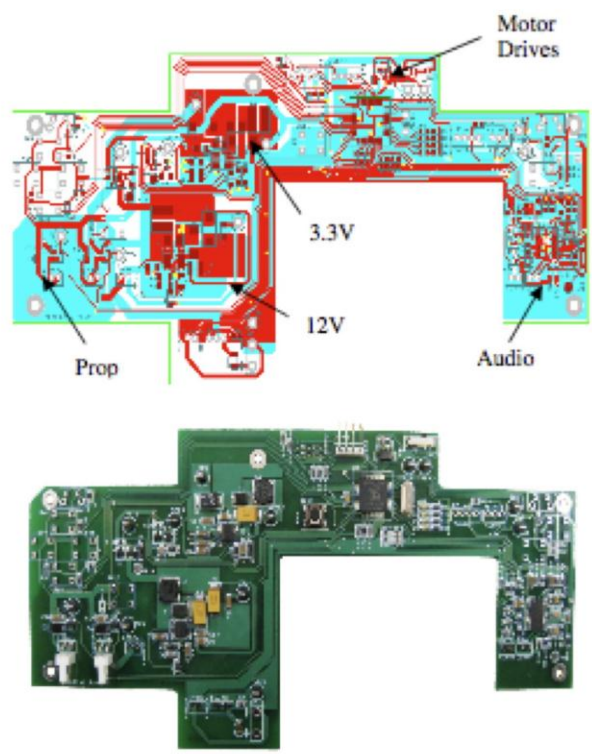

Fig.11.3. PCB layout (top) and final PCB (bottom).

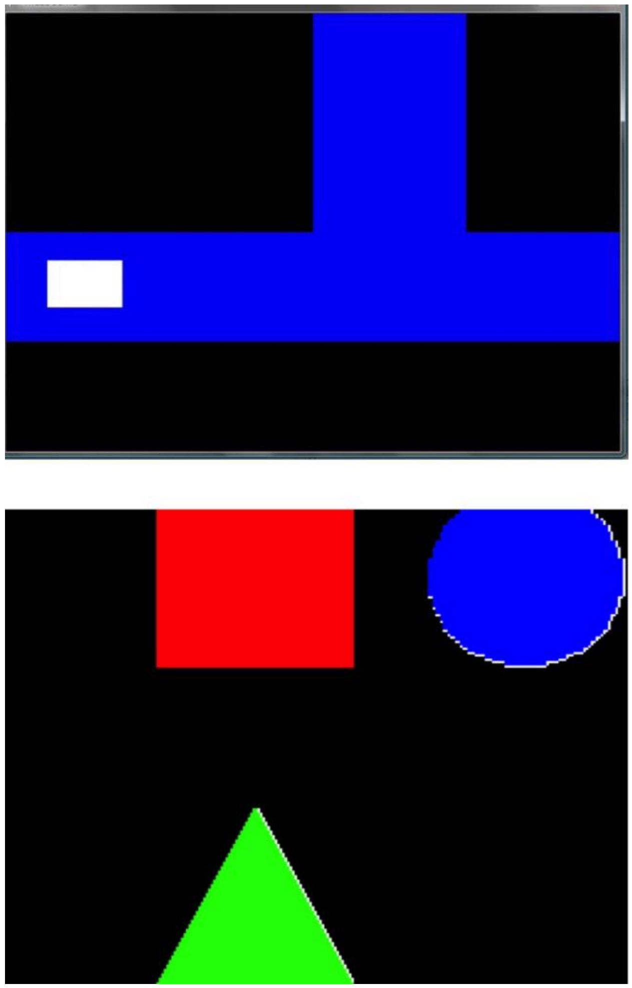

Fig.11.4. Screenshots from Maze (top) and Avoidance (bottom) games.

The Maze game focuses on navigating through a series of pathways to reach an end target. This game utilizes the system of navigation known as "Hot vs. Cold".

The player follows audio cues, rather than having to look at the screen, in order to navigate the map. The player listens for "Hot" sounds to indicate getting closer to the target and "Cold" sounds to indicate moving away from the target. This system allows the player to almost completely eliminate the visual aspect of the game pending appropriate level design.

Design of the casing involved prototype sessions with our client to determine his preferences as far as shape, size, and color. The overall casing is made to be as simple as possible to maximize internal volume and reduce the cost of manufacturing. During earlier prototype sessions, our client showed a preference for the Sony Playstation 2 controller, which has smaller, rounded handles compared to the Nintendo Entertainment System and Microsoft Xbox 360 controllers. The main body of the casing is expanded from the thinner designs seen on early concepts in order to accommodate internal electronic components. A white color scheme is utilized because it is easier for the customer to identify buttons against a white background as opposed to a black one. The handles are placed slightly closer to the top of the console. This is intended to shift the point of balance further away, causing the console to tilt slightly towards the user. This adds to long-term user comfort. The curvatures of the handles are intended to allow some variations in grip while maintaining easy button accessibility.

One facet of the mechanical design that was closely coordinated with the electrical team is the dimensions of the PCB. Additionally, coordination is needed on the placement of the buttons on the PCB. This is important not only for the PCB layout itself, but also for the design and constraint of the mechanical buttons. The PCB is attached to the case using threads cut in the plastic.

The casing is made using a SLA process with DMX-SL-100 material, which has mechanical properties similar to ABS. The casing has a wall thickness of 3mm, approximately twice that of an Xbox controller. The LCD, the two halves of the case, and the screw for the battery cover, are mounted with M3-0.5 hexagonal electrical standoffs as screw bosses. In a production part, these would be molded in to the case, but with that option unavailable, the bosses are glued in place. While there is a possibility of the glue failing, the fix is simple enough to be done by the user if needed. It is a concern that if the plastic was taped instead of using the metal bosses that the plastic threads would have a limited number of uses before becoming too worn to function properly. A repair to these threads would be much more involved, even if they prove to be slightly more durable initially than the metal bosses. However, the plastic is taped for the PCB mounts, since it is mounted in a position that did not leave enough depth to insert a standoff. The PCB should not need to be removed unless a replacement is needed.

The components that do not have fixed mounting points are constrained by a variety of methods.

Molded pegs are used for the power switch and volume control knob. The parts are then permanently glued onto the pegs. The headphone jack is glued on three sides, and further limited by the protrusion of the jack itself. The vibration modules sit in grooves to prevent axial motion and limits radial motion as well. The speakers, lacking attachment points, are similarly constrained, but are also glued in place to limit axial motion.

The design of the mechanical buttons was accomplished with the collaboration of the industrial designers on the team, who modeled the exposed portions of the buttons. The basic shape of the buttons extends downward and flares out to prevent the button from falling out of the case. The extended section matches the extended guides that follow the holes in the top of the case. This prevents the buttons from wobbling in their holes. Finally, the buttons rest on their respective electrical buttons. The electrical buttons provide a surprisingly good "feel" to the button action, and the SLA buttons are light enough that they do not accidentally actuate the electrical switch.

The total cost of the project is $3,962.39.

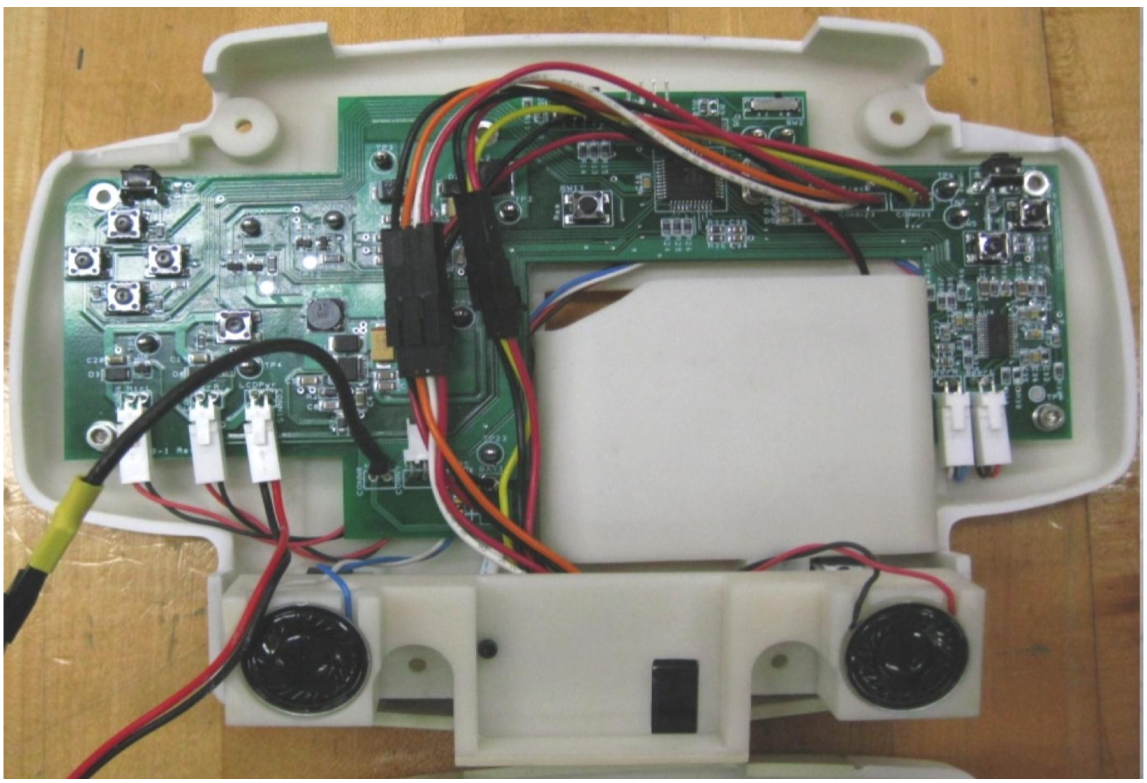

Fig.10.5. Interior of case with PCB mounted.

UPPER EXTREMITY EXERCISER

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INTRODUCTION

Following a stroke, it is common for persons to lose significant amounts of functionality and range of motion in the upper extremities. Should some range of motion be restored, the arm may still feel heavy and difficult to move. Often times stroke patients will compensate with their upper body, specifically their upper extremities, in ways that may cause further damage to the muscles that are involved in upper limb control. The proper method for rehabilitation is to constrain the upper extremities to motion that is considered safe to perform, and to encourage the use of these particular motions as much as possible. The purpose of this project is to create a device that can be used by individuals in the rehabilitation of the muscles involved in upper limb control. A prototype and first generation device were created for this specific type of rehabilitation, but fail to sufficiently fulfill the primary needs of the project customer. As a result, it is this team's principal objective to redesign or create a completely new device that more effectively meets the most critical needs of the client. In particular, the range of motion in extending and raising the arm must be increased, motion must be limited to the sagittal plane, and the device's size and weight must be reduced.

SUMMARY OF IMPACT

The redesigned system met or exceeded the customer's most critical needs. Figure 11.6 shows a comparison of (a.) the therapist prototype, (b.) the first-generation project, and (c.) the design created in this project. The range of motion at the shoulder is increased by 40° (120° shoulder extension), weight was reduced by 70% (5 lb.), and storage volume was decreased by 95% (24" x 10.5" x 6"). The elbow joint has a 168° range of motion and the amount of resistance and/or support provided by the system can range from 2 lb. to 9.5 lb., exceeding the customer requirement of 3 lb. to 8 lb. The device can

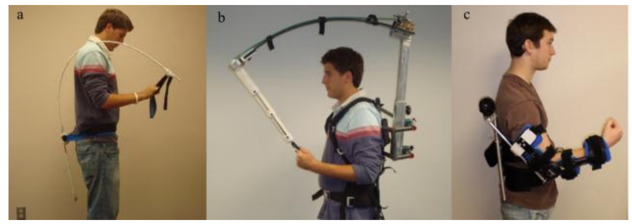

Fig.11.6. Left to right: therapist prototype, first-generation exerciser, and present design.

be used on either the left or right side, although there is minor interference when the device is used on the left side of the body. The device is adjustable to accommodate 5th percentile females through 95th percentile males. Shrug-type motion is not well-constrained, but this is a lowest-priority customer need and does not negatively affect the rest of the system. Overall, the client was extremely pleased with the new design and plans to begin clinical use in the fall.

TECHNICAL DESCRIPTION

The design has three subsystems. The first subsystem is the shoulder subsystem (Fig. 11.7), which provides assistance/resistance for flexion and extension of the shoulder joint. The spring subsystem is composed of five individual components. The first is the torsion spring, which is removed from an EMPI Advance® Dynamic ROM elbow rehabilitation device. The spring is manually removed from the brace and implanted into the design as the source of assistive and resistive force for the patient's arm. A pin is inserted into the spring to cap its range of motion at 120°, as indicated in the specifications. The second component is the upper arm shaft, fabricated from an aluminum rod and threaded at an end. The upper arm shaft's function is to provide a track on which the upper arm will translate as it is raised and lowered. The third component is the torso shaft

Fig.11.7. Shoulder subsystem.

which, similar to the upper arm shaft, is fabricated from an aluminum rod and threaded at one end.

Several small holes are drilled into the torso shaft to provide vertical adjustability to accommodate numerous patient torso lengths. The fourth and fifth components are the spring arm bases which are fabricated from square aluminum bar stock. Each has a threaded hole for assembly of the upper and lower spring arms, and two non-threaded holes for spring attachment.

The second subsystem is the elbow subsystem (Fig. 11.8). The elbow subsystem is composed of three components. The first component is an EMPI® Advance Dynamic ROM. The function of this part is to assist the patient in achieving extension in their elbow. The second component is the upper arm cuff, fabricated from the moldable polymer Orthoplast. Its function is to join the shoulder and elbow subsystems and rigidly attach the arm subsystem to the patient. The third component is a linear ball bearing within a polymer pillow block. Its function is to provide smooth translation of the arm subsystem along the upper arm shaft during device operation.

The third subsystem is the torso subsystem (Fig. 11.9). The torso subsystem is composed of three

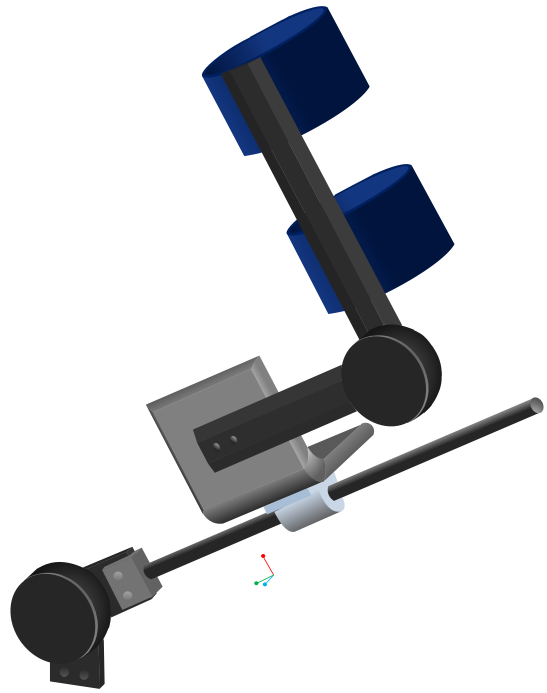

Fig.11.8. Elbow subsystem.

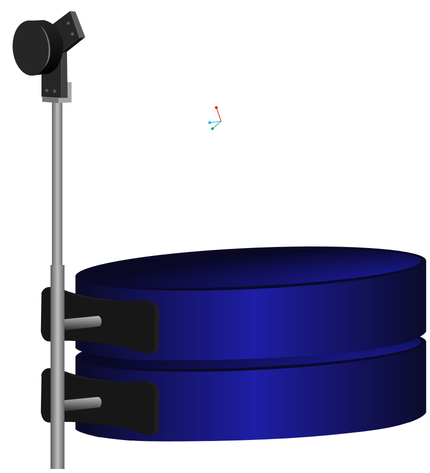

Fig.11.9. Torso subsystem

different components. The first and second components are Valeo lumbar belts. These belts serve to rigidly anchor the spring subsystem to the patient's body. The third component is the vertical adjustment sleeve, fabricated from a long hollow aluminum tube with two shorter aluminum tubes welded perpendicularly. This sleeve links the shoulder and torso subsystems, and provides for patient adjustability. The total cost of the project is approximately $2120 (includes $1300 worth of donated equipment).

MANUALLY OPERATED WHEELCHAIR FOR USE WITH ONE ARM

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INTRODUCTION

The goal of this project is the design and creation of a one-arm, manually powered wheelchair. The design is inspired by our client, a stroke patient with mobility of only one arm. Following a stroke, it is normal for patients to lose some or all of the functionality in one side of their body. As a result, it is inconvenient for them to use a normal, two-arm wheelchair. This wheelchair will provide the means for our client to propel himself with the use of only one arm in and around his home or at a long-term care facility.

SUMMARY OF IMPACT

The design chosen for this prototype is based on a push lever for propulsion of an existing wheelchair. The finished product meets nearly all of the initial specifications, and the client uses the wheelchair in many day-to-day activities and provides feedback to the team. He is comfortable moving the chair using the push lever and feels that the wheelchair is satisfactory for transportation on a daily basis. He expresses some concerns about performing sharper turns and controlling the brakes, but overall has provided very positive feedback.

TECHNICAL DESCRIPTION

The prototype is designed against existing wheelchair models that are used by individuals with the use of one arm. The two primary designs that exist are electric wheelchairs and wheelchairs with both push rims on one side of the chair. The electric chairs are significantly heavier than manual chairs, and often require the user's car to be custom-outfitted for transportation. They also lack therapeutic benefits because propulsion is joystick-based. Designs with both rims on one side create problems when the user tries to grip both push-rims simultaneously. It is difficult to grab both rims with the same amount of force when attempting straight-line travel, which results in the wheelchair deviating from its intended path.

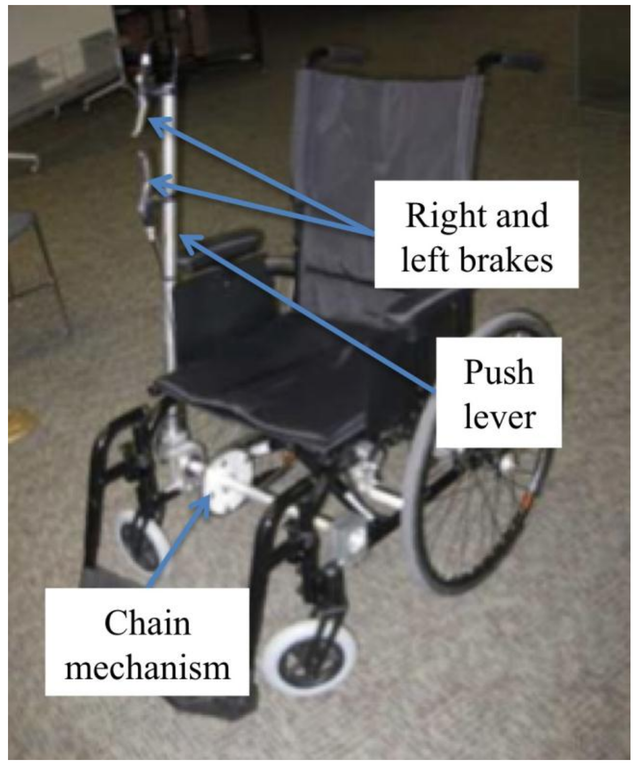

Fig.11.10. Final wheelchair design.

Based on all of this information, a push-lever design is implemented in this project. This new system requires the user to push forward on the lever to move forward and to use the right and left brakes on the lever to slow and stop the chair as well as to control turns. The rear axle is split, and a differential allows the two rear wheels to rotate independently for making turns.

Based on the client (50th percentile male), the design can achieve a 2 mph top speed without exceeding an acceptable amount of required grip or push force. Similar analysis ensures that the user is able to operate the hand brakes. Three lever pushes at 100 N, which is within the client's ability, will accelerate the chair to 2 mph within three seconds. Four lever pushes at 60 N increases the time to four seconds, and still brings the chair to just under 2 mph. This means that even if the client is not able to push with 100 N of force, a significantly lower push force still allows him to reach cruising speed fairly quickly. Bicycle brakes, similar to the ones used in the wheelchair system, require approximately 30 kg to operate. Through dynamometer testing, it was determined that our client is able to achieve 25 kg in grip strength. Therefore, the brakes are adjusted to accommodate the client's slightly lower grip strength to assist in stopping the wheelchair.

The three modifications made to the existing chair are (a.) the addition of the push lever for propulsion, (b.) the chain drive and the differential under the seat and on the rear axle, and (c.) the integration of the braking system into the rear wheel hubs (Fig. 11.11). The biggest challenges the team faced include maintaining chain tension and machining custom parts with close enough tolerances to off-the-shelf parts to eliminate poor fits. The chain does slip at full push forces, but limiting the force to approximately 60 N eliminates slip and delivers adequate propulsion. Shims are used to minimize mismatches in part sizes, which can be eliminated by custom made parts. Overall the system is fully functional and provides an alternate means of transportation for the customer.

The total cost of the project is $2,113.

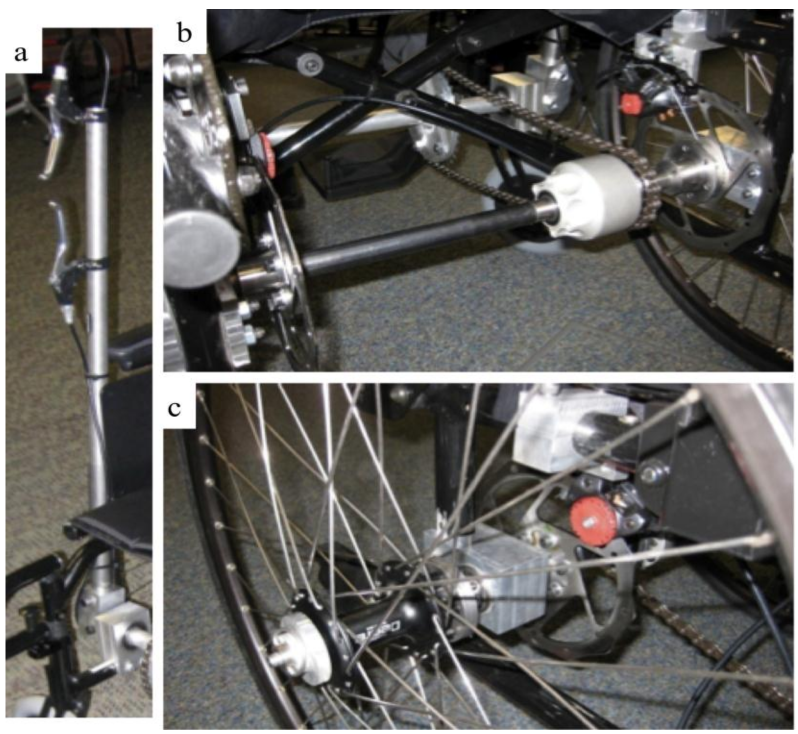

Fig.11.11. Key propulsion system components: (a) push lever and brake handles, (b) chain drive and differential, and (c) rear wheel hub and brakes.