

CHAPTER 6

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THE FOOT AND HAND CYCLE: FIRST ITERATION

Designers: Alex Arsene, Edwin Diego, Nathaniel Hague & Denver Schaffarzick

Client Coordinator: John Lee, Central Coast Assistive Technologies Center (CCATC), San Luis Obispo, CA

Supervising Professor: Lee McFarland

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INTRODUCTION

The Foot and Hand Cycle, First Iteration (FAHC1), is an exercise vehicle for persons with varying physical disabilities which prevents beneficial physical exercise through traditional cycling. The FAHC1 allows a rider to use both their hands and feet to power a tricycle intended for street use. Upon completion, the device was given to Central Coast Assistive Technologies Center (CCATC) in San Luis Obispo, CA. It is currently being used by John Lee, who has difficulty using a bicycle due to a degenerative muscle disorder and lack of balance. As a source of beneficial physical exercise. His long term test results are being used to generate requirements for an improved second generation device for use by a wider range of persons with disabilities. Overall, the FAHC1 has great potential for being a fun and useful workout device as well as providing its user with increased mobility.

SUMMARY OF IMPACT

Cycles are a popular choice for recreation, exercise, and sport. Unfortunately, those with limited use of their legs and other persons with physical disabilities are unable to fully participate in these activities because standard cycles are not tailored to their needs. There are currently cycles on the market that are powered by either the user's feet or the hands, but not typically both simultaneously. The FAHC1 fills this gap. The prototype implements both hand and foot movement for power and is specifically designed for a user with limited strength in either or both the hands and feet. This device offers a unique opportunity for the client to exercise both body systems. Both upper and lower body movement is utilized to power the cycle over a flat terrain. Current foot-powered cycles, designed for people with disabilities such as EZ Chair from Premier Designs, have limitations such as relatively high cost and they do not provide upper body exercise. The FACH1 is an ideal platform for a user



Fig. 6.1. Final Product.

to exercise both upper and lower bodies and make use of the combined strength for increased mobility.

TECHNICAL DESCRIPTION

The device is a purely mechanical device. The FAHC1 combines the ergonomics of an elliptical aerobics machine with the traditional pedal and gear system of a recumbent bicycle for its power train. The tricycle is composed of two wheels in the front and one wheel behind the seat. For its frame and other structural components, the FAHC1 uses round steel tubing. A rack and pinion steering system is connected to the power arms to translate the steering motion to an Ackerman setup at the front wheels. The seat is padded with weather-proof material and has shocks on the rear base to isolate the rider from vibrations caused by the road. Braking is accomplished by hydraulic hand brakes on the rear wheel. Among the many user requirements satisfied by this design is a firm upright seat with high visibility. The seat sits at a comfortable height that allows easy transition from a

standard wheel chair. The three wheeled design is extremely stable. The widest geometry of the frame does not exceed 30 inches which allows the vehicle to pass through a standard doorway with the front wheels removed. The force required to initiate motion is comfortable for our sponsor and tester, John P. Lee for whom the cycle is designed. The cycle can be started from rest by the arms, legs or a combination of the two.

Testing results indicated that the vehicle had comparable cruising speed to a standard road bicycle with testing speeds easily reaching 25 mph. The force required to initiate motion is slightly higher than traditional bike design using foot power only. This is due mostly to the fact that the power stroke is initiated normal to the pull of gravity; however, with the addition of hand power, initiating

motion is relatively easy, and sustaining a constant velocity required is the same or less force than a bicycle. The steering is intuitive and easy to control after an average of 10 minutes training on the vehicle. The minimum turning radius is larger than a traditional bike at approximately 13 feet. The final phase of testing was conducted by John Lee. His suggestions for improvements include shortening the length of the foot crank pedal from seven to six inches, shortening the total travel of the power arms from 15 to 12 inches, and raising the seat by 1.5 inches. Mr. Lee is currently performing longer term testing which result in an improved set of requirements for the second generation machine.

The cost to produce the prototype is \$2188.00 in materials.



Fig. 6.2. The Foot and Hand Cycle in action.

THE WIIFIT

Designers: Steven Pungdumri, Mallory Embree, Bunvandy Taing, Matthew Hall
Client Coordinator: Paul Mortola, Central Coast Assistive Technology Center, San Luis Obispo, CA
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INTRODUCTION

It can be difficult for people with quadriplegia to participate in certain forms of exercise. The primary intent of this project is to develop a form of exercise for people with quadriplegia, using the Nintendo Wii system. The Wii-B-Fit takes the Wii's engaging and fun game play and adapts it to meet a set of user defined requirements. Individuals with quadriplegia also face very limited access to video games.

Although Nintendo claims the Wii targets a broad demographic, the ingenuity of the Wii's remote actually excludes people with quadriplegia. The Wii requires players to have control of their arms and upper body to make full use of the accelerometer and infrared based remote system. In order to make exercise with the Wii possible, the ability to play the Wii must be an inherent property of the device. Thus, this project will also increase the accessibility of the Wii system to people with disabilities. This in turn will provide those with quadriplegia the opportunity to enjoy the health benefits of physical exercise and play.

SUMMARY OF IMPACT

In general, it can be difficult for people with quadriplegia to find suitable forms of physical activity. Using the Wii and a customized Wiimote, the WiiBfit system makes the Wii accessible to people with quadriplegia and provides a fun form of exercise. Specific design criteria met by the system include a device that operates similarly to store-bought Wiimotes, a remote that can be tailored to a client's specific needs, compatible with at least two Wii games, and provides a fun and safe form of exercise.

The clear impact and potential of this system can be summarized by one user's blog entry. "After my accident, I never expected to be able to play my Wii

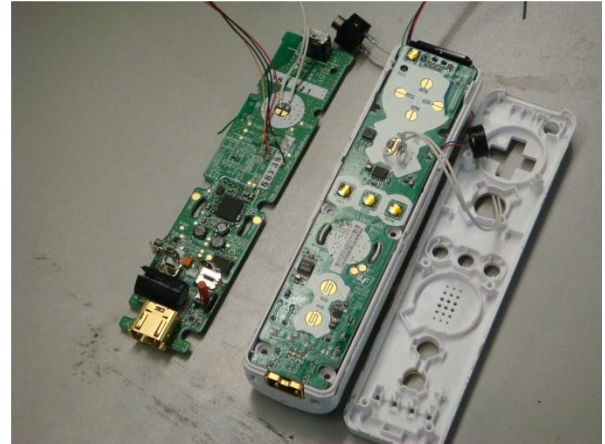


Fig. 6.3. Customized Wiimote. and User Focusing on the WiiBfit game



Fig. 6.4. Client being fitted with the WiiBfit Wiimote.

games. But now, despite my disability, I can play my Wii whenever I want. I can even use it as a physical therapy tool, which is great. It's nice to be able to have fun and exercise at the same time. Now, when I'm using it, I forget that I'm actually exercising.

TECHNICAL DESCRIPTION

The overall system design includes the use of the Polybot custom microprocessor board that is

interfaced to a modified Wiimote to take accelerometer data. The accelerometer data from a standard Wiimote is not sensitive enough to pick up the subtle head movements of many individuals with quadriplegia. The accelerometer signals must be “boosted” before they are fed into the regular Wii console. Software running on the microprocessor interprets accelerometer data and communicates to the Wii console to provide input to the standard Wii games. The mechanical system includes a custom

bandana that can be easily and comfortably attached to the users head with Velcro. This holds the modified Wiimote that can sense the subtle movements of the users head. By boosting the accelerometer signal, the modified Wiimote can then communicate to the main Wii console with inputs that look the same as any Wiimote. This allows the user to play games by themselves or against others.

The cost to produce the prototype is about \$800.00 in materials.



Fig. 6.5. Client focusing on the WiiBfit Wiimote.

SIT SKI FOR THE US ADAPTIVE SKI TEAM

Designers: Marc Bergreen, David Bydalek, Ross Gompertz
Client: Mr. Marlon Shepard, U.S. Adapted Ski Team Member
Client Coordinator: Mr. Jon Kreamelmeyer, Developmental Coach of the US Adaptive Ski Team
Supervising Professor: Sarah Harding
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INTRODUCTION

The purpose of this project is to design, build, test and deliver a Sit Ski for the US Adaptive Ski Team member, Mr. Marlon Shepard. Mr. Shepard is new to the team and his event is Adaptive Cross Country Skiing. Sit Skis consist of light, form-fitted frames and seats mounted to standard cross country skis that allow the athletes to use poles to propel themselves along with their upper body. The frame and seat of the sit ski are mounted onto the skis using either standard cross country ski bindings, custom proprietary mounts or a combination of the two. Like all team members, he has unique requirements for his Sit Ski in order to optimize performance. Interviews revealed the top design priorities which included reduced weight, increased rider comfort, and increased durability over existing designs. The intent of the project is to develop a new Sit Ski design that can be used in international competition at the Paralympics.

SUMMARY OF IMPACT

Quality Function Deployment (QFD) is used to create engineering specifications from the stated user requirements. This process indicates an interdependence of several of the design specifications. Some of these interdependencies include seat height and restraint systems; as well as sharp edges, pressure points and restraints. The top three most important requirements all relate to holding the user's torso secure. The next most important design requirement is the seat height since this directly affects power transfer and the ability to right oneself after a fall. The last critical requirement is to keep the weight of the device as low as possible. The end result of the design process is a sit ski that will provide Mr. Shepard with the best performance outcome. Initial testing has shown that the design satisfies the majority of the



Fig. 6.6. Custom Sit Ski.



Fig. 6.7. Computer model of the custom Sit Ski.

requirements. Some modifications will need to be made before the winter racing season.

TECHNICAL DESCRIPTION

The final design utilizes a combination of an injection molded plastic seat and a space frame

made from aluminum tubing. These materials are chosen due to their light weight, strength and availability. The design can be broken down into four components including the frame, seat, bindings, and restraints. The frame uses three different tubing sizes to construct a sit ski that is as light and as strong as possible. The bucket seat is constructed from injection molded plastic. The seat is supplied by Enabling Technologies, LLC. After the frame and seat, the third element of our design is the binding system. The sit ski uses two NNN bindings on each ski. They face in opposite directions to keep the skis rigidly attached to the frame. The final element of the design is the restraints which hold the rider in the sit ski. They consist of 2" wide nylon straps for the seat and 1" wide nylon strap to secure the feet to the foot plate. An additional nylon strap is riveted to the footplate and attached to the back seat support so that Mr. Shepard can pull his legs tight

should spasticity occur. This will effectively stretch his calves and allow the spasticity to subside.

The analysis performed on the sit ski design focuses on the strength of the frame. The initial hand calculations performed on the frame gave rough engineering estimates for appropriate sizing. The structure is highly indeterminate and challenging to analyze with traditional methods. Although hand calculations are used to gain an understanding of how the structure responds to loads; a more detailed finite element analysis was used to get a more accurate prediction of frame strength and deflection. The final product performed well in initial testing and has been delivered to the client for further testing next winter.

The cost to produce the prototype is \$1167.00 in materials.



Fig. 6.8. Custom Sit Ski Testing.

THE ADPATED PADDLE LAUNCH VEHICLE

Designers: Duane Menton, Erik Granstrom, Matthew Resendez, Shannon Crilly
Client Coordinator: John Lee, Central Coast Assitive Technology Center, San Luis Obispo, CA
Supervising Professor: Dr. Louis Rosenberg
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INTRODUCTION

At California Polytechnic State University, the Kinesiology department has created an adapted exercise program that provides different means of exercise for people in the community. One such activity is the adapted paddle program, which allows community members with varying forms of paralysis to participate in an organized kayaking trip to the local estuary, Morro Bay. This activity provides a fun way to exercise as well as a sense of freedom in the open water that may not be experienced on land. The Adapted Paddle Launch Vehicle (APLV) is a device that allows the kayak launch and retrieval process to be safe and more efficient than previous designs allowed. The APLV allows the kayaker to transfer from their wheelchair into the kayak, and then safely lower the kayak into the water from a boat ramp. After finishing kayaking, the APLV safely brings the kayaker back up the boat ramp.

SUMMARY OF IMPACT

There are five major user requirements that drive the design to insure a successful APLV. The first requirement is that the device be accessible to as wide a range of users as possible. The adapted paddle launch program has clients with a wide range of disabilities; the APLV is usable by the majority. The second user requirement is to make the transfer from the wheelchair to the kayak comfortable and safe. Without meeting this goal, the users may get discouraged and not participate in the adapted paddling program. The third requirement met by the APLV is that it can transport two kayakers (the person with the disability and the volunteer that shares the kayak) and the kayak itself from the top of a boat ramp, down to the water, and back up safely. The fourth user requirement is to make the vehicle easily transportable to and from the launch site. The fifth major requirement is to make sure the vehicle requires little maintenance.



Fig. 6.9. The completed APLV.



Fig. 6.10. Close-up of the 'Dead' Man Breaking System.

The APLV has been commissioned and is used regularly by the adapted paddle program and has made a huge impact on the ease of transferring the participant's' wheelchairs to and from the water. Surveys of the users indicate a high level of satisfaction.

TECHNICAL DESCRIPTION

The APLV consists of two independent systems. The first is a commercially available hoist which is used to transfer the clients from their wheelchairs to and from the kayak. The second system is the APLV which is used to transport riders and kayak to and from the water. The APLV has a rigid frame. It consists of two main rails that support the riders and kayak. These two main rails are detachable with locking pins to allow for easy transportation of the vehicle to the launch site. The rear axle is mounted to the rails and has a handlebar attached to allow for steering. A Delrin flanged bushing acts as the steering mechanism bearing which results in low wear, a smooth feeling and will require no maintenance. Delrin bushings also support the wheels so they roll with much less resistance. Delrin is a high-strength, low-friction plastic that is lightweight and non-corrosive, making it ideal for our needs and works well in the salt-water environment.

The handlebar is equipped with a dead man's brake for speed control of the APLV as it is led down the incline of the boat ramp. This can also be used as an emergency brake. A dead man's brake works like a traditional brake, except the lever is released rather than pulled to engage the brake. The braking system uses a bicycle hydraulic bicycle disc brake that is reconfigured to work backwards, so when the brake lever is released the brake is engaged. With this feature, the cart will automatically stop if the person steering loses their grip on the handle bars. The rigid frame allows for ropes to be attached to the vehicle to help pull the loaded cart out of the water and up the boat ramp if necessary.

The vehicle is fabricated by using common sizes and parts that are readily available from vendors. The APLV frame is made from 6061-T6 aluminum. This aluminum is selected due to its non-corrosive properties and high strength-to-weight ratio. The



Fig. 6.11. Prior to the APLV, Kayaks were launched by assistants carrying the kayak (top) or with the use of hand cart (bottom).

wheels are rated for a load roughly twice that which is anticipated in use. Other parts including the bicycle brake system and various fasteners are readily available and easy serviced.

Thorough analysis of the APLV design was performed prior to construction. A static force analysis was used to find reaction forces in the critical members of both the launch vehicle and lifting mechanism. Deflection, stress and fatigue analysis was performed to insure that the system would perform within specifications.

The total cost to produce the prototype is \$1166.00

THE STRIDER

Designers: Alex Trask, Eric Johnson, Ricardo Garcia
Client: Nathan Cooper who has Spinal Muscular Atrophy (SMA)
Client Coordinator: Amy Cooper, Nathan's Mother, San Luis Obispo, CA
Supervising Professor: Dr. Louis Rosenberg
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INTRODUCTION

The overall goal of the STRIDER (STanding RIDER) project is to provide children with Spinal Muscular Atrophy (SMA) or similar illnesses with a device that will allow them to exercise, sustain mild impact to promote bone density growth, and to move around in a vertical position. The STRIDER is designed for the needs of a specific client, Nathan Cooper (a four year old child with SMA). Nathan is a four year old boy in San Luis Obispo, CA with Spinal Muscular Atrophy (SMA). SMA is a neuromuscular disease which results in weakness and limited mobility in the limbs, particularly the legs. Because of this weakness, Nathan is forced to spend most of his time in a sitting or lying position. The STRIDER project resulted in a device that supports Nathan in a standing position, facilitating better circulation and physical exercise. With increased exercise, the hope is that Nathan will develop strength and endurance, breaking some of the barriers previously associated with patients having SMA.

The STRIDER is a mechanical device that supports Nathan in a vertical position and allows him to independently navigate over varied terrain. The adjustability of the STRIDER will accommodate Nathan over the next two years as he grows and gains weight. The lessons learned from the development of the STRIDER will be used in the future to develop a more advanced and universal device for other clients.

SUMMARY OF IMPACT

There is no specific therapy for patients with SMA. Treatment is usually only supportive, with its primary aim towards preventing the development of complications like respiratory infections and scoliosis. Therefore, a new therapeutic strategy that may offer a form of therapy and exercise is of great



Fig. 6.12. The side (top) and rear (bottom) views of the STRIDER.

importance. A recent study conducted in 2005 (see *The Journal of Neuroscience*, August 17, 2005) determined that regular exercise prolongs survival in type 2 SMA on mice. The study consisted of three different physical exercises that tested a mouse's endurance, strength, and ambulatory behavior. Although these tests were conducted on lab mice that share like symptoms and characteristics found in humans with SMA, the article strongly suggests that similar results can be achieved with humans. The results concluded that the mice experienced better sustainability of their motor functions, and lived about 57.3% longer. This research provided the first evidence of the benefits of exercise in SMA patients and might lead to important therapeutic development for humans.

In order to meet the needs of the client, Amy, Nathan's mother, spends a great deal of time and effort trying to find the best means of transportation and exercise for Nathan. His current means of exercise include water therapy, stretching, swinging, and vibration therapy from his current standing electric wheel chair. Missing from this regimen is a therapy that gives Nathan moderate impact in his legs which will help to build up his bone density. High bone density correlates to stiffer bone, which minimizes the chance of braking or fracturing.

The primary need addressed by the STRIDER is that it provides exercise and health benefits for Nathan through the age of six. Nathan needs loading (both static and dynamic) on his bones to promote proper growth and would also benefit from more exercise. Currently Nathan spends time upright in a hip, knee, ankle, and foot orthosis which provides some bone loading, but unfortunately does not provide freedom of movement. To move around Nathan has a Go-Bot® which does not allow him to traverse varied terrain. The STRIDER has the potential to provide Nathan with physical exercise by allowing him to use a limited gait motion to move the system in any direction he chooses. Also the standing position will load Nathan's bones. Ultimately it will provide Nathan with necessary exercise and increased mobility to explore his world.

The design requirements for the STRIDER are developed to meet the needs of Nathan. The main user requirements are to provide exercise and health benefits for Nathan, be able to provide him with these benefits through age six, be enjoyable, durable, lightweight, compatible or in place of HKAFO,



Fig. 6.13. Nathan moving around in his Go Bot.

adaptable for future improvements, variable weight bearing for different levels of exercise, maneuverable, cleanable and maintainable.

These user requirements were used to develop a more detailed list of quantifiable engineering requirements that were necessary to satisfy Nathan's needs

TECHNICAL DESCRIPTION

The design of the STRIDER is governed by a specific set of engineering requirements developed to satisfy Nathan's needs. The first major requirement is to provide for multi-terrain use. To accomplish this requirement, the system is designed with four large wheels and an adjustable suspension system. A coil over suspension is located between the support harness and the lower frame. This system can be adjusted both in height (to accommodate Nathan as he grows) and in spring stiffness. The springs are relatively soft which will isolate Nathan from large ground induced shocks as the STRIDER moves. The springs also allow Nathan to "walk" using the system as he can bounce up and down to alternatively touch the ground and lift his feet as he

propels himself forward. A system of nuts and screws allow adjustable pre-tensioning of the spring to accommodate Nathan as his weight changes over the next few years.

The basic frame supporting the system is made from 6061-T6 aluminum to keep the system relatively light. This allows Nathan to move the STRIDER under his own power. This independence is an incentive for Nathan to get more exercise. The castor in the front wheels allow the system to be "steered" through inputs by either Nathan's feet or by his mother. Handles in the back allow a parent to use the system more or less like a stroller. An optional footplate is provided when the STRIDER is used as an upright stroller to keep Nathan's feet from dragging on the ground. This can be removed when Nathan is using the STRIDER independently. The post at the back of the STRIDER allows the carriage to move vertically as Nathan is moving. The carriage has a welded structure which allows the attachment of Nathan's harness. This carriage can be replaced with a larger structure as Nathan grows. Lastly, the STRIDER is designed to be collapsible so that it can be transported easily in a duffel bag.

Safety is a top priority in the STRIDER's development. One of the primary concerns is stability. The system was design to insure no tipping when placed on a 30° incline. Basic static analysis indicated a base width of 20 inches or more to ensure stability up to 40°. Testing validated the design. The harness support is made from tubing with a minimum wall thickness of 0.5 inches and an outside diameter of one inch. This provides an ample factor of safety with regard to any structure failure. The end result was a system that Nathan is delighted to use. It also allows Nathan more independence from his Mother in how he obtains exercise. The STRIDER will provide an enjoyable way to exercise and health benefits for Nathan for the next two years. Long term testing results will be analyzed to developed design criteria for a more universal product.

The cost of materials and supplies to produce the STRIDER was approximately \$1356.78.



Fig. 6.14. Nathan enjoying his new device.



Fig. 6.15. SolidWorks Model of the STIDER.

