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Redesigning the Walker: A More Durable & Dignified Device

Gianna M. Curcio

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A Capstone Project Submitted in Partial Fulfillment of the Requirements of the Renée Crown University Honors Program at Syracuse University

Gianna M. Curcio
Candidate for Bachelor of Science in Mechanical Engineering Degree and Renée Crown University Honors
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Honors Capstone Project in Mechanical Engineering

Capstone Project Advisor: ________________________
Advisor Title & Name

Capstone Project Reader: ________________________
Reader Title & Name

Honors Director: ________________________
Stephen Kuusisto, Director

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Abstract

Aging and Rehabilitation Engineering is a prominent field with ample room for development of and improvement upon existing options. Surveying city sidewalks, family gatherings, hospital waiting rooms it becomes apparent that the need for mobility aids is abundant. My proposal for Capstone is to redesign the walker from both my mechanical engineering and sculptural perspectives. A walker is meant to improve the quality of life for those who are unable to walk unassisted, but should not come at the cost of the user's dignity. The way we carry ourselves says a lot about us (i.e. character, will, and level of care for our bodies). I want to further improve quality of life by elevating the walker to a dignified piece of equipment. I propose to focus on ease of use, opportunity for customization (for those individuals with specific needs in addition to stability while walking), and improving the aesthetics of this important device that serves as a daily presence in many people's lives.

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Executive Summary

To redesign is to take what is and make it better. To redesign requires an existing process or product with ample room for improvement and a keen eye to see that potential. By choosing to redesign the walker, I have chosen to state outright that existing models are less than favorable and propose that my design would be better suited to serve the end user. The overall objective of this Capstone has been to identify the major shortcomings of existing mobility aid models, rectify them by taking an inclusive design approach to accommodate the user more comprehensively, and create detailed representations of this design for patent purposes in the future.

A short list of the process involved in completing this Capstone is as follows: (1) the generation of individual feature designs (divergent from existing models) based on consumer feedback, (2) material selection and manufacturing considerations in keeping with existing cost thresholds, (3) the development of a full assembly model using computer aided design (CAD) software, (4) performance of stress analysis on said CAD model, and (5) the construction of a full scale prototype to convey the desired form.

While advancements continue for high-tech assistive technologies in the field of Rehabilitation Engineering it seems that designs of purely mechanical devices at the other end of the spectrum have remained stagnant. Existing models of low-technology mobility aids, consisting of walkers and “rollators”, sacrifice dignity and accommodation in the predominantly cost-driven fabrication. A

“rollator” has become the generically adopted term for full-wheeled mobility aids, coming in three- and four-legged models. Though rollators offer smoother navigation than the traditional walker, which consists of either two front wheels or no wheels at all, issues with rollator devices stem directly from their hand brake systems. The hand-trigger brake mechanism implemented in rollator design is akin to that of a bicycle. It requires finger dexterity and contraction of muscles in the forearms, to grip and activate a damper on the wheels.

Individuals who require the assistance of a mobility aid often experience intersections of additional impairments. For example, those suffering from arthritis of the hand and wrist have tremendous discomfort when using the hand trigger brake system, described earlier. Alternatively the walker user may have previously suffered a stroke or perhaps has an upper extremity prosthetic, and in both situations would be best served by a device that accommodates for asymmetric motor control. Changing this traditional interface of squeeze-trigger hand brakes and parallel handle bar arrangement became the primary feature to address in this redesign challenge. Redesigning the handle configuration and nature of the applied forcing-through-squeezing, led to the creation of a distinct layout. In turn this layout called for nontraditional material selection and manufacturing considerations. As proposed from the earliest phases of this Capstone the final model will be a more durable and dignified piece of equipment than options currently on the market.

Preliminary research began with a questionnaire requesting first hand commentary on the strengths, weaknesses, and associated conceptions with existing mobility aid models. These surveys were distributed among primary users and candidates (of mobility aid devices) within Englewood Medical Center in Englewood, NJ, and the Syracuse VA Medical Center. Based on survey feedback, designer preferences, field professional consultation, and observation features were selected to concentrate on. This focus centered on addressing primary issues of non-user-friendly brake systems (great difficulty for arthritic individuals) and stigma attached to the stark, medical, barebones form. Secondary features such as LED photo-detecting lights for the purposes of nighttime navigation, for example, were also considered and included in this proposal.

Methods employed for producing the various models and renderings involved extensive sketching, CAD design iterations, and construction of an appearance model out of hand-carved Pine. Truly, though, a decade of research through observation preceded this academic venture, as more of a brainstorming hobby. I often wondered why my relatives needed to experience so much difficulty with their devices, when the technology claims to be assistive as its most fundamental intention. Now, through the application of my interdisciplinary studies of mechanical engineering, sculpture, and Disabilities Studies, I am able to look beyond the question and offer a potential solution.

Throughout the process I consulted with professionals in the fields of Mechanical Engineering, Disabilities Studies, and Industrial Design in order to approach the design from several angles. The insights gathered from one-on-one meetings were invaluable, and led to cleaner iterations with each discussion. As the form became more streamlined and manufacturing processes became leaner, in terms of cost and material savings, I began to realize what original sources of inspiration were showing through in the final design.

In the final design there are furniture undertones as well as an allusion to biomimicry, at least from the designer’s perspective. Early sketches called upon form from natural structures such as a bird’s breastbone, or furcula. The gradual slope leading from the inclined handlebars to the floor continues to carry that natural form through to the final prototype. This nuanced involvement of nature’s elegant construction is especially exciting when the product at hand will be fabricated from industrial grade material, namely polypropylene and anodized aluminum.

Focusing on ease of use, opportunity for customization (for those patients with specific needs in addition to stability while walking), and improving the aesthetics of this device is important because it serves as a daily presence in many people’s lives. With a focus on stress analysis and overall cost evaluation the intentions of this design are to meet the needs of all those who have access to a walker at this point in time, but with a better model they have at this point in time. This design is not intended for the market as a luxury item, but instead as a widely accessible piece of assistive technology that meets expectations of strength, stability, and durability. All of this with no sacrifices made to visual esteem of the device or perceived dignity of the user. The idea that better product design can bring about change in human-to-human perception is certainly a concept worth pursuing.

Acknowledgements

Many thanks to my core support team of advisors and interdisciplinary resources who brought energy and enthusiasm to the project. The discussions held with my Capstone Advisor, Reader, and main consultants brought me knowledge far beyond the project-based issues I was hoping to address at a fundamental level. The opportunity to work with my Capstone Advisor Professor Fredrick J. Carranti and my Capstone Reader Director Diane Wiener is one that I am thankful for on both academic and personal levels. I would also like to extend a warm thank you to Research Professor Jurgen Babirad who assisted me in preliminary research and shared his insights from working closely with the field of Rehabilitation Engineering.

Outside of Syracuse University faculty, I owe several key individuals my appreciation for offering their time and extending their warm words of encouragement for the duration of this process. I thank Mr. Roger H. Hamilton for the sound advice he provided regarding my design process and the shared sentiment of seeking better design as a means to improve the daily living conditions of a loved one. In addition, I would like to thank OT Supervisor Cynthia Massara for distributing my survey to her patients at the Syracuse VA Medical Center. I would also like to thank my peer Ms. Laura Wright for providing several hours of consultation based on her knowledge from her course of study in Industrial Design.

Perhaps my greatest thanks must go to Ms. Columba Curcio, my Great Aunt, who planted the seed of my inspiration.

Advice to Future Honors Students

To all aspiring Honors Capstone Students reading this report, I recommend that you begin contemplating possible Capstone topics prior to your junior year. At the beginning of my senior year, I changed the entire premise of my Capstone because of difficulties with the scope and ambiguity of my initial proposal. In light of my difficulties with finding a new topic during the hectic academic semester, I would suggest utilizing summer interludes as times to think creatively and find the intersection of your array of interests so that when you return to school you can not only solidify a topic, but know with certainty that it is a topic in which you will be personally invested.

From the onset, I would suggest forming a network of resources and supporting figures that express an interest in your topic. Coupled with this support system it is important to be respectful of your Advisor and Reader's time, and keep them updated weekly about project status.

Now, I'll give a special "shout out" to my fellow engineering students out there! I did it, and so can you! Think long and hard about your senior year work load and goals leading up to graduation. If you are ready to handle the volume of research, analysis, and compilation required for independent study in addition to Senior Design, full steam ahead. It's no joke!

Preface

For this Capstone my motivation has been to bring about change in the way people interact with and view assistive technology, through better design. Among Merriam Webster's dictionary entries for the word engineer I found one that fit most appropriately with my goals for this project. The definition appears as follows:

engineer |□enjə□ni(ə)r|
noun

- the action of working artfully to bring something about

Chapter 1

Introduction

Project Background

With a multitude of disabilities and then intersections of these, the demand for better design to smooth the interface between the human body and augmenting technology is ever increasing. Based on several factors including scope, personal connection, and room for collaboration of both my mechanical engineering and sculptural perspectives, I chose the walker as my assistive technology to reevaluate.

The walker is an important piece of equipment, vital to maintaining a healthy quality of life for many people. Individuals who use mobility aids span a broad range of ages and medical backgrounds. In an effort to address form as well as function I have proposed to redesign the walker. My focus is on structural and material modifications for sleek manufacturing and ease of use. My design is customizable to accommodate multiple possible disabilities that users may have in addition to limited mobility (e.g., arthritis, asymmetrical effects of a stroke, upper-extremity prosthetic). Seeing my elderly relatives have difficulty maneuvering their mobility aids, I would often think to myself there must be a better way. This thought sparked a personal investment in proposing a solution, but I did not expect my pet project to evolve into a Capstone journey.

Motivation

By definition, dignity is the state or quality of being worthy of honor or respect[1]. Individuals with disabilities often face a reality wherein they are not respected at the same level as able-bodied persons, and much of this has to do with stigma and social constructions. Will power only goes so far. Beyond the limit of an individual's strong character, external support and organized efforts to lift barriers of stigma may become necessary to liberate individuals from isolating practices causally linked to disability. Since the United Nation's Ad Hoc Committee on a Comprehensive and Integral International Convention on the Protection and Promotion of the Rights and Dignity of Persons with Disabilities is bringing about change through a redesign of legislation[2], and architects promote inclusive access through considerations of Universal Design[3], then engineers can

[1] Merriam-Webster's Dictionary provides this widely supported definition of dignity.
[2] The Convention states that its purpose is to promote, protect and ensure the full and equal enjoyment of all human rights and fundamental freedoms by all persons with disabilities, and to promote respect for their inherent dignity. The convention goes on to say that persons with disabilities include those who have long-term physical, mental, intellectual, or sensory impairments which in interaction with physical, social or cultural barriers and attitudes may hinder their full and effective participation in society on an equal basis with others.
More information can be found on the website:
http://www.un.org/disabilities/convention/media.shtml
[3] Universal Design makes things safer, easier and more convenient for everyone. The methodology involves designing products and spaces that can be used by the widest range of people possible. Universal Design evolved from Accessible Design, a design process that

help facilitate change through a redesign of assistive technologies for individuals with disabilities.

Imagine being a person with a disability that impedes your ability to walk. You are presented with the opportunity to maintain your independence through the use of a mobility aid. Reviewing your options you may feel initial hesitation, noting how strongly the apparatus ties into thoughts of aging and physical decline. This commonplace notion that such mobility aids mark their user as *declining* rather than *enabled*, as is their function, shows a critical disconnect between function, form, and perception. Many older adults who might benefit from using mobility aids will not use them based on negative attitudes of what a mobility aid may symbolize. Studies show that attitudes and beliefs strongly affect the decision to use mobility aids[4]. When you choose independence it should not come at the expense of perceived dignity, and with this assertion I began my quest to design a more durable and dignified device.

This study is heavily informed by my exposure, through my Disability Studies course work, to different lived experiences and interfaces with assistive technologies as well as the overall environment that we all must learn to navigate in different ways. Disability Studies involves interdisciplinary, cross-cultural, and round-table dialogue. The field focuses on intersectionality of identities, directly related to the aforementioned intersectionality of multiple disabilities existing

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addresses the needs of people with disabilities. Universal Design goes further by recognizing that there is a wide spectrum of human abilities. Everyone, even the most able-bodied person, passes through childhood, periods of temporary illness, injury and old age. By designing with human diversity in mind, we can create things that will be easier for all people to use.

[4] A study published in the Disability and Health Journal (2009): Perspectives on Use of Mobility Aids in a Diverse Population of Seniors: Implications for Intervention

within any given individual, which this redesign challenge seeks to address, or at least consider with seriousness. The course also helped to open my eyes to the different ways in which disability is framed and presented. Disabilities are social, cultural, environmental and individual. Throughout Disability Studies history both causing and resulting in various disability movements, two emergent models have come forth for framing disability in a scholastic way: the Medical Model[5], and Social Model[6]. As a class it was concluded that neither model adequately presents the multifaceted arena of disabilities and disability culture when taken as an isolated framework. With this project, seeking to apply my newly acquired Disability Studies lens, I hope to challenge the medical model. By visually and mechanically changing an external factor such as a conventionally stark medical assistive technology, individual users will feel more in control of their supportive navigation technology. Thus a social model may be explored as perceptions of users being feeble and deteriorating may gradually fall away, because of a new awareness of the user's level of control and manipulation of these visually appealing portable furniture-like support structures.

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[5] Medical Model of disability frames disability with the same language and categorization used to diagnose and catalogue illness and disease. At the core of this model is the idea that disability is the result of a physical condition which is part of the individual's own body, in effect discounting the environment's role, and this model emphasizes curing, managing, or treating the disability through diagnostic identification and application of scientific understanding.

[6] In reaction to the functional analysis of the 'body as machine' presented in the longstanding Medical Model, the Social Model of disability focuses on factors external to the individual which act as disabling barriers. These barriers include negative attitudes and exclusionary practices, that, when coupled with preexisting physical, sensory, intellectual, or psychological impairments of an individual can lead to (an otherwise preventable) disability.

One specific resource, introduced by my Disability Studies faculty members, successfully reenergized my efforts for this capstone. This resource is the documentary titled: "Fixed: The Science/Fiction of Human Enhancement"[7]. This film is intensely thought provoking and provides a rare glimpse into the field of radical human -enhancing innovative technologies. What makes this documentary so special and captivating is its investigation of perspectives from either end of the technology, both from the creators and users. In addition, the main speakers in the film represent an array of disabilities. The common thread between their stories involves interactions with their assistive technologies and with the environment as lived experiences, with a definite direction of seeking to enhance the interaction between human and assistive technology.

This film was important for my design endeavors because it reaffirmed my idea that working with design on the individual case-study basis can be a very effective design strategy. Firstly, this approach forces a focus on addressing specific issues with an individual's interaction with the environment, i.e. double lower extremity, bellow knee, amputee (specific parameters), needs assistive technology applicable to rock climbing (specific environmental conditions), needs to enable user to progress in the sport and adjust to different climbing terrain (specific desired outcomes). Secondly this strategy, as demonstrated by Hugh

[7] FIXED: The Science/Fiction of Human Enhancement is an award-winning documentary produced by Reagan Brashear. It is 61 minutes in length and covers the perspectives of 5 individuals regarding what agents and ideals continue to drive radical technology innovations pushing to be *better than human*. A link to the trailer is found here: http://www.fixedthemovie.com

Herr's narrative[8], does indeed have potential to expand into a Universal Design model, accessible to a broad range of technologies and users.

[8] Hugh Herr is an Associate Professor at MIT researching Biomecatronics He has presented several inspiring TED talks on his innovated prosthetics design strategies and developments. A link to his most recent TED talk is provided here: https://www.ted.com/talks/hugh_herr_the_new_bionics_that_let_us_run_climb_and_dance

Chapter 2

Research

<u>Research Methods</u>

I knew early on that my design would be distinct based on its interchangeable features to accommodate patients with other conditions, ailments, or disabilities in addition to their need for stability while walking. Working with Professor Babirad in the Biomedical Engineering department, I familiarized myself with an array of disabilities that are often coupled with a need for mobility assistance. A sub-list[9] which I extracted from the full database, included conditions such as Multiple Sclerosis, Muscular Dystrophy, arthritis (Psoriatic and Rheumatoid), Cerebral Palsy, obesity, Frederich's Ataxia, Hemiparesis, and Spina Bifida, as well as a list of patients who had sustained a traumatic brain injury, stroke, or amputation.

As I set out to sketch preliminary designs several key questions arose. One preliminary method of research involved conducting interviews with current walker patients and members of the nursing and personal aid professions. The responses gathered from these preliminary interviews were not exceptionally enlightening, which may have been due to my inexperience with successful interview formatting. Moving forward I created a survey[10] (both through an online survey website as well as in a printable format) to be distributed to a wider pool of participants in order to pinpoint the most common issues and most advantageous features of existing models. To meet the needs of the target market it is vital to

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[9] Refer to Glossary in Appendix A.1 for descriptions of medical conditions.
[10] Refer to Appendix A.2 for a word file copy of the online survey.

gather first-hand accounts of the daily obstacles individuals encounter while manipulating their mobility devices. Surveys were distributed among patients in Englewood Hospital and Medical Center, in Englewood, New Jersey and the VA Medical Center, in Syracuse, New York.

Research also involved speaking extensively with Mr. Roger H. Hamilton, founded of TO_2TE, based on his patented invention of oxygen tank holders for wheeled walkers and wheelchairs. As a professional in the field of assistive technology Mr. Hamilton developed a very lucrative business because he identified a need (based on his mother's experiences with using an oxygen tank along with her walker) and met that need through intelligent design. Coming from a similar academic background in mechanical engineering with experience in machining, Mr. Hamilton discussed his own design development process and addressed questions I had along the way to meet my project goals.

Survey Results & Considerations

For my design ideas to yield a competitive product in the mobility aid equipment arena customer needs must be satisfied and then expectations, based on current models, must be exceeded. Initially I anticipated that frame strength, stability, weight, and dimensions would be the most critical factors to focus on in designing an equally, if not more, durable alternative to existing models. Prior to considering additional features and before committing to a particular curvature based on my aesthetic preference I knew my design would need to withstand at least the maximum carrying capacity of current models (250lbs for standard models and up to 400lbs for bariatric models). I knew from the onset of the design process that I wanted give the form proper visual weight to promote confidence in its balanced and sturdy geometry. Survey results support my initial conjecture that the components of safety: reliability, durability, and stability, are the prime concerns for individuals who use walkers on a daily basis.

The second most prominent division of customer needs identified from survey results is maintaining a level of independence. Though at the same time many survey candidates expressed displeasure with the stark, medical appearance of existing walker models. Comments such as "Initially I was worried that using a walker would make me appear weak, thought I feel healthy and just tend to need balance" demonstrate that, though secondary to function, form does certainly play a role in humans' interaction with assistive technology.

Through casual observation over the years, of individuals having difficulty manipulating grip systems as a result of arthritic hands, I knew that my design would primarily accommodate arthritis of the hands, among other disabilities that may be simultaneously present with the need for stability. Survey feedback supported this idea that there is often an intersection of disabilities. Further the survey results affirmed my belief that given the chance to replace an existing model with walker with one that was more accommodating, they, the survey candidates, would absolutely make the switch.

Existing Solutions

It is important to establish the key differences between what is meant by "walker" and "rollator". At the fundamental level walkers have a simplified four-legged frame and can either include two front wheels with rubber plug stubs on the rear legs (Figure 1.a), or rubberized stubs at the base of all four legs (Figure 1.b). These are the models that are so often seen sporting tennis ball caps to allow for sliding with low friction, so that users are not forced to lift the device as they walk.

(a)

(b)

Figure 1

Pictured in Figure 1 are two examples of traditional walkers. The first, Figure 1.a. (on the left-hand side) depicts a walker with four legs, where the front two legs each have one wheel and the rear legs have rubber caps. To the right of this is Figure 1.b. (on the right-hand side) that displays a short-term rehabilitation walker with no wheels, so that all four legs are capped with rubber stops.

A rollator (a term that has been adopted generically but originated as a brand name for a walker on wheels in 1978) is a mobility aid with either three (Figure 2.a) or four-wheeled mechanism frames (Figure 2.b). Three-wheel designs are advantageous for maneuverability around corners and through narrow spaces, while four-wheel designs are often chosen for greater stability and offer the unique option of including a seat.

(a) (b)

Figure 2

Pictured in Figure 2 are two examples of mobility devices referred to as rollators. The first, Figure 1.a. has four legs, each with one wheel. There is a seat and storage basket beneath. This style has a cable brake system activated with hand triggers similar to brakes found on a bicycle. To the right of this is Figure 1.b. that displays a rollator with three legs, each with one wheel. The cable brake system and hand triggers are the same as on the previous model. This rollator has a small storage compartment in the triangular space that would approximately come to knee-level of the user.

Existing models of rollators employ one of three types of brake systems. Cable brakes, as shown in Figure 2, are most commonly employed; they are similar to the brake mechanism found in bicycles and can be controlled with one or two hands. Reverse brakes are the second type of wheel-brakes used. This type involves a default locked-brake system, which users can unlock by squeezing the handle. The least common set up, referred to as pressure brakes, requires the user to exert enough force (more than the pressure applied by their leaning) onto the frame to illicit a brake response.

Alternatives to utilizing tennis balls, for walkers with two wheels or without wheels, include products called “glides”, “coasters”, and “skis” that come as accessories to put over or replace existing rubber end caps. While it is true that these add-on products may ease navigation by providing a smooth sliding action with low friction between the plastic surface and the ground, many of the products do not solve the issue of being visually displeasing. Why should ease-of-use not be a factor executed very well by the baseline device itself? I am of the opinion that it should not require additional $10-$30 accessories to fulfill an otherwise assumed basic function.

Lighting is another add-on feature, as opposed to a baseline feature, in the low technology assistive device arena. Plastic hook and Velcro attachments are sold separately to attach small flashlights to walkers and rollators. I believe that having access to light for night-time or low-light navigation is not given enough consideration, despite this being a regularly occurring need for many walker and rollator users. To follow, the inclusion of photodetecting LEDs is an integral feature of my design.

Chapter 3

Design and Analysis

Design Overview

From the vast array of design methodologies, the critical first step of any design process begins with formulating a problem statement and identifying a need. The primary issue identified among current models of walkers and rollators is the user-brake trigger interface. For current models the brake triggers, which control the activation and release of the brakes, require dexterity and strength in the user's fingers, wrists and forearm tendons. Specifying this **interface** as the primary issue acknowledges that the remaining layout of existing brake systems (the cables and mechanism which directly locks the wheel) is adequate. Therefore this set up can be adapted to fit within the redesigned model, under the condition that the manual trigger used to activate and release the brakes is more universally accommodating for walker users.

A secondary issue identified is the multitude of commonly associated negative attitudes associated with the walker and rollator, intrinsically linked to the device's appearance. The medical appearance is a visual cue that its user is "a patient", rather than a person who is able to maintain an ambulatory lifestyle. From a sculptural perspective I insist that form follows function. More importantly I assert that with the introduction of a redesigned model, a form that moves away from the current stark, clinical, medical appearance will simultaneously move away from the stigmatization associated with the traditional medical aid.

After much consideration I formulated the following problem statement:

Create a low-tech assistive device that combines the advantages of a walker and rollator while improving upon the areas of weakness that exist for both mobility aids. Allow knowledge of disability studies and inclusive design to drive mechanical and aesthetic design.

Current models employ grip triggers for brake systems that are not user-friendly for individuals with limited dexterity. Many individuals who are presented with the reality of needing mobility assistance are often resistant to use mobility aids for the negative feelings, attitudes, and perceptions associated with them.

First-hand perspective from mobility aid users will be gathered through interviews and surveys, to garner an accurate understanding of the advantages and disadvantages of current models. Overall an interdisciplinary approach will be applied to tackle both the mechanical modifications and aesthetic transformation so that the resulting design is one that candidates will be pleased to use.

The base-line model (presented in Appendix A.4) will be similar to existing models in its primary function of strong, reliable stabilization, but proudly diverges in all other aspects. This design combines the sturdy frame of a walker with the ease of navigation offered by rollator mobility aids. The first distinct feature I devised for this redesign challenge was the incorporation of spherical rollers, as opposed to wheels of plastic glider accessories, which are currently, utilized modes of smooth motion. In fabricating the prototype I will be using flange-mounted ball transfers[11], including a 1.25" diameter steel ball, within a housing component of black oxidized steel. One foreseen obstacle for this type of roller is cleaning and maintenance for removing particulates that may become trapped within the ball transfer housing. A simple solution for this is to include a slot in the back of the housing with a tang to slide open the chamber and release any dust, dirt, and other foreign particle collection. This emptying action requires the ability to reach and slide the tang component. If the primary user does not wish to call upon another person to assist with this cleaning procedure, they will be able to employ a reaching aid[12] and manipulate the tang from a seated position.

The main frame of the redesigned walker will be fabricated out of anodized aluminum, chosen because it is both a lightweight and extremely durable material. Two frame versions were proposed: quadrupedal and tripedal. The sleek form was initially inspired by the gradual curvature of a bird's furcula[13], along with the visual weight of simplistic furniture pieces. These elements of inspiration were then adapted to suit the scale and arrangement for an adult standing upright and leaning their weight forward. Ultimately I eliminated the tripedal design based on the high probability for interference of the front post

[11] This component can be found in the McMaster-Carr catalog, under Ball Transfers, model No. 5.

[12] Low-technology assistive device that extends the user's scope for clasping and manipulating objects otherwise out of reach. These are sometimes referred to as a grabbers, reachers, or pick-up aids. This device can be considered inclusive design as the benefits of extension and grabbing what was before out-of-reach applies to many different people with and without disabilities.

13 The furcula ("little fork" in Latin) or wishbone is a forked bone found in birds and some other animals, and is formed by the fusion of the two clavicles.

with the user's legs while walking. I also determined that the additional member and four-legged spatial arrangement provides the structure necessary to hold the potential add-on feature of a storage compartment. For the quadrupedal frame each of the four legs contains one flange-mounted ball transfer in contact with the floor, as previously described. For cosmetic purposes the mounting hardware of the ball transfers will be well hidden from view with a stylized cover that is a continuation of the anodized aluminum frame. Also, in the spirit of accommodation, customization, and aesthetics, an array of colors will be available due to the versatility of the anodizing process.[14]

To solve the primary issue of the user-brake trigger interface I have proposed the following modifications. The brakes will be engaged as the model's default state, which is fundamentally similar to reverse brakes of some existing models. However, I have also designed a crossbar, slide-grip system as the interface to control the brakes (a key difference from traditional grips). The crossbar will have one sleeve on either side that disengages the brake when pushed inward towards the midpoint of the crossbar. Each sleeve will have a hilt on the inner edge to support the hand, forearm, prosthesis, or whatever the individual uses to apply a slight force against the sleeves in the axial direction. The cables attached to the sliding sleeves will be hidden within the hollow frame members and will be directly accessible through a slot on the underside of the

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[14] Aluminum anodizing is an electrochemical process in which an oxide (anodic) layer is chemically built on the surface of the metal. This oxide layer acts as an insulator and can be dyed in a wide variety of colors. Anodizing provides surface corrosion protection along with an excellent substrate for decorative finishes.

crossbar member. The sleeves will be spring loaded to return to a parked state when the user is not applying that inward pressure. Spring stiffness will need to be evaluated further once the minimum expected force is determined. Elbow guards will be an optional add-on feature for those users who need to lean their forearms on the frame, to provide comfortable support and a platform from which to press off of to create the inward pushing motion on the crossbar sleeves.

Another distinguishing feature I have proposed for the baseline model is the inclusion of photodiodes[15] that will only illuminate when switched on and in the presence of limited light. Occasions for users needing to safely navigate in darkness include nighttime bathroom trips, power outages, or walking in dimly lit rooms for individuals with low vision. Perhaps for cost reasons, lights are not integral to existing models, but rather are available separately as clip-on flashlight accessories. The lights on my model will be located on the two front legs, approximately 1’ from the floor, illuminating the immediate foreground. In this situation the photodiode will be used as a photo detector and will generate current in the circuit when in direct exposure to light. To avoid one foreseen issue of the lights illuminating in the user’s bedroom while not in use (disturbing the user as they try to sleep) the circuits will be activated with a control switch located near the main crossbeam for easy access. The user will turn the switch to ON as needed and it will be ready to serve in dark situations.

[15] To read more about photodiodes please refer to a brief presentation from UNLV: http://www.physics.unlv.edu/~bill/PHYS483/LED_PIN.pdf. By definition photodiodes are a type of photo detector (meaning that it senses the presence of light) that is capable of converting incident light into either current or voltage, depending upon the mode of operation employed.

Final base-model features to discuss which distinguish this design from existing models are an increased range of heights for the user's initial fitting and an inclined top frame. The hole-and-peg system used in most canes and walkers is simplistic and adequate for achieving the one-time height adjustment that will remain intact for the duration of the individual's use of mobility aid. The main modification for this redesign challenge involves adding more length for both the overlay component and inner lower component of the legs.

Addressing the second named feature, the portion of my model including the crossbar and top-most frame connection will be on a 5° incline from the top of the back legs up to the top of the front legs. This will provide more stability and support for those individuals who lean forward on their forearms, exerting a significant increase in bearing weight.

Computer Aided Design

Designers and engineers utilize powerful object and/or equation driven software to create 3D models that are accurate depictions of the real piece in terms of dimensions, appearance, and material properties. Material properties being integrated into this computer aided design (CAD) is critical for testing how the design will behave under different conditions, before investing time and money into the construction of a physical prototype. Simulations can be run for an array of thermal conditions, mechanical loading schemes, and motion analysis. This study required linear stress analysis, modeling a simple scheme of evenly distributed loading on the forearm rests of the polypropylene top frame. It is important to note that possibilities abound for more complex assemblies and assemblies that the designer anticipates will undergo a high level of wear. In additional to linear stress analysis, packages also include, non-linear stress, plastic and rubber part, finite element, thermal structural, computational fluid dynamics, metal fatigue, frequency, and dynamic analysis.

Translating the form conceived in my mind into several iterations of sketchbook renderings and finally into a computer aided design model was a challenging process. Pulling from my sculptural discipline as well as foundational drafting skills from my Mechanical Engineering curriculum I created two potential frames to compare structural integrity and select a final concept for overall form. The two frames were categorized as (1) Angular Cuts Model and (2) Gradual Curves Model.

The most difficult part of CAD modeling was basing curved slopes of the frame on easily reproducible geometries as a consideration for machine processing down the line during the manufacturing stage. With an inclination to utilize the free-form spline tool for every gradual curvature, it was a real learning experience to restrain from that tendency and instead design for a future stage when other people and machines would be involved with the actual fabrication of these parts.

Running a linear stress analysis for the top frame component required several iterations of design for both the angular model and gradual curved frame. After creating an overall framework with specified dimensions (i.e. distance between the arm rests, distance from the end of the frame to the crossbar, length from the front to back of the top frame, and outer limits of the frame driven by standard doorframe dimensions), determining the wall thickness of the top component was the next dimensional decision to be made. Selecting rotationally molded polypropylene posed a challenge in determining the part's wall thickness, but this was ultimately selected based on similarly fabricated furniture of 0.5" thickness for support. This uniform wall thickness was applied to both frame models for comparison of structure, in the aftermath of the same applied loading scheme.

Figure 3 offers an isometric view of the angular cuts model's basic structural assembly, composed of 6 separate parts. These parts consist of four anodized aluminum legs, one anodized aluminum cross bar, and the main polypropylene top component. All parts are hollow and, except for the polypropylene top component, designed to the appropriate thickness of 13-gauge (0.072 in.) aluminum as the material chosen for the actual fabrication. Crossbar sleeves and hilts, not shown in the CAD model, are to be fabricated out of plastic, using an injection molding process.

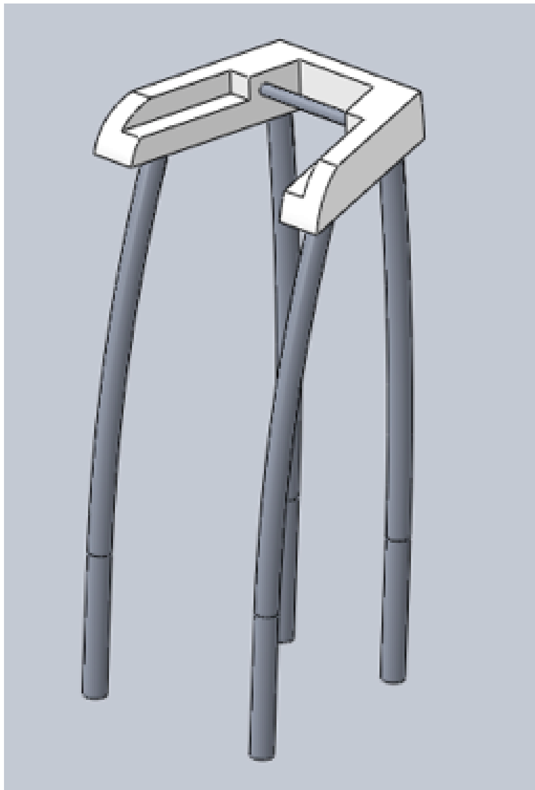


Figure 3

Pictured in Figure 3 is a structural assembly of the angular cuts model, showing four tubular leg components of gradual slope meeting at a top component displayed in white to represent the material polypropylene. The crossbar is also depicted in gray, located at approximately 1/3 from the front, of the full depth of the top component. This angled orientation shows the rear, side, and top views in one snapshot; it is referred to as an isometric

For comparison, the next figure, Figure 4, offers an isometric view of the gradual curves model's basic structure.

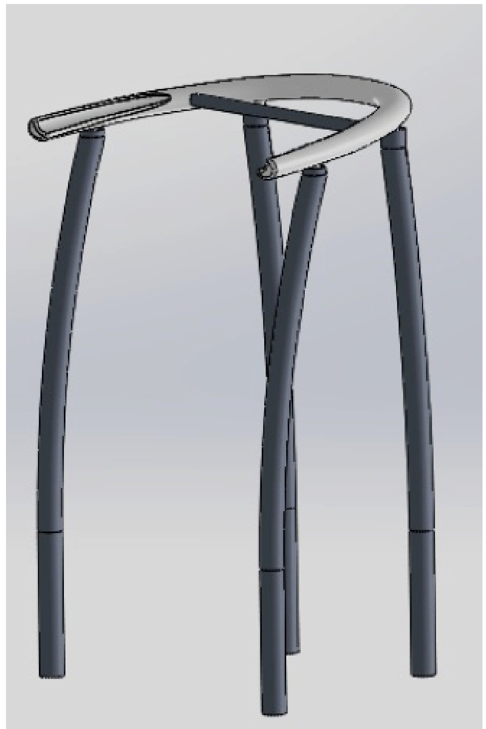
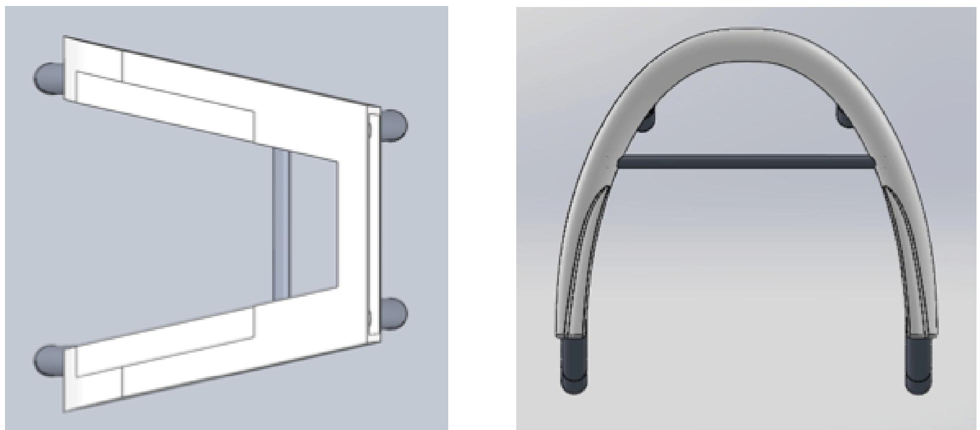


Figure 4

Pictured in Figure 4 is a structural assembly of the gradual curves model, showing four tubular leg components of gradual slope meeting at a top component displayed in white to represent the material polypropylene. The crossbar is also depicted in gray, located about midway along the length of the top component. This angled orientation shows the rear, side, and top views in one snapshot; it is referred to as an isometric view, as explained in the caption from Figure 3.

The next image, Figure 5, provides top view orientations of both models to more clearly show the armrest grooves with elbow support for those who need to bend over to lean fully on their forearms. The depiction helps show crossbar (which will also include brake sleeves in the fabricated model) positioned halfway between the front and back of the top framework, just beyond the armrest grooves. In addition to accommodating leaning individuals described previously, this crossbar placement allows individuals with more upright posture to comfortably navigate the walker with the slightest inward pressure on the sleeve hilts.

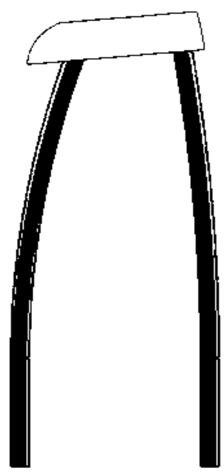


(a.) (b.)

Figure 5

Pictured in Figure 5 are the top views of the angular cuts model (Figure 5.a. on the left hand side) and the gradual curves model (Figure 5.b. on the right hand side). The angular cuts model shows that the top component follows a trapezoidal shape, narrow towards the front, where the crossbar is located 1/3 offset from the front of the frame. Looking down upon the gradual curves model, the top component appears to follow a parabolic curve.

Referring to the side views of both models, seen in Figure 6, there is a 5º tilt to the upper framework which is intended to accommodate both leaning and more upright individuals. For those leaning this will provide a slight upward lift, helping raise the user's gaze and encouraging them to lean without feeling any downward tipping. For those with a straighter spine this upward tilt will lend itself to comfort with a gentle bend in the elbow rather than requiring extended arms or any downward reach that may strain their shoulders while using the walker.



(a.)

(b.)

Figure 6

Pictured in Figure 6 are the side views of the angular cuts model (Figure 6.a. on the left hand side) and the gradual curves model (Figure 6.b. on the right hand side). The profiles look similar, both top components are tilted at 5° from the horizontal, where the placement of the user elbows will be lower than their wrists and hands when leaning into the walker.

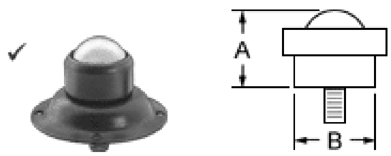
Prototype Construction

While the CAD modeling is necessary for mechanical analysis, I had planned on taking a slightly unconventional approach to prototype construction in that a portion of the project would serve as an outlet for my second area of study, sculpture. Due to my experience in the wood shop and metal shop within the ComArt facility on Syracuse University's campus I have the ability to fabricate a full-scale prototype. Due to my academic and sport team requirements I did not allocate the appropriate time to finish this possible prototype.

Had I finished this is what the process would have been like. As this was intended to be strictly an appearance model from the beginning I was more concerned with translating form than accurate material selection or total function. Pulling from the furniture undertones of the piece I aimed to treat the walker prototype as such when I began to construct the model. Hence, I selected a soft wood to achieve the desired curvature in the forearm rests and because there is less of a time demand with wood than metal for a final polished finish. Pine seemed to be the most viable option because it is readily available at home centers, and as part of the soft woods variety it lends itself to hand carving. Though wood takes less time than metal manipulation, hand carving is a highly time intensive endeavor and I became aware of this midway through the process.

Though I stopped construction during the intermediate stages of arm piece carving, the next phase would have been to incorporate ball transfers, pictured below in Figure 7 from the McMaster-Carr online catalogue, at the base of each leg and then secure legs to the wooden top component.

Stud-Mount Ball Transfers



5

Transfers can be used ball up, ball down, or at an angle, unless noted.

	Ball Dia.	Housing Material	Cap., lbs.	(A)	(B)	Thread Size	Stud Lg.		Each
General Purpose									
Steel Ball									
5	1"	Black-Oxide Steel	150	1 1/2"	2 7/16"	3/8"-16	11/16"	6460K45	$13.08
5	1 1/8"	Black-Oxide Steel	200	1 21/32"	2 7/16"	3/8"-16	11/16"	6460K46	13.90
5	1 1/4"	Black-Oxide Steel	250	1 3/4"	2 7/16"	3/8"-16	11/16"	6460K47	14.57

Figure 7

The objective of this prototype is to demonstrate the form on a realistic scale. In light of this it is not detrimental to the presentation that the members will remain solid, for instance the wooden top component, as opposed to hollow as in true model of anodized aluminum.

As a proof of concept for the lights, which will be integrated into the two front leg members of the design, I had planned to arrange a demonstrative circuit. The circuit would involve a 9V source, four resistors, one light emitting diode (LED), a preset for varying resistance, and one LM339 compactor to show that the LED's illuminate with preset sensitivity in limited light. LED's are expected to last a minimum of 50,000 hours. This long projected operating life implies, that if, hypothetically, an individual were to keep the two LED bulbs on for 1 hour during the night, every night, each year, they would continue to function for 136 years. Even with more frequent use, it will be years before the walker bulbs will need to be replaced.

Manufacturing and Cost Evaluation

Choosing anodized aluminum as the main material for this product and due to defined cross sections of the hollow frame, extrusion is the appropriate choice for manufacturing. Quotes obtained from the Adagio Corporation listed extruded anodized aluminum tubing for $17.50 to produce each unit. This would involve the specified diameter to accommodate ball transfers in a 1.5 in housing, as well as manipulate the tubing into gradual curvature. Four of these per walker unit would come out to $70 before polypropylene fabrication or assembly costs.

As mentioned previously, the top component will be manufactured through the process of rotational molding. Also referred to as the roto-mold or rotocasting process, this manufacturing method involves pouring "powder or liquid resin into a hollow mold and then rotating that tool biaxially in an oven until the resin melts ad coats the inside of the mold cavity"[16]. After these hollow parts are cast the tool is cooled and the part is removed from the mold to finish cooling and solidifying. Some advantages of this fabrication method include design flexibility allowing for the creation of complex geometry, cost savings for

[16] A full guide to the process of design and engineering for rotationally molding plastic parts is provided by the following URL: http://www.theplasticprofessionals.com/rotational-molding/rotational-molding.htm

mass production (50 to 30,000 is considered an ideal range for savings per unit), low tooling costs, shortened time spans between initiation and execution of production, stress free parts, consistent wall thickness, limited materials waste, the allowance for a wide array sizes for hollow parts, and the versatility it allows for different surface textures during the finishing process of manufacturing. In addition to consistent wall thickness, rotationally molded parts can have multi-layered walls made up of different kinds of materials. Looping back to earlier design considerations lining the inter layer with a reinforcement material may further reduce the fractional displacement demonstrated in CAD simulation under linear stressing. Estimated cost for manufacturing the custom part is primarily driven by tooling time and measured volume of polypropylene, but up front costs of mold creation and tooling are relatively low compared to injection molding and other manufacturing processes. Producing a single unit has been priced at $200, based off of SolidWorks files submitted online to The Plastic Professionals[17], however individual unit costs will be considerably less when parts are mass-produced. Should production increase to 100 models, the manufacturing cost per unit would be driven down to approximately $50, not including tooling and mold maintenance.

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[17] The Plastic Professionals Rotational Molding Inc. is a polymer-based manufacturing company located in Iowa. Their website provides information about the process, an array of sample products, and videos on the specialized manufacturing method. The following URL connects to this company’s home page: http://www.theplasticprofessionals.com/home.htm

Chapter 4

Analysis and Results

Stress Analysis

To compare loading capacity of both the angular cuts model and gradual curvature model to requirements of existing standard models, three loading schemes were applied to the frame, assuming an individual weighing 250lbf (the maximum carrying capacity of standard walkers) was applying these loads. The first two loading schemes applied downward forcing to the top frame assuming that the individual would apply forcing with both of their hands, or forearms. Contrarily the third scheme assumed that the individual only had motor control of one upper extremity, and therefore would only apply forcing on one side of the crossbar.

To run a linear stress analysis on the angular cuts model, simulations needed to be run on a component basis, because SolidWorks software does not allow testing on assemblies. The first step to running this type of stress analysis involved establishing fixtures, or locations were the member in question is rigidly fixed and will not be displaced due to applied forcing. The fixtures chosen for this angular cuts model top component included two holes where the crossbar would attach and four holes on the underside of the component where legs would be connected. Then loading, in the form of vectors with a prescribed magnitude and direction. On the top component loading was applied along the forearm grooves in a downward and outward direction simulating a person leaning against the linear supports. With a magnitude of 300lbf total (as a maximum carriage capacity for current walker and rollator models before upgrading to a bariatric model) and the realistic multi-directional range explained above, testing yielded results of twisting and buckling. An early demonstration of deformation under evenly distributed loading can be seen in Figure 8, shown next.

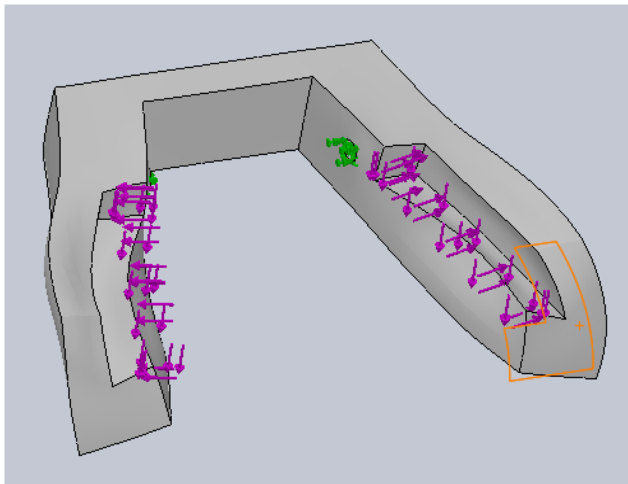


Figure 8

Pictured in Figure 8 is snapshot of a 3D model simulation of the angular walker's top component, made with the computer aided design program called SolidWorks. Green arrows show where fixed positions have been created, for example at the perimeter of the holes where the cross bar is secured to the top component. In addition loads have been applied and have caused the component to bend and twist. These loads are depicted as purple arrows pointing in the direction of a walker user's force, leaning against the top component with their forearms resting in the forearm grooves.

Later iterations of the angular cuts model included more shallow forearm grooves to increase the amount of support material. Simulation demonstrated that the maximum displacement occurred at the midsection of the forearm rests but only reached a magnitude of 2.16e-003 inches. This maximum displacement under maximum loading, of 300lbf total, is negligible. The next, Figure 9, demonstrates displacement results after the final iteration for the angular cuts model was introduced to evenly distributed loading.

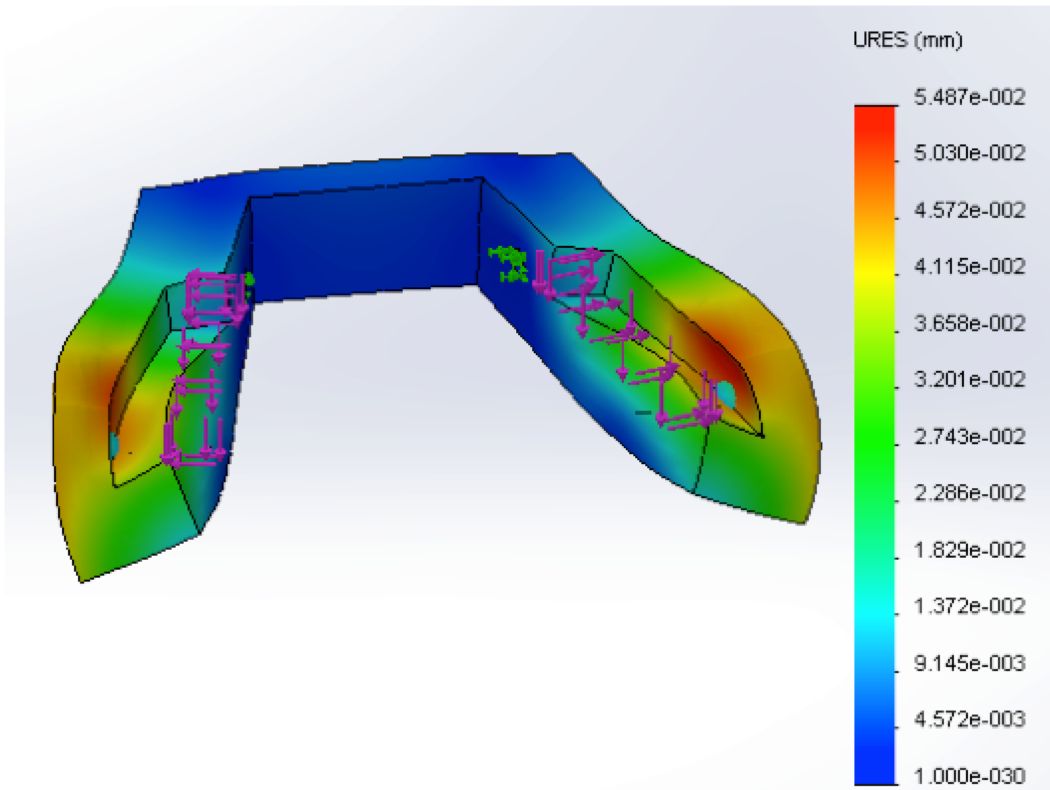


Figure 9

Pictured in Figure 9 is a color-coded gradient of displacement as a result of applied loading on the angular cuts model's top component. The gradient (provided in a legend to the right hand side), ranges from dark blue, representing 3.937e-32 in (1.000e-030 mm), to red, representing 2.160e-003 in (5.487e-002 mm) of displacement.

The first trial run was also the most basic forcing scheme to test. For a maximum loading capacity of 300lbs, two point loads were applied to the left and right sides of the crossbar, each with a downward force of 150lbf. This scheme was applied to both models. Figure 10 displays a wire-frame view showing where point loads have been applied, as well as the displacement results for the gradual curves model. Some assumptions made here include even loading on both sides, and that the individual would not create significant additional loading, beyond that of their body weight. To analyze stresses resulting from other possible cases of walker use within this two-point load scheme, additional trials may be run. This analysis might involve applying unequal percentages of the total loading on either side of the crossbar. For example, an individual recovering from surgery or injury on one lower extremity would tend to favor the unaffected leg and apply unevenly distributed forcing to compensate for lightness on the sensitive leg.

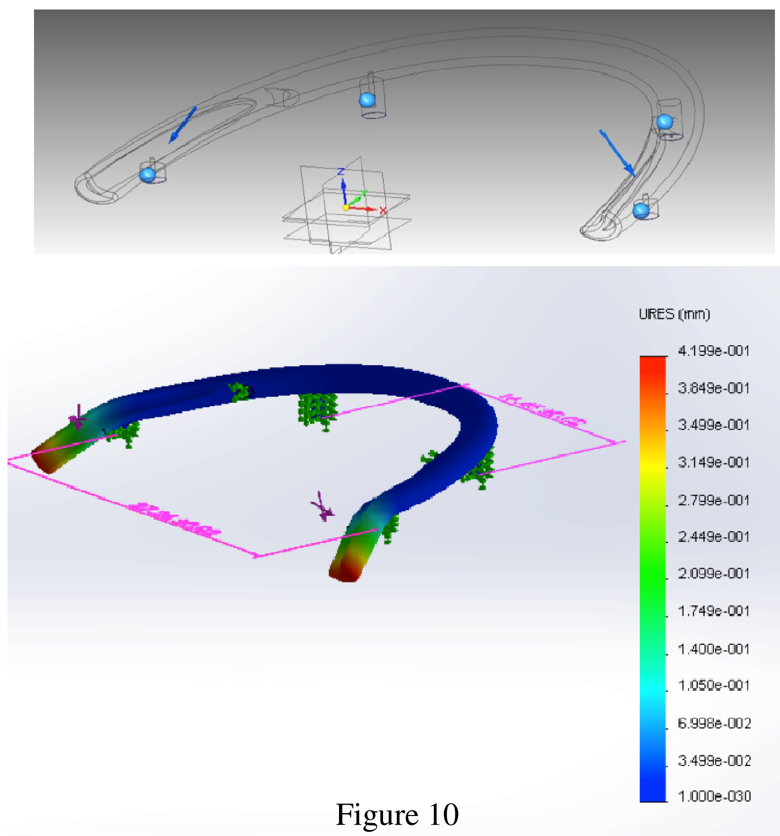


Figure 10

Pictured in Figure 10 are tow images. At the top there is a wire-frame representation of the gradual curves model showing fixtures at the holes where legs would be attached (represented with blue spheres) and two point loads. The bottom image shows displacement results from this point load scheme ranging from 3.937e-005in (1e-003mm) to 1.653e-002in (4.199e-001mm).

The second trial run, shown previously in Figure 9, was repeated for the gradual curves model. To reiterate this involved a distributed loading scheme, which was applied along the armrest grooves. Each armrest groove was subjected to the same 150lbf downward force, as applied previously, but for this trial the load vectors were evenly distributed over a distance of 12" for the full length of the groove.

The final test, applied a point load of 300lbf magnitude to the center of the crossbar in an effort to mimic the forcing of a stroke patient who may only have motor control on one side of their upper extremities.

Results & Considerations

For the first scheme of two 150lbs point loads, the greatest stress occurred midway along the forearm grooves for the angular cuts model, and at the free-ends of the gradual curves model. There is no cause for concern for either of these regions. Maximum deflection at the free ends occurred on the gradual curves model, equal to 1.653e-02 in (4.199e-001mm) which is negligible for this application.

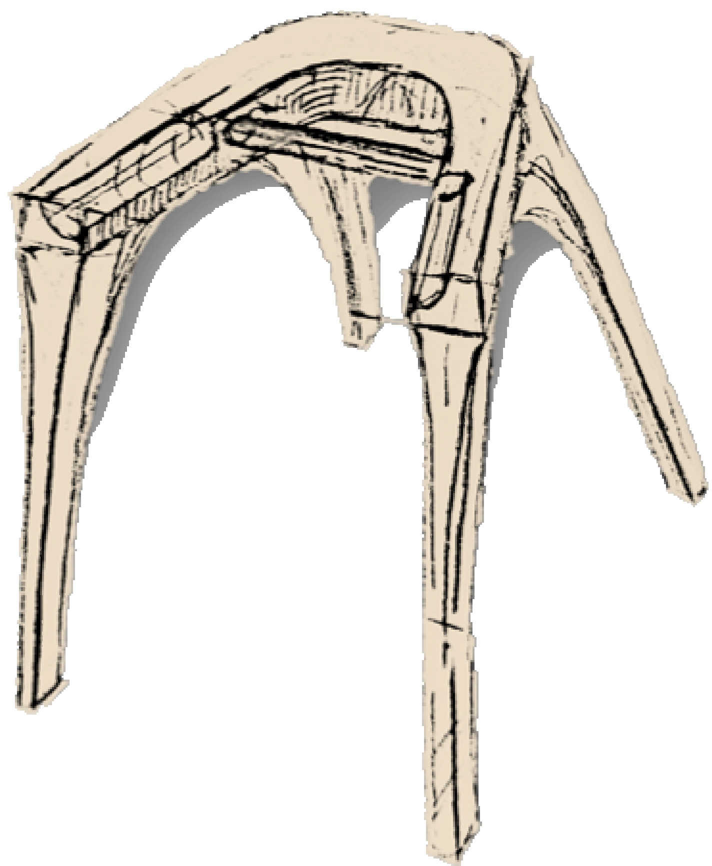
Wall thickness may be increased from 0.5 in with addition material layers or this component can be subjected to hardening processes. Reinforcing this member with aluminum flat bar can prevent deflection and strengthen the top component framework as a whole, allowing load to be distributed across the supportive member rather than concentrated in the current locale.

Chapter 5

Final Concept Selection & Conclusion

Final Concept Selection

Due to successful testing under all three loading schemes for linear stress-strain analysis, the angular cuts model was chosen for the final concept selection. I also believe that, though my preferences draw me to the angular curves model based on visual appeal, I believe that the angular cuts model has the potential a broader appeal.



Concluding Remarks

Overall the process of working through a redesign challenge was one that I enjoyed, as it required input from my various skill sets and interests. Initial concept generation was one of the most thought intensive tasks because there were so many facets I tried to consider: alternative brake systems, overall adaptability, and overall accessibility in terms of pricing (affected by material selection and manufacturing processes) and appeal. The most difficult part of the process was translating 2D sketches into 3D models and choosing what the basic frame assembly would consist of without focusing on the end product's overall aesthetic. The fundamental frame and top component is what needed to be tested, without the subtleties of design that require additional material and machining.

I believe there is certainly more work to be done with this project and plan to continue working with CAD software to better represent the full model and complete internal system. Someday I will file for a patent, as it has become a long-term life goal.

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Appendices

A. 1 Glossary of Terms

Aesthetics – a set of principles concerned with the nature and appreciation of beauty, esp. in art

Amputation - the removal of an appendage from the body

Cerebal Palsy - a disability resulting from damage to the brain before, during, or shortly after birth and outwardly manifested by muscular incoordination and speech disturbances

Friederich's Ataxia - an inherited disease that damages a person's nervous system. The damage affects the spinal cord and nerves that control muscle movement in the person's arms and legs. Symptoms usually begin between the ages of 5 and 15. The main symptom, called ataxia, is having trouble coordinating movements. Specific symptoms include difficulty walking, muscle weakness, speech problems, involuntary eye movements, scoliosis (curving of the spine to one side), and heart palpitation from the heart disease, which can happen along with Fridreich's ataxia. People with Friedreich's ataxia usually need a wheelchair 15 to 20 years after symptoms first appear.

Hemiparesis - muscular weakness or partial paralysis restricted to one side of the body

Isometric – (in technical or architectural drawing) incorporating a method of showing projection or perspective in which the three principle dimensions are represented by three axes 120° apart

Muscular Dystrophy - a group of muscle diseases that weaken the musculoskeletal system and hamper locomotion. Muscular dystrophies are characterized by progressive skeletal muscle weakness, defects in muscle proteins, and the death of muscle cells and tissue.

Multiple Sclerosis - a nervous system disease that affects the brain and spinal cord. The material that surrounds and protects nerve cells becomes damaged. This damage slows down or blocks messages between the brain and body, leading to the symptoms of MS. They can include visual disturbances, muscle weakness, trouble with coordination and balance, sensations such as numbness, prickling, or “pins and needles”, and thinking and memory problems.

Psoriatic Arthritis - a skin disease that causes itchy or sore patches of thick, red skin with silvery scales. These usually appear on elbows, knees, scalp, back, face, palms and feet. Psoriasis arthritis causes pain, stiffness, and swelling of the joints. It is often mild, but can sometimes be serious and affect many joints.

Rheumatoid Arthritis - a form of arthritis that causes pain, swelling, stiffness and loss of function in joints. It can affect any joint but is common in the wrist and fingers.

Rollator - also called wheeled walker, invented by the Swede Aina Wifalk in 1978. The device consists of a frame with three or four large wheels, handlebars and a built-in seat, which allows the user to stop and rest when needed. Rollators are also often equipped with a shopping basket and are typically more sophisticated than conventional walkers with rear wheels.

Spina Bifida - a developmental congenital disorder caused by the incomplete closing of the embryonic neural tube. Some vertebrae overlying the spinal cord are not fully formed and remain unfused and open. If the opening is large enough, this allows a portion of the spinal cord to protrude through the opening in the bones. There may or may not be a fluid-filled sac surrounding the spinal cord. Other neural tube defects include anencephaly, a condition in which the portion of the neural tube that will become the cerebrum does not close, and encephalocele, which results when other parts of the brain remain unfused.

Stress Analysis – an engineering discipline covering methods to determine the stresses and strains in materials and structures subjected to forces and loads

Stroke - sometimes referred to as a cerebrovascular accident (CVA), is the rapid loss of brain function due to disturbance in the blood supply to the brain. This can be due to ischemia (lack of blood flow) caused by blockage (thrombosis, arterial embolism), or a hemorrhage. As a result, the affected area of the brain cannot function, which might result in an inability to move one or more limbs on one side of the body, inability to understand or formulate speech, or an inability to see one side of the visual field.

Traumatic Brain Injury – (according to Mayo Clinic staff) occurs when an external mechanical force causes brain dysfunction. TBI usually results from a violent blow or jolt to the head or body. Mild traumatic brain injury may cause temporary dysfunction of brain cells while more serious traumatic brain injury can result in bruising, torn tissues, bleeding and other physical damage to the brain that can result in long-term complications or death.

Universal Design – broad-spectrum ideas meant to produce buildings, products and environments that are inherently accessible to older people, people without disabilities, or people with disabilities

A.2 Survey

Capstone Topic:
Re-designing the Walker

1. If given the opportunity, would you be interested in improving the form and function of your mobility aid?

Yes
No
I am not sure.

Let's weigh the pros and cons of existing models.

2. To begin, what words come to mind when you think of your walker? (Please choose any and all that apply)

- o stability
- o life-saver
- o independence
- o durability
- o aging
- o rehabilitation
- o medical
- o dependence
- o industrial
- o tennis balls
- o other

3. If "Other" which words come to your mind?

4. What are some of the things you (1) like and (2) dislike about your walker?

Likes ___________________________________

Dislikes ___________________________________

5. Please number the following features in order of benefit, based on your personal experience:

- seat
- storage compartment(s)
- alert system
- lights (for nighttime navigation)
- storability
- comfortable grip
- arthritis-friendly brake system
- streamlined design
- ability to adapt to (and ease) stair navigation

6. What other features might you add to your walker?

7. Under what conditions and in what places is it most difficult to navigate with your walker?

Looking to gauge your initial response to needing a mobility aid.

8. Did your doctor recommend the use of a walker?

Yes
Not by a doctor, but instead:
____

9. Were you initially reluctant to use a walker?

Yes
No
If so, why?
____
____

Form Meets Function

10. If someone gave you the option, would you choose to improve the look and feel of your walker (without sacrificing the structural integrity)?

Yes
No

Additional thoughts:
____
____
____

Thank you! Your input is greatly appreciated.

If you would like to check in for updates on this Capstone project you may contact me at: **curcio.gi@gmail.com**

A.3 CAD Model Images

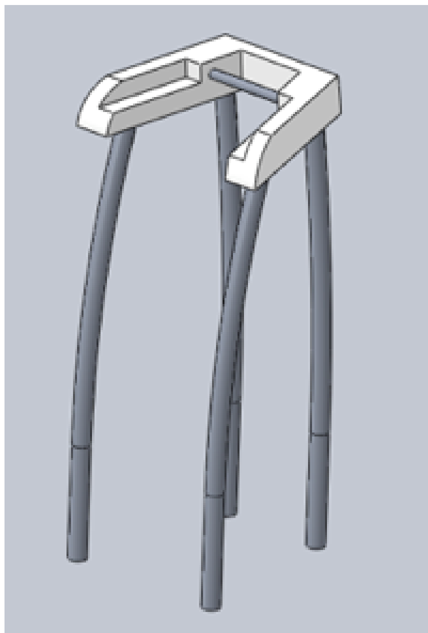
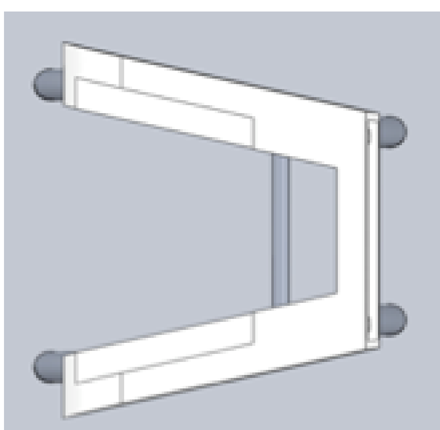


Figure 3

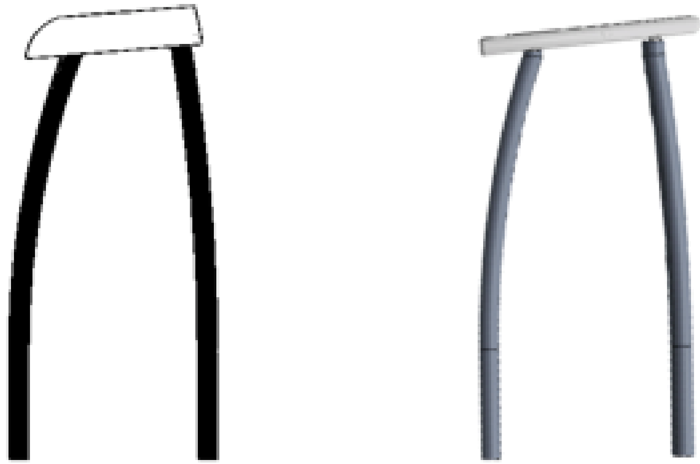
Figure 4



a.

b.

Figure 5



a. b.

Figure 6

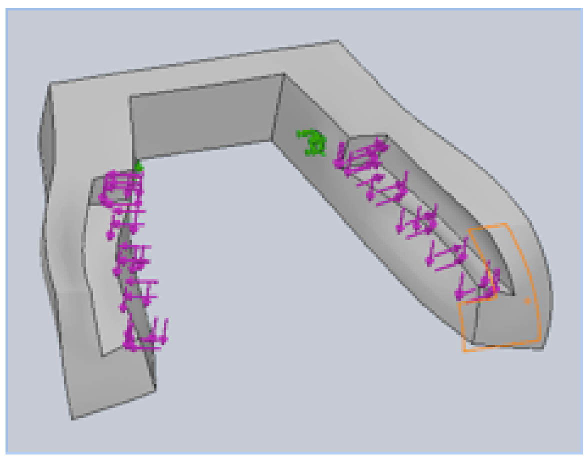


Figure 8

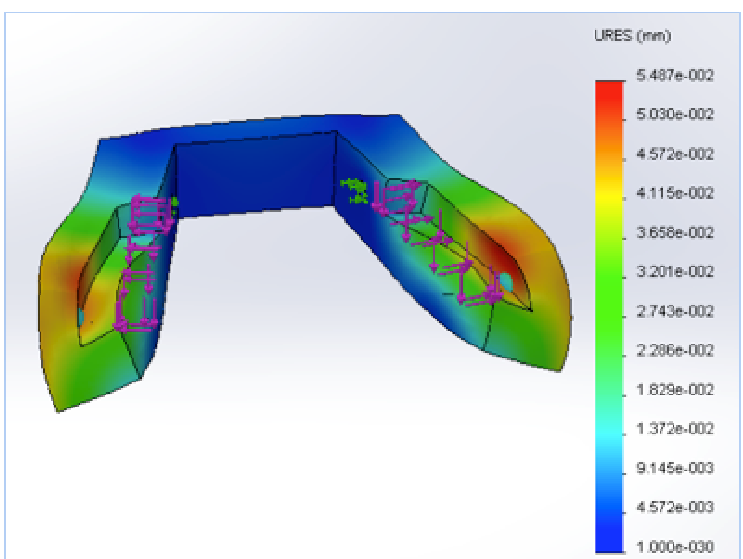
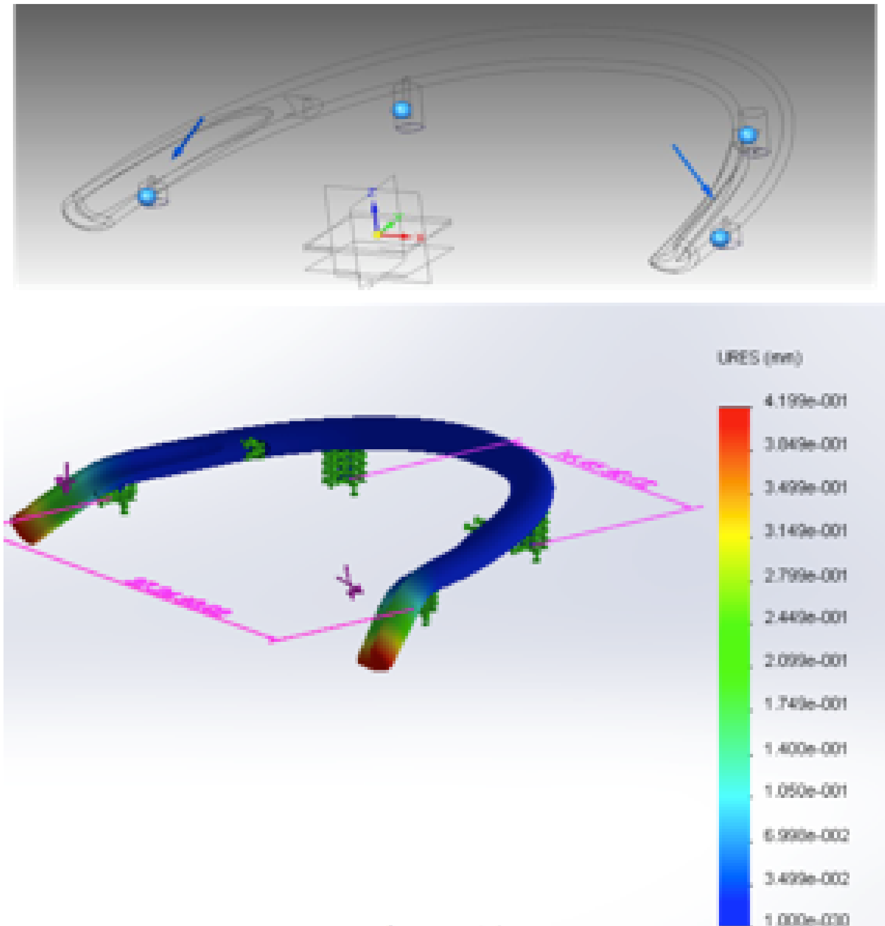


Figure 9



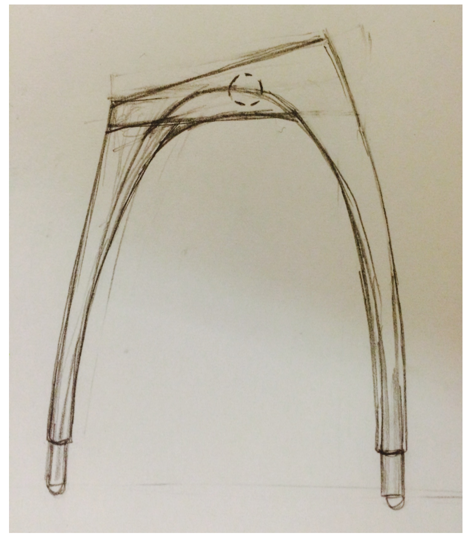
URES (mm)
4.199e-001
3.849e-001
3.499e-001
3.149e-001
2.799e-001
2.449e-001
2.099e-001
1.749e-001
1.400e-001
1.050e-001
6.998e-002
3.499e-002
1.000e-030

Figure 10

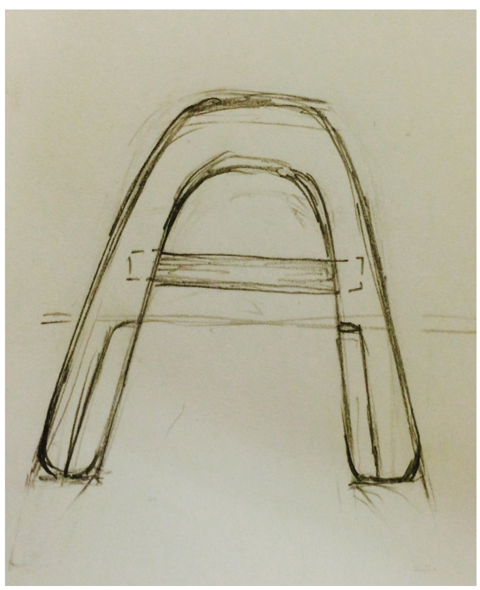
A.4 Prototype Images

Sketches

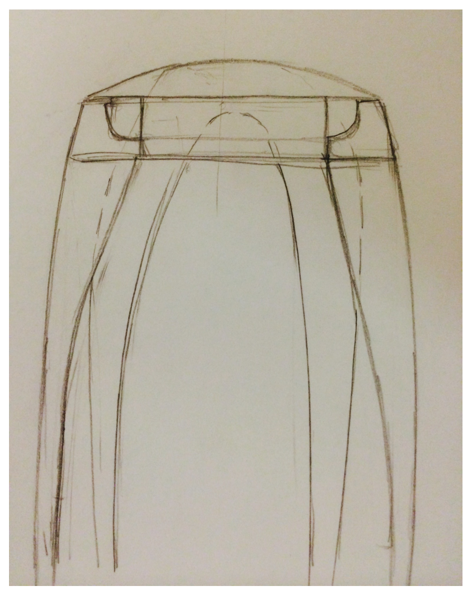
Isometric View



Side View

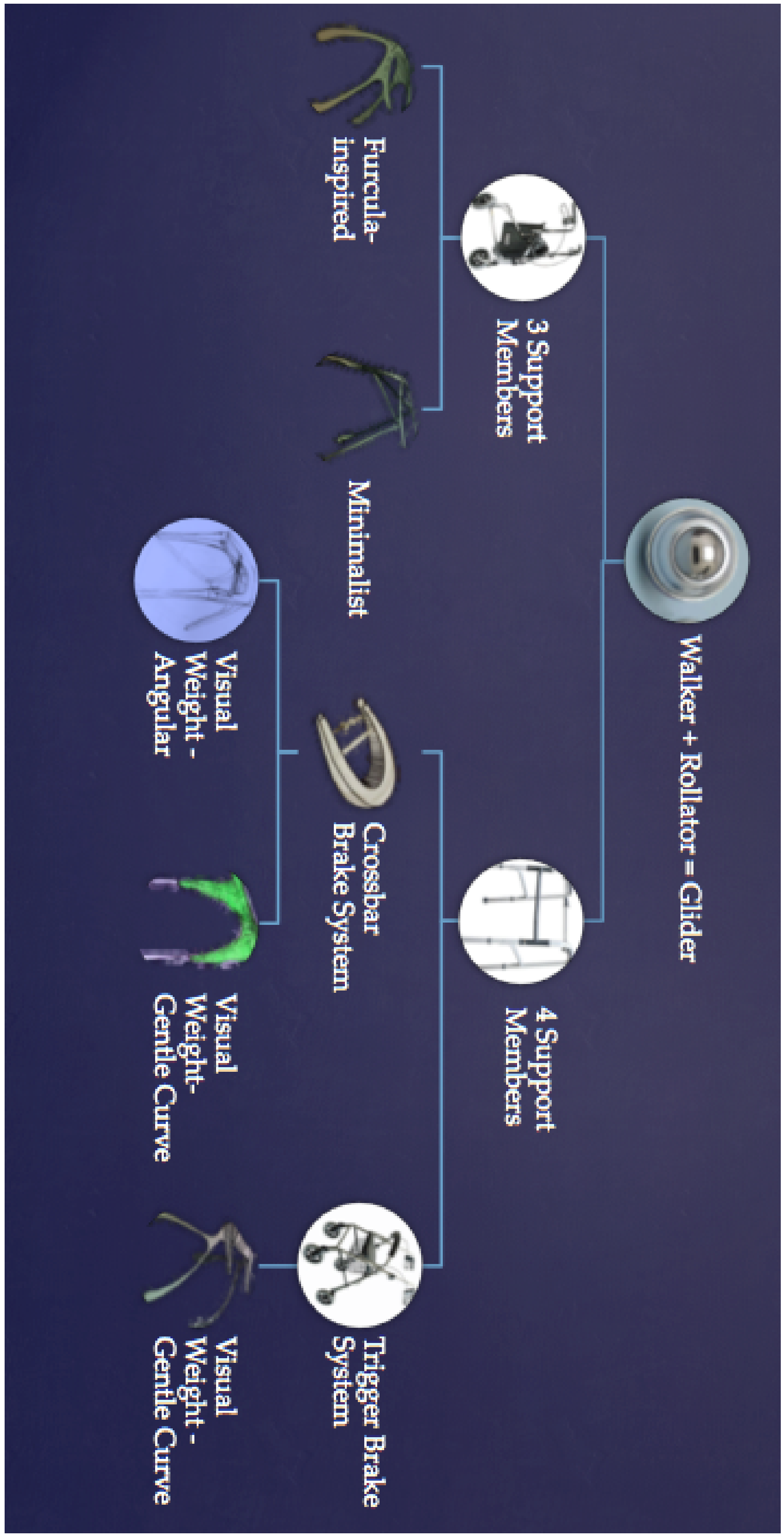


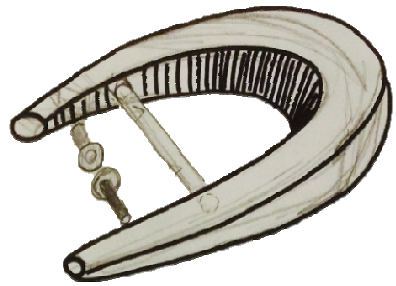
Top View



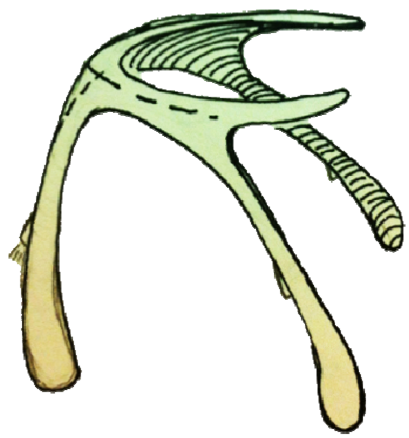
Front View

A.5 Design Process & Concept Generation



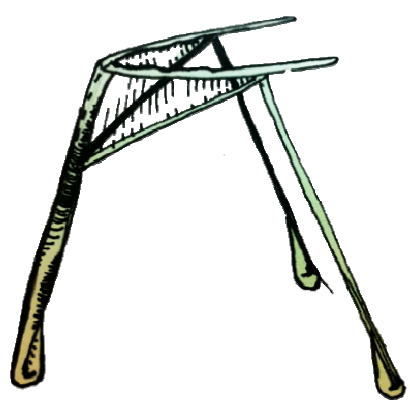


- Crossbar system
- Plastic sleeves/hilts

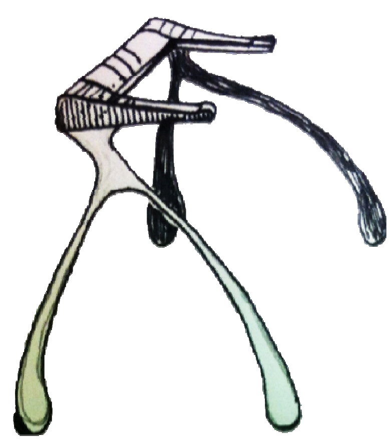


- 3 Legs
- Gradual Curves
- No crossbar

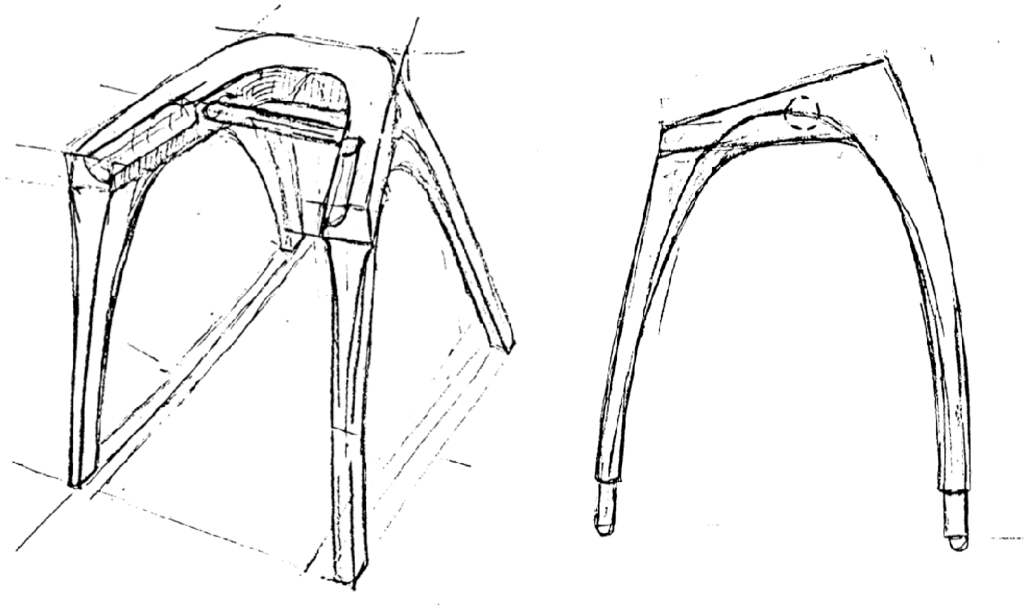
- 4 Legs
- Gradual Curves
- Crossbar system
- Default brake



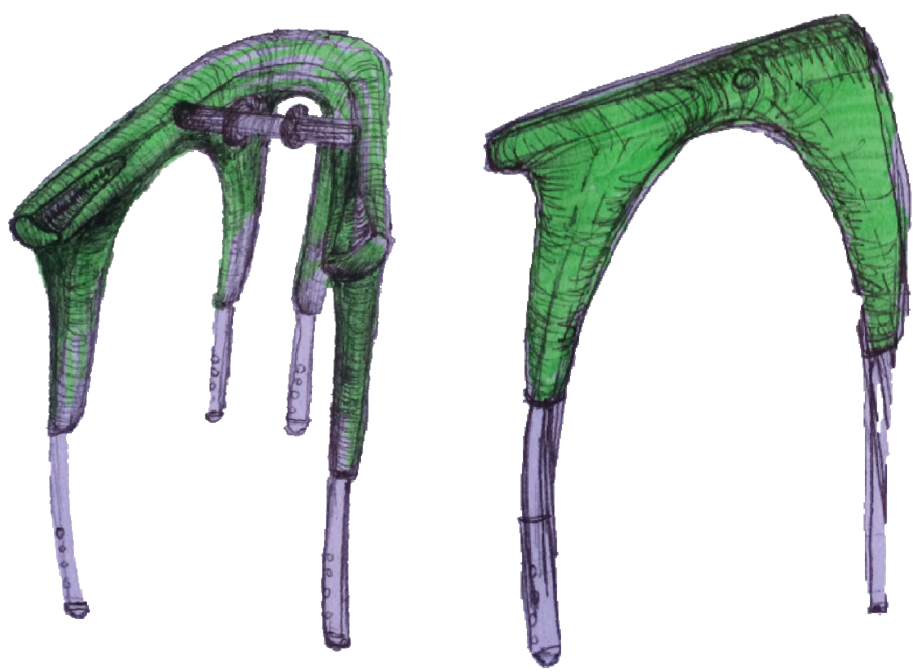
- 3 Legs
- Minimalist
- No crossbar
- Visual weight in base



- 4 Legs
- Minimalist
- Crossbar system
- Default brake



- 4 Legs
- Crossbar
- Default Brake
- Angular Cuts Model



- 4 Legs
- Crossbar
- Default Brake
- Gradual Curves Model