EDNS 151 Final Report

Team 4

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EDNS Section V

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1.3 Introduction

1.3.1 Background

Due to decreasing fertility rates and increased life expectancy, the world's population is steadily aging. Our team was tasked with designing a product that could be used to meet the needs of this aging population. After completing the brainstorming and stakeholder engagement process to build empathy, our team decided to focus on the issue of decreased mobility in older generations and the risk factor of falling that accompanies this problem. According to the article *Practical Neurology*, "The risk of falling increases with age: about one third of those over 65 years of age fall at least once a year, and about half of them even more often" [1]. Individuals older than 65 represent about 16% of the population in America, equating to about 54.1 million people. This number will only grow in the future, as life expectancy continues to rise. Additionally, aging is an unavoidable situation that most will experience during their lifetime. Because of this vast demographic and the relentless need for solutions to this issue, this is a valid problem that must be addressed.

1.3.2 Team Problem Definition

After the initial round of stakeholder interviews and research, this problem definition could be asked: "How would we look into the issue of deaths and injuries caused by accidents when it comes to the aging population, especially movement-based ones?". We will look further into this topic and report accordingly.

1.3.3 Context

Stemming from the problem definition, we reached out to various stakeholders to gather data and point us in the right direction. According to the CDC, in 2019, falls among adults who are older than 65 years caused 34000 deaths, making it the leading cause of death for that group[?]. Why does this happen? One of the biggest factors is the gradual muscle deterioration of people of age. They will start to lose balance due to their leg muscles not being as proficient as before, and the deterioration of the eyesight can be a crucial factor as well. While the world has improved with healthcare and tools to prevent falls, many lives being claimed by falls are still substantial and need to be addressed.

However, the stakeholders do not have to stop at people of age. We can think about people who are injured, visually impaired, or people with disabilities that can prevent them from maintaining a good balance and being prone to falls.

1.3.4 Existing Solutions

Mobility and safety amongst the elderly have always been a major concern for stakeholders. Falls are an unfortunate reality and lead to 3 million elderly people ending up seeking emergency assistance due to these falls. Falls can happen in any situation, whether they are walking up the stairs or shoveling snow. These falls often result in a hip fracture or head trauma. The severity of the dangers of falls has resulted in hundreds of anti-fall products being released. Canes and walkers are the most common means of prevention and life alert buttons can be worn in case of a fall to allow the wearer to contact medical personnel. Even with these precautions in place, many elderly people refuse to use the products in place, or the products simply do not work to the desired effect. Even with a walker, many elderly people still fall, and life alert will only work if the fall victim is awake to press the button. Our goal as a team is to develop a product that will successfully reduce the number of emergency room visits every year due to falls. This product will better the quality of life for the elderly as they will no longer live in fear of a fall and have greater mobility when moving.

1.3.5 Ancillary Issues

An important aspect of considering the issues that the aging population face are the ancillary issues. According to an article from the University of Minnesota, some of the most significant problems that older people face in everyday life are social isolation, along with healthcare and health issues. They indicated from another study that about 50% of all elderly not living in nursing homes have arthritis, while 56% have high blood pressure and that roughly 32% struggle with heart disease, etc. [2] Despite the fact that a lot of the elderly have access to Medicare, insurance usually doesn't pay all their costs, which can make it harder for them to access healthcare, given the high costs. Another issue that the elderly usually face is also social isolation, as they usually live alone and find it harder to reach out to others, either due to the lack of mobility or their environment.

1.4 Stakeholder Outreach/Problem Validation

- Tulga Javkhlan – in person interview (3 points), in person interview (3 points), in person interview (3 points), and scholarly article (1 point)
- 10 points
- Megan Meehan- 5 stakeholder interviews (2 points), 1 subject matter expert interview, off campus (5 points),
- Anne Marie Covlin – Two in person interviews (3 points each), two video chat interviews (2 points each), one scholarly article (1 point)
- Jalen Perkins- 2 documentaries > 30min (2 points ea.), scholarly article (1 point), simulated experience (3 points)
- Iseah Hasan- Videos containing user-experiences (0.5 points each), scholarly/authoritative articles (1 point each)

Group References

[1] Practical Neurology 2007; **7** 139-139 Published Online First: 21 May 2007.

https://pn.bmj.com/content/7/3/158.short

[2] "6.5 problems facing older Americans," *Social Problems*, 25-Mar-2016. [Online]. Available: https://open.lib.umn.edu/socialproblems/chapter/6-5-problems-facing-older-americans-2/#:~:text=The%20US%20elderly%20experience%20several,home%20residents%20is%20fairly%20common. [Accessed: 01-Mar-2022].

1.5 Individual Sections

Author: Megan Meehan

1.5.1- Summary

The first interview that I conducted was with Jennifer Marron and her husband, John Marron. Jennifer (age 49) is a director at Webster Bank and John (age 52) was a former IT consultant but is currently out of work on disability. Jennifer's major concerns regarding aging are the financial and social aspects. She worries about inflation affecting her retirement plans as prices rise. The social aspect of aging also worries her as she and her husband are already housebound due to his disability and immunocompromise. She worries that aging will make their isolation worse as she will no longer be able to go on outings to work or the store with decreasing mobility. John is also prone to fall, resulting in his disability and making it so mobility is more difficult for him than most.

The second interview was with Eamon Meehan (age 73). Eamon expressed concerns about decreasing mobility and balance issues. Like John Marron, he is prone to fall, resulting in many shoulder injuries. He also expressed concerns about the cold. He said that the cold itself affects him more and the ice has proven to be dangerous. Aches and pain in his lower back were another issue that he is currently experiencing.

The third interview was with Daria Gregg (age 75). She is currently experiencing macular degeneration. This will result in her going blind over time. She has noticed a slower reaction time, decreasing strength and longer recovery time for injuries. One of her greatest fears is being unable to walk. She also worries that she may outlive her money and be forced to rely on her children for support.

The fourth interview was with Eileen Meehan (age 73). She fell a few months ago in her front yard and broke 3 ribs. She has noticed that her recovery time has increased. Her loss of balance and slow reaction time resulted in this fall. She worries about being dependent in the future and being immobile. As time goes on, she sees how her family has less trust in her ability to care for herself and maintain her own safety.

The final interview was with Ita Dempsey who worked as a registered nurse at Swedish Medical Center. She described how the body will naturally deteriorate as a person ages. This includes how arthritis sets, making mobility increasingly difficult. She explained how the most common injuries she has seen in the elderly have been a result of falls. Some of the most common fall injuries are broken hips or cracked ribs. Head trauma and broken arms are also common. For the elderly, these injuries may never fully go away, as recovery time is much longer.

1.5.2- Remaining Unknowns

There are still many unknowns regarding the prevention of falls. It is impossible to physically cure aging, but we can develop a means to make mobility easier and safer. We are still trying to figure out if products would make a bigger difference in prevention or reaction. With prevention, we could stop injuries from ever occurring, but it would be very difficult to create a failproof system. With reaction, we could ensure a much more reliable way of treating injuries and helping the elderly get help when something goes wrong much faster.

1.5.3- Individual Bibliography

[3] J. Marron, private communication, February 2022

[4] J. Marron, private communication, February 2022

[5] E. Meehan, private communication, February 2022

[6] E. Meehan, private communication, February 2022

[7] D. Gregg, private communication, February 2022

[8] I. Dempsey, private communication, February 2022

Author: Anne Marie Covlin

1.5.4- Summary

For my first stakeholder engagement, I interviewed my friend Nicole Cuevas (via Facetime) on February 4th, 2022 [9]. Nicole is 19 years old and has worked at the assisted living center Touchmark in Bend, Oregon since 2018, seeing first-hand the issues facing older generations. When asked what she believed was the most pressing issue facing older generations, Cuevas heavily emphasized the fact that old people are constantly cold. “We were always told that old people are always cold, but I don’t think very many of us realize that this is true. It’ll be

80 degrees outside, and I'll walk into a resident's room to deliver their dinner and it's like I'm walking into a sauna! They have the thermostat cranked at full volume still!" Cuevas mentioned that she is particularly concerned about their cold hands. "They can always stick their feet in a pair of slippers or wrap themselves in a thick jacket, but their hands need to remain open and mobile so they can carry out their everyday tasks." Although Cuevas is only an observer of issues faced by older generations, her input was very helpful in forming an initial idea of what aging feels like and I was able to begin building empathy.

Following my stakeholder interview with Cuevas, I was put into contact with one of her residents at Touchmark: David Mooney [10]. David Mooney is a 76-year-old senior citizen living in the retirement home Touchmark in Bend, Oregon. Mooney has been living in Touchmark since 2020, just before the COVID-19 pandemic swept through America. The intent of the interview was to build empathy, and discover what Mooney believes to be some of the major issues facing an older population today. According to Mooney, his children insisted he move to an assisted-living retirement home because he "began showing signs of dementia, which led to him forgetting to take his medication or forgetting to do everyday tasks like feeding his dog". In addition to issues with memory, Mooney believes that loneliness is often a prominent issue in older generations. He feels his sense of freedom is diminished by his age in that he is unable to do things he used to take for granted, like comfortably walking his dog or driving to visit friends or family every weekend. This interview was very helpful in that I was able to hear first-hand issues older generations face every day, rather than hear from an outside observer or through online articles.

On February 6th, 2022, I held a joint interview with family friends Kathleen [11] and Bob Burtchaell [12] (in-person) to hear their thoughts on issues pertaining to an older population. Bob and Kathleen are both 79 years old and live in their house unassisted by caretakers. Bob has worked as a private investigator for the last 46 years, and feels his work is mostly unaffected by his age besides his lack of knowledge pertaining to new technology like computers [12]. He was never taught to type properly on a keyboard, so his work is often very slow. His arthritis makes taking notes on paper equally difficult however, so he is uncertain how his age will affect his work as he continues to age, and his arthritis worsens. Kathleen works as "a full-time housewife", tending to the garden and taking care of the house [11]. She noted that trimming the undergrowth or hedges in the garden has become increasingly difficult in the past few years, as she both "lacks the energy to tend to these issues and struggles with her balance, so bending down to trim undergrowth can put [her] at risk of falling". Kathleen's issues with balance also pose a threat when walking their dog, Lacey. "Lacey likes to pull, so when walking her, I often feel like every squirrel we pass could be the start of something terrible". When asked why she does not just ask one of her several grandchildren to walk Lacey instead, Kathleen replied that she "looks forward to these walks as it gives me an opportunity to get some fresh air and exercise, which helps me feel accomplished and keeps me mobile". These interviews provided another viewpoint on the issues faced by older generations that maybe aren't as obvious to younger generations.

Following my interview with stakeholder Kathleen Burtchaell, I decided to do more research on why older people are particularly prone to balance issues and falls. This article explains the severity of falling and the compounding effects elderly falls have on the emergency response and healthcare systems. According to the article, “Falls in the elderly are a major health problem, first and foremost for the affected individuals whose quality of life is markedly reduced, and also for the public health system because of the immense costs associated with falls and the resultant injuries.” Severe falls often require financial assistance from insurance companies and can potentially lead to lasting physical injuries. Furthermore, “The risk of falls increases with age: about one third of those over 65 years of age fall at least once a year, and about half of them even more often.” With life expectancy steadily increasing, the issue of elderly people falling becomes even more severe, and we must account for this as we as engineers design the future.

1.5.5- Remaining Unknowns

One of the biggest unknowns that remains is what exactly causes older people to struggle with their balance. If the issue mostly stems from a biological stance, like problems with the fluids in the inner ear, we might want to design something medically geared or a procedure, which is way beyond our scope of knowledge. However, if their balance problems are rooted in physical problems like posture or weakened muscles, we could easily engineer some contraption to manipulate movements.

1.5.6- Individual Bibliography

[9] N. Cuevas, private communication, Feb 2022.

[10] D. Mooney, private communication, Feb 2022.

[11] K. Burtchaell, private communication, Feb 2022.

[12] B. Burtchaell, private communication, Feb 2022.

[13] *Practical Neurology* 2007; **7** 139-139 Published Online First: 21 May 2007.

https://pn.bmj.com/content/7/3/158.short

Author: Jalen Perkins

1.5.7- Summary

I watched a documentary about how society changes as the number of people who are past the traditional retirement age increases, and what problems can arise from that. The main cause of many of the problems that the documentary discussed was rooted in the problem that a lot of the infrastructure and how our society functions in general was designed when the average life expectancy was 63. Now that the current life expectancy is closer to 78, we find ourselves in a situation where most people are living well past the age that our current system was designed for. This can easily be seen in the design of suburbs, which were designed for young couples who would then have children. What was not planned for was what happens after their kids eventually graduate high school and they’re left by themselves and eventually become isolated. They will eventually reach the age where they stop driving and are find themselves stuck in their

homes because there is a lack of public transport and since the suburbs were designed as these dense clusters of homes to be accessed by car, they become physically isolated. There eventually comes a time when they also become emotionally isolated as they can no longer drive themselves anywhere and their communities slowly get replaced by younger and younger people.

I watched a second documentary about how the brain changes as it ages. The documentary discussed data sets that showed an increase in some of the brain's functions as well as an increase in others as people aged from their 20s to 80s. The data showed a steady decline in processing speed, executive function, episodic memory, and working memory. The decrease in processing speed can be associated with a decrease in problem solving capabilities. Executive function refers to a set of skills associated with the ability to manage oneself, such as the ability to plan, prioritize, and self-regulate. The data also showed that proficiency in skills associated with semantic memory, implicit memory and procedural memory either stayed constant or improved as people aged. Semantic memory, which is associated with the memorization of simple facts such as the meaning of words, was shown to increase as people aged simply because they have more experience. Implicit memory which is associated with the ability to recall recently processed information did not seem to decline in the older age groups. Similarly, procedural memory, which is associated with what is often called muscle memory, involves skills like playing an instrument or speaking a language, did not see a decline in older age groups. Overall, these changes can be summarized as having a decrease in fluid intelligence, which is associated with the ability to process new information and solve novel problems, and an increase in crystalized intelligence, which is associated with the ability to process and solve problems related to information that has already been memorized.

I also read an article that discussed the problem of the lack of public transportation outside of large cities in America, which is where a lot of the older population lives. Which leaves a generous portion of the population without a reliable form of transportation if they do not have a car. This leads to a reliance on other people to do basic things such as getting groceries or driving to doctors' appointments.

I did a simulated experience at Safeway where I did my grocery shopping using one of the motorized carts. Overall, the experience was bad, I found it difficult to maneuver the cart through the aisles and grabbing things off shelves that were above or below eye level was extremely difficult as well was it difficult to find things that I did not previously know the location of (granted I already experience some difficulty with that). Something interesting that I experienced was that I was unable to see around corners to avoid running into people.

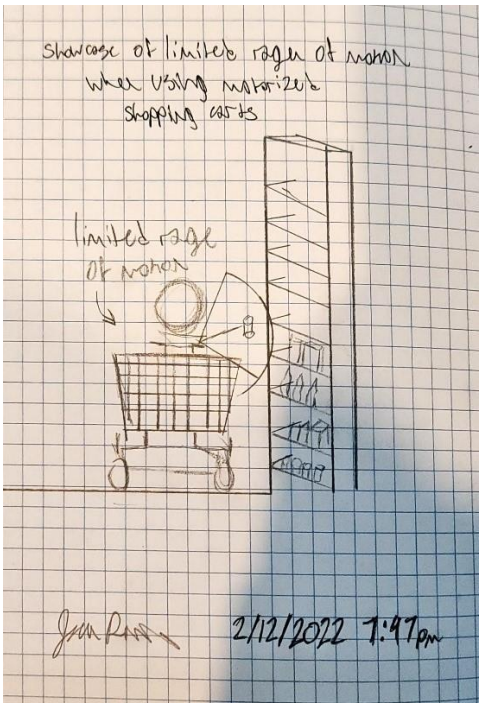


Figure 1: visualization of the difficulty of reaching the upper and lower shelves when using the motorized shopping carts

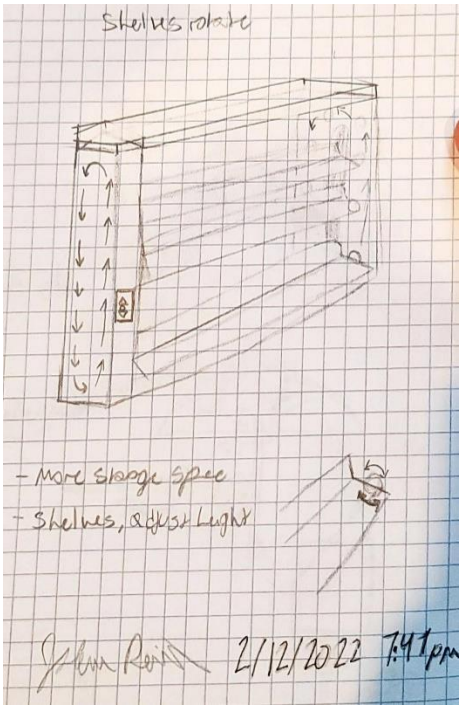


Figure 2: diagram of my idea for rotating shelves

1.5.8- Remaining Unknowns

An unknown thing on the rotating shelf is how it may be implemented in existing stores. Existing stores may not be inclined to install the shelves in their stores as this may not be a priority for them. Another unknown is how the shelves would work for commercial use versus home use. For example, for home use it would be better to have an attached control of some sort so the user can move the shelves to the desired position, however in a commercial setting this approach would create an issue were you would have multiple people looking at the same shelving unit and wanting things on various parts of the shelf. Another issue would arise if the shelves are stationary by default then it may become difficult to find a specific item.

1.5.9- Individual Bibliography

[14] D. Lin and J. Cui, "Transport and Mobility Needs for an Ageing Society from a Policy Perspective: Review and Implications," International journal of environmental research and public health, vol. 18, no. 22, p. 11802–, 2021, doi: 10.3390/ijerph182211802.
[15] C. Herbes-Sommers, San Francisco, California, USA. Coming of Age in Aging America, (2018).

[16] San Francisco, California, USA. The Aging Mind: What Changes?, (2017).

Author: Tulga Javkhlan

1.5.10- Summary

The first part of my stakeholder was a talk my relative that lives in Washington D.C. His insight got me thinking about the culture towards the aging population in the US. His name is TJ, and we are both originally born in Mongolia. The culture towards the aging population is different than here in the US. Since the universities that people attend are within walking distance of the capital, college students will usually live with their parents, therefore keeping them company. However, in the US, it is culturally acceptable to "abandon" your parents or family by going to a location far away to pursue education. It is obvious that college students will see their family again, but often their relationship does not get close to how they were before. That got me thinking about the loneliness and the lack of social activity that the aging population faces. (In person interview, 3 points)

The second part of my stakeholder was a talk with my friend's mother who graduated with a psychology major and has been an Occupational Therapist for 6 years. Her occupation revolves around talking to older people to make sure their daily needs are taken care of. There have been many new technological "advances" that made day to day life easier than it was before, such as the grabber tool, and sock aid. Additionally, the weight threshold has increased and day to day needs. The integration of technology into old people's lives is immensely helpful. (In person interview, 3 points)

The third part of my stakeholder was a talk with Scott Houser, who is an Economics professor here at Mines. The technological advancement of communication revolutionized the way people interact from a distance. He also feels like we can do even more for the aging population. The participation of the older population in the technological advancement wave is underestimated, and they are willing to try if their life improved due to it. If they wanted to, they would adapt. (In person interview, 3 points)

The fourth portion of my stakeholder was an article about the lack of physical activity in the aging population. The article talks about the theoretical presence of physical activity in someone of the aging population could prolong their life expectancy. Additionally, the lack of physical activity can increase the risk of injuries or deformities. One of the most severe side effects is the loss of the ability to keep a good balance. The reason that it is so severe is that losing balance is a catalyst to falling and obtaining further and severe injuries. That is why keeping a good balance and working out is crucial, to prevent injuries and prolong life expectancies. (Scholarly article, 1 point)

Overall, I learned about the basic level of the problem. I learned that old people struggle a lot because of things that they cannot control. Technology has been making the lives of people of age easier, and I think it can go even further.

1.5.11- Remaining Unknowns

The things I still need to find out is how much the loss of balance issue affects people in other states or countries, and if they get help for that at all. Another thing I need to look at more is how technology could help people of my age walk around safely and potentially solve the problem. I am still not fully confident. I want to investigate balance and walking problems but that is where I am starting.

1.5.12- Individual Bibliography

[17] TJ Tumee, private communication, Feb 2022.

[18] D. Gifford, private communication, Feb 2022.

[19] S. Houser, private communication, Feb 2022.

[20] Ratz, T., Pischke, C., Voelcker-Rehage, C. and Lippke, S., 2022. *Distinct physical activity and sedentary behavior trajectories in older adults during participation in a physical activity intervention: a latent class growth analysis*.

Author: Iseah Hasan

1.5.13- Summary

I focused on the research part of this process, as I looked through several articles and videos that explained what it was like to experience the current ageing crisis and some of the issues they face nowadays as they experience old age. Some of the most prominent issues associated with aging were loneliness, as well as the lack of capabilities to perform daily functions depending on the person. One of the articles that I read—which was written by the National Institute of health (NIH)--indicated how the issue with the population aging can affect the overall productivity of the labor force, as well as the labor force in general [21]. As more people begin to retire, more people begin to leave the workforce, which in turn, can ultimately produce labor shortages if nothing is done to address the issue. With that being said, the increase of the elderly population can also impact policymaking, typically in economic and healthcare policies. According to an article from the International Monetary Fund, it illustrated how the

growth rate of people within the next 40 years is expected to be about .29%, as opposed to 1.24% from 1975-2015 [22]. As the growth rate of the working age population slows down over time, it can be expected that it would ultimately lead to a decline in the GDP since there are less people within the workforce to contribute to the economic output.

Aside from the economic/social impacts that an increase of the elderly population can pose, another issue with the increase of the rate of the population aging has to do with the ancillary issue concerning the aging. According to an article from the University of Minnesota, some of the most significant problems that older people face in everyday life are social isolation, along with healthcare and health issues. They indicated from another study that about 50% of all elderly not living in nursing homes have arthritis, while 56% have high blood pressure and that 32% struggle with heart disease, etc. [23] Despite the fact that a lot of the elderly have access to Medicare, insurance usually does not pay all their costs, which can make it harder for them to access healthcare, given the inflated costs. Another issue that the elderly usually face is also social isolation, as they usually live alone and find it harder to reach out to others, either due to the lack of mobility or their environment.

What I have learned from these articles was how the growth of the elderly population can have a greater impact than expected, in addition to some of the everyday struggles that the elderly face. As the working age population decreases, it is likely that some might have to increase their productivity to supply more care to the growing elderly population, or that the amount of dependency among elders would increase leading to other social problems within a country, which is why policymaking is important to adapt to this situation. Additionally, the everyday issues that they face, such as health complications and social problems can complicate their quality of living where they are more limited in their abilities to perform daily tasks, which is why it is important to innovate upon ways to make their lives easier.

1.5.14- Remaining Unknowns

One main unknown in this problem on ancillary issues is trying to figure out how to address these issues for seniors, specifically how can technology be used to improve their livelihood through improving their abilities to perform daily tasks, as well as connecting to others more easily. What I want to investigate is how technology can be used to make it easier for people who have conditions like arthritis or are immobilized to perform their daily tasks.

1.5.15- Individual Bibliography

[21] National Research Council (US) Panel on a Research Agenda and New Data foran Aging World, "The health of aging populations," *Preparing for an Aging World: The Case for Cross-National Research.*, 01-Jan-1970. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK98373/. [Accessed: 20-Feb-2022].

[22] R. Lee and A. Mason, "Cost of Aging," *Cost of aging -- Finance & Development, March 2017*, Mar-2017. [Online]. Available: https://www.imf.org/external/pubs/ft/fandd/2017/03/lee.htm. [Accessed: 24-Feb-2022].

[23] “6.5 problems facing older Americans,” *Social Problems*, 25-Mar-2016. [Online]. Available: https://open.lib.umn.edu/socialproblems/chapter/6-5-problems-facing-older-americans-2/#:~:text=The%20US%20elderly%20experience%20several,home%20residents%20is%20fairly%20common. [Accessed: 01-Mar-2022].

2.1 Stakeholders and Existing Solutions

The stakeholders for our project are the elderly. Statistically speaking, many people in the older generations are prone to falls and this limits their ability to leave their homes to socialize. This increases depression amongst this population and creates a feeling of isolation. To combat these problems, we had to consider low-risk activities that will help the elderly remain engaged and help their mental health. Our solution was gardening. Plants boost serotonin levels in the brain, which will help decrease depression in the elderly. However, gardening is an activity that requires lifting heavy materials and bending over, which can lead to falls or back pain. Thus, we produced our concept of rotation shelves that will prevent the user from having to bend down.

The shelves will also have a built-in irrigation system that will run on a timer to ensure that the plants will be cared for. The elderly will be able to grow herbs, flowers, and even some vegetables from the comfort of their homes without causing damage to themselves.

There are two potential existing solutions for our concept. The first is a Lazy Susan (figure 3). A Lazy Susan is a shelving system that spins for easy access to goods that may be in the back of a cabinet. This system is often used in pantries to maximize storage. This system is manually spun and is rarely used outside of the kitchen.

Figure 3: Lazy Susan

The second preexisting concept is an automated sprinkler system (figure 4). Automatic sprinklers are used outside and in greenhouses. These systems are normally used on a large scale, like in gardens or in the agricultural industry. These systems can be run on a timer or manually hooked up to a hose to work.

Figure 4: Sprinkler system

Our prototype will combine these ideas to create a product that will make gardening safer and easier. Our prototype will also have other alterations like a motor and lighting system to combat other problems that can be faced in the gardening process.

2.2 Requirements, Customer Needs, and Technical Specifications

General Design Requirements:

The overall designs of our products are as follows:

- **Relatively low manufacturing cost:** Since we want to keep the design simple and easily understandable, we want to keep the manufacturing cost down to reflect that.
- **Relatively easier to repair:** Our expectation is that, since the design will be simple, and it will be relatively cheaper to produce, the repairs will be simple and will not cost that much
- **Relatively waterproof:** Since one of the product's functions is to water plants, making it waterproof will be a no brainer and make the product overall higher quality.

Stakeholder Needs:

The overall needs of our stakeholders are as follows:

- **Forgetting to water:** Since it is likely that people will start to forget more as they get older, we solved this problem by making our product able to water the plants on its own.
- **The need to micromanage sunlight:** Since someone can have different types of plants that require different amounts of sunlight to grow, we thought it would be wise to put in a function that provides different amounts of sunlight to different types of plants.
- **The accessibility of the hobby:** We are hoping that since our product makes gardening and owning plants easier, the overall mental health aspect of the owner will improve.

Technical Design Specifications:

The technical design specifications of our product are as follows:

- **Very easy to use:** The hardest part of using our product will be putting the plants on the shelf itself. Afterwards, the shelf will handle the rest.
- **Prevents fall:** The shelf will stay near the house or the porch, preventing walking on uneven ground across a backyard to take care of plants.
- **Fetching water:** The shelf will allow the stakeholder to attach a line to draw water or put in water inside the shelf itself to water the plants.

2.3 Individual Looks-Like Prototype and Concept:

Anne Marie Covlin

2.3.1 Prototype Description

I prototyped a no-pull dog leash that is designed to accommodate a dog slightly pulling on its leash during a walk, which will allow those who struggle with balance to be able to comfortably walk their dogs without fear of being pulled over. The leash features a bungee cord stitched into a nylon webbing, which will stretch as the dog begins to pull, lessening the force felt directly by the walker. The leash will contain a force sensitive strip just above the bungee cord that is designed to temporarily separate the top half of the leash from the bottom if the plate detects a preset force deemed strong enough to max out the bungee cord and therefore have the full force of the dog's pull potentially harm the user. If this occurs, a small tracking device attached to the base of the leash will activate and sync to an app on the user's phone. This will allow the user to track their dog if it were to run off. Additionally, the leash features an arthritis friendly grip handle, designed to minimize the force on the user's joints.

2.3.2 Solution Field Sketch

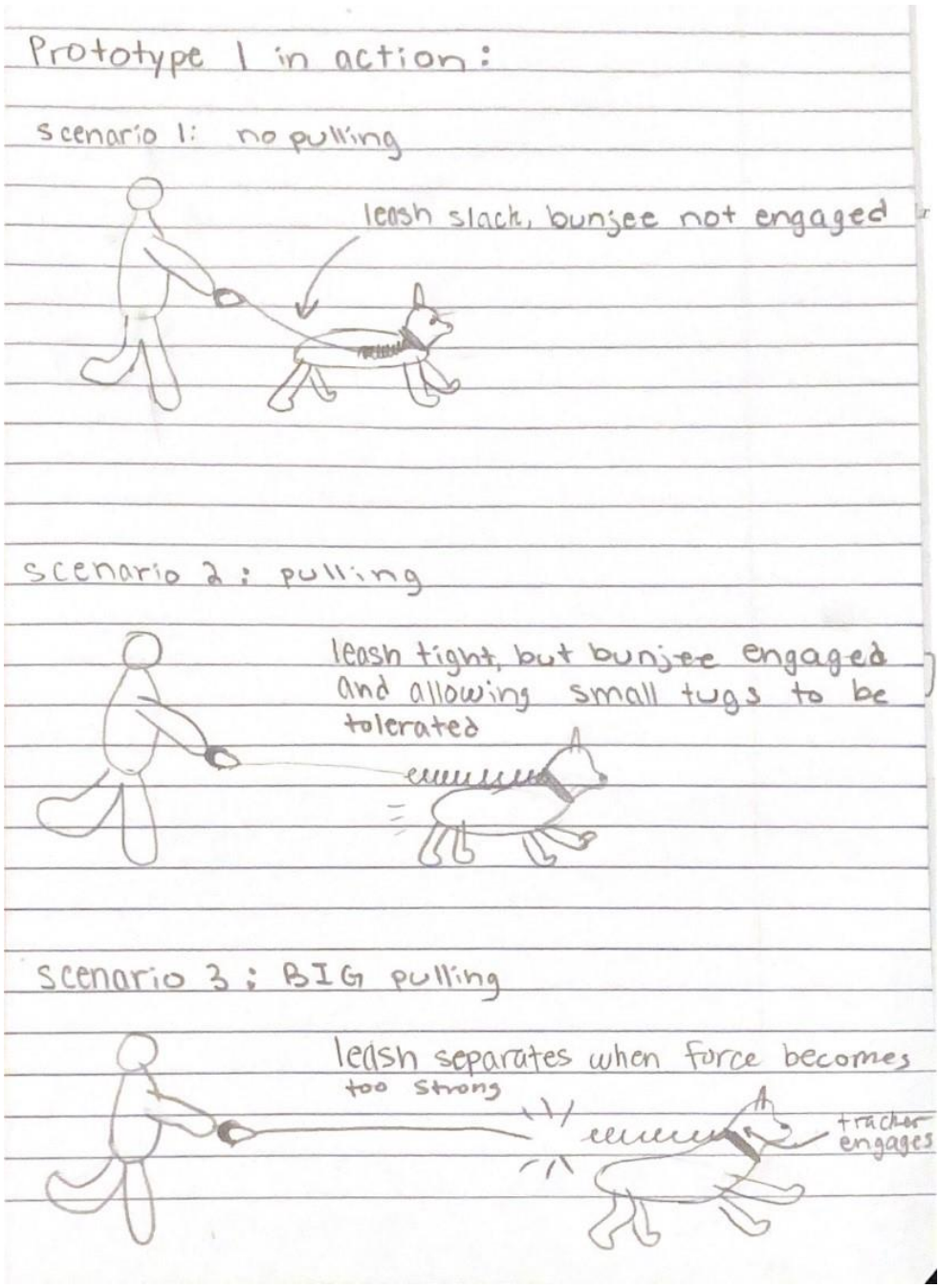


Figure 5: Prototype Field Sketch

2.3.3 Looks-Like Prototype Photo

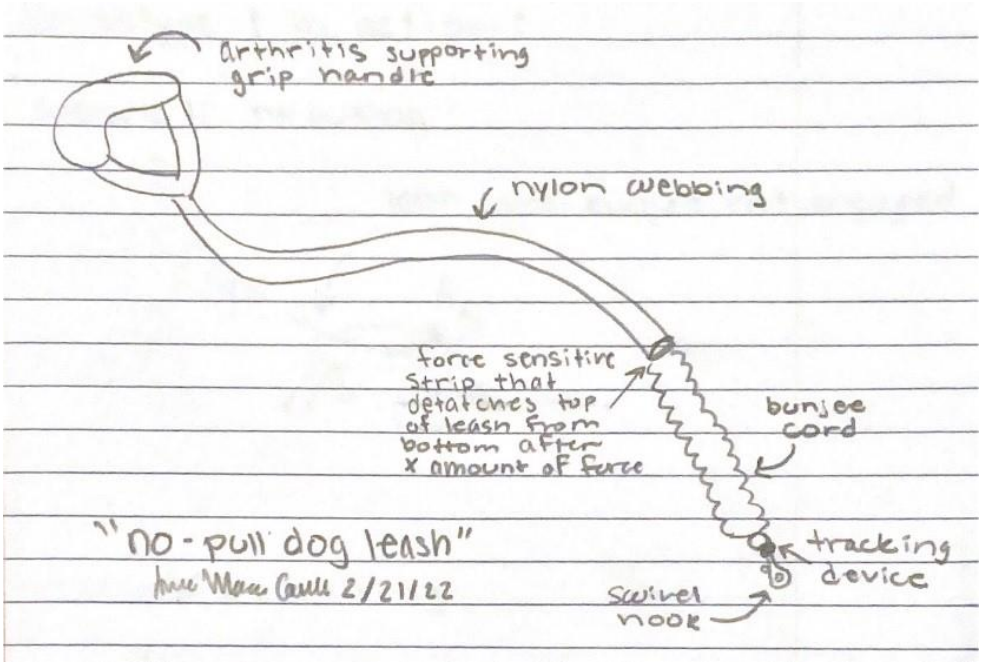


Figure 6: Looks-like prototype Sketch

2.3.4 Solution Value Summary

During my stakeholder engagement, I learned that older generations often struggle with balance and are prone to falling. Additionally, the elderly often feel lonely or isolated due to their reduced mobility and inability to get out and socialize like they could when they were younger. Having a dog or other pet can help alleviate these feelings of loneliness, as well as give the user an excuse to get outside and exercise during the dog's daily walks. This will keep the elderly user active and improve their overall quality of life. However, dogs are often unpredictable, and sudden pulling brings the risk of pulling the user over, which could cause serious damage to the user. This leash will absorb some of this pulling, allowing the user to walk their dog without the fear of being taken out by a squirrel sighting or any other exciting encounter the dog might face.

Iseah Hasan

2.3.1 Prototype Description

The drone is a subcompact drone that is typically flown around the house. It is like the Roomba, except it is a flying drone that can help carry items from hard-to-reach spots. The drone is equipped with a bunch of sensors that help track assorted items, as well as its surroundings. Additionally, it is also equipped with dynamic claws to help maintain grip on the object when flying, and that it also acts as the drone's legs. Finally, the drone also contains a camera which helps the user see the drone's surroundings when flying. The drone can either be controlled

manually through a mobile app, or it can fly autonomously to the user to call the drone. Intended for those who struggle with balance and immobility, the drone is designed to ease the burdens of having to put extra strain on their bodies when trying to carry or reach a certain item.

2.3.2 Solution Field Sketch

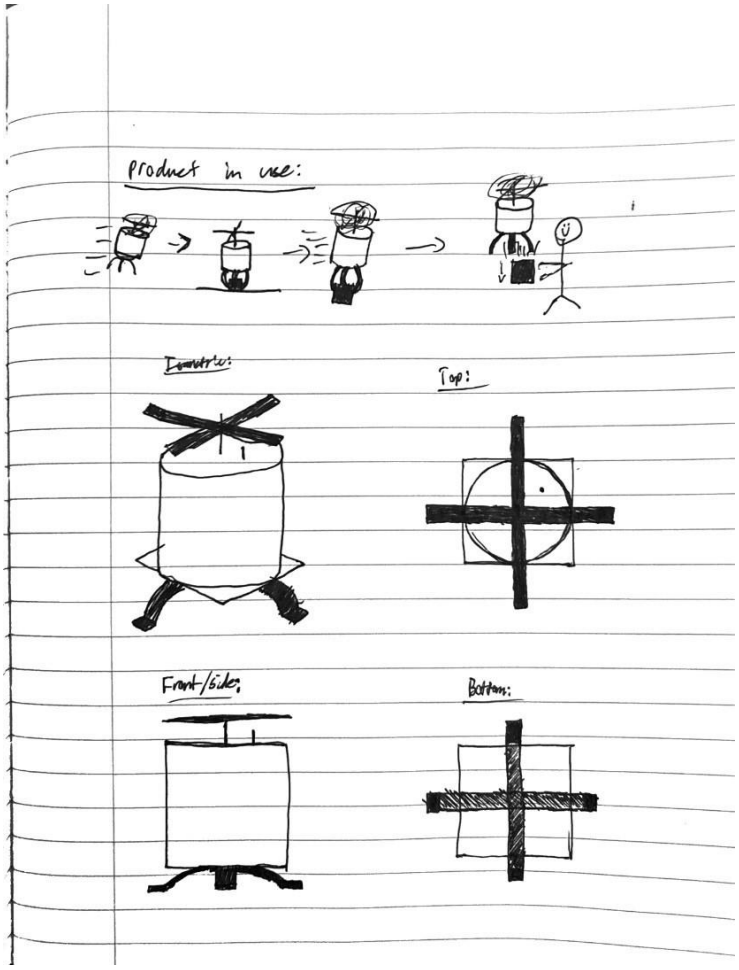


Figure 7: Prototype Field Sketch

2.3.3 Looks-Like Prototype Photo

Figure 8: Looks-like protype

2.3.4 Solution Value Summary

This solution addresses some of the needs for consumers, as well as the problem statement that we had determined, which is how to look into the issue of injuries and deaths caused by accidents concerning the aging-population who struggle with mobility challenges. The drone can provide a user-friendly experience for users to ease up their chores and that they can prevent themselves from putting strains on their body that could cause a potential accident when reaching for an object or carrying them. As a result of these qualities, this solution can work both indoors and outdoors, as it can help obtain objects from hard-to-reach areas or from separate floors without causing any stress to their bodies.

Jalen Perkins

2.3.1 Prototype Description

I designed a shelving system that rotates to allow users to reach both the top and bottom shelves more easily. By having the shelves rotate we can bring the desired shelf to a more accessible height. This allows for easier access to the items stored in the shelving system while also potentially increasing the total storage space.

2.3.2 Solution Field Sketch

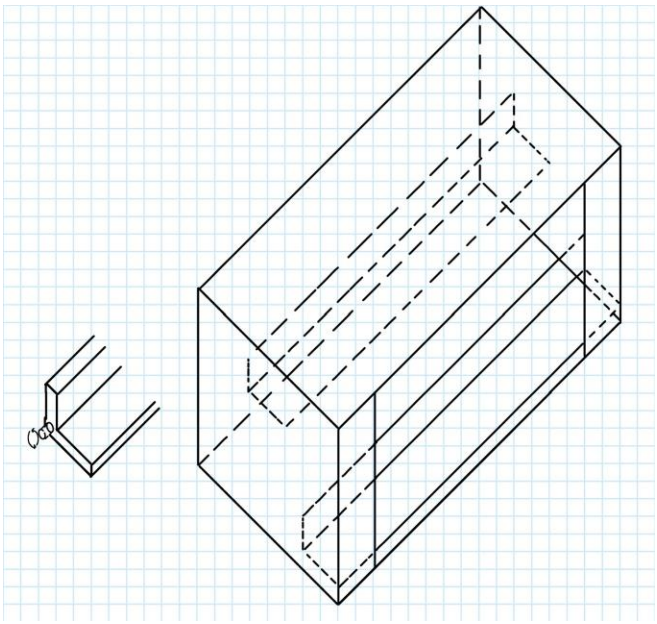


Figure 9: Field Sketch

2.3.3 Looks-Like Prototype Photo

Figure 11: Looks-like prototype

Figure 12: Looks-like prototype

2.3.4 Solution Value Summary

By bringing the top shelves down we can reduce the risk of injury associated with trying to acquire a large/heavy item from the top shelf. Similarly, we can reduce the risk of injury associated with bending down to get items placed on the lower shelves. By reducing these risks, I hope to improve the quality of life of our customers by improving their ability to be independent.

Megan Meehan

2.3.1 Prototype Description

I designed a smartwatch that would detect when the wearer fell and would immediately alert authorities. The watch would detect the fall by monitoring vitals and has shock detection software built in. The watch has the look of a traditional watch with a leather or metal band. This traditional look encourages usage as it looks like accessories that the elderly already wears on a regular basis. The watch will also constantly track the health of the wearer and send it directly to their primary care physician to create a health baseline. Unlike other smartwatches, this watch will not have a digital face or connect to phones, eliminating too many complications for the older generation. The watch is different from other fall detection devices because it is not activated by a button, making it so that it will be useful even if the wearer is unconscious.

2.3.2 Solution Field Sketch

Figure 13: Prototype Field Sketch

2.3.3 Looks-Like Prototype Photo

Figure 14: Looks-like prototype

2.3.4 Solution Value Summary

Through our stakeholder engagement, we learned that many older people have issues regarding balance and are prone to falls. These issues inhibit them from going out and socializing through the fear of falling and overall decreased their quality of life. Through this product, I hope to ease some of those fears as if something were to happen, they would receive help immediately.

Tulga Javkhlan

2.3 Individual Looks-Like Prototype and Concept: Automatic Closet:

2.3.1 Prototype Description:

The prototype I designed is an automatic closet that helps people get clothes off hangars without people getting up or putting in much effort. This can help prevent falls or injuries by not requiring the individual to stand up to get their clothes or potentially other objects if the person's legs do not function enough to complete that task.

More specific details, there will be a wheel-based system that will allow the individual to pull, and the wheel will lock to allow the clothes to be pulled down. The wheel will be pushed back to its original position when a firm force is applied, ideally a caretaker that will routinely reset the hangers.

Additionally, the hangers will have a function to fold so the two ends will fold down and allow the user to pull down the clothes easily. The concept behind my closet is that it is attachable to any rod in a closet so it can be integrated very easily, which keeps the cost low.

2.3.2 Solution Field Sketch:

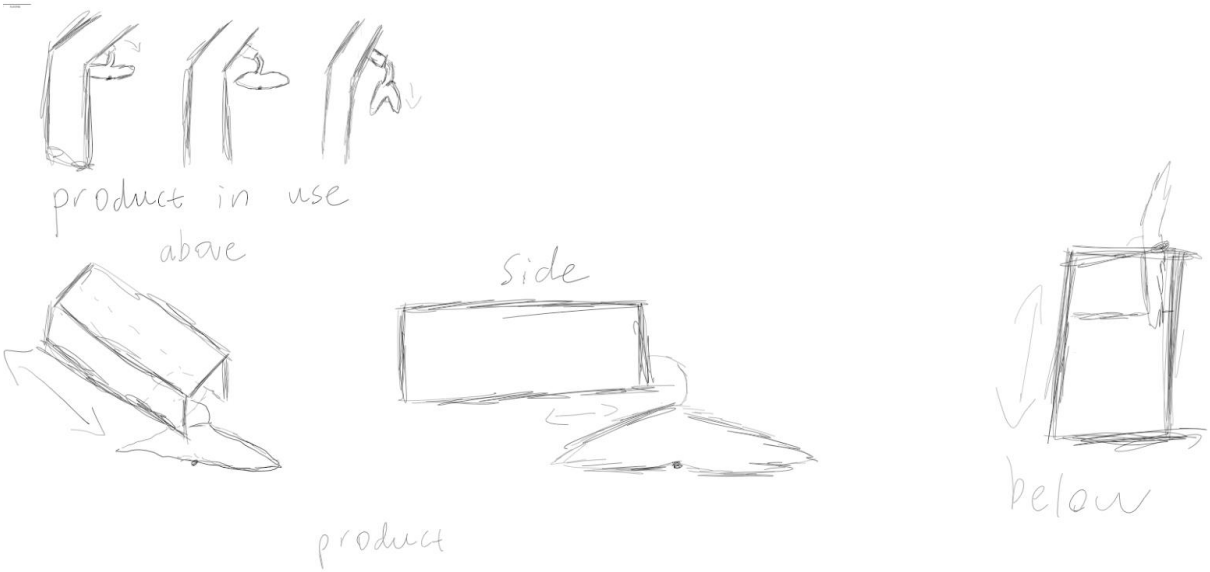


Figure 15: The Automatic Closet in Use

2.3.3 Looks-Like Prototype Photo:

Figure 15: Looks-like prototype

2.3.4 Solution Value Summary:

The value of this solution is that it will be very affordable and is able to be easily mass produced. Also, it is a simple idea which affects a big part of an individual's day-to-day life. One problem that could pop up was the idea of people not using hangers. That is okay, but the implementation of my special hanger could solve various problems.

2.4 Decision Analysis Summary

After receiving a variety of user input to determine our problem statement, we weighed different ideas on what prototype we could make. As depicted in the table below, we measured each idea using several factors such as viability, desirability, sustainability, etc. After gathering the ideas together, we found out that the top 3 ideas that stood out were rotating shelves, kitchen-drawers extending upward, followed by a back-posture corrector, since they had the most points out of all the other ideas. By comparing these top three, we decided to follow through with the rotating shelves since they received the most total points, and we believed that this would be the most feasible product for customers.

2.4 Decision Analysis Matrix

Ideas	Viability	Desirability	Sustainability	Feasibility	Originality	Total
Wheelchair that lifts up	6	3	7	8	5	29
Fall detector watch	3	7	7	6	3	26
Balance shoes	7	5	4	3	6	25
Rotating shelves	**8**	**7**	**7**	**9**	**4**	**35**
Dog leash that has a bungee to prevent falls	7	6	6	5	2	26
Automated closet	3	4	4	5	1	17
Kitchen drawers that extend upward	**6**	**7**	**6**	**8**	**6**	**33**
Pantry conveyor belt	3	2	4	3	3	15
back posture corrector to correct stride	**7**	**7**	**6**	**7**	**3**	**30**
Lawn-mower Roomba	4	10	4	5	1	24

*Figure 16: Decision Matrix (*Scale: 0-10 (0: Worst; 10: best))

2.5 Proposed Final Design

Our final prototype design is a rotating shelf system (figure 17). There will be 3 shelves with a rotatory motor that will spin them at a preprogrammed time to ensure that each plant will have the proper amount of sunlight. The bearings will be able to rotate to make sure that the plants do not fall out of the shelves. The shelves themselves will be 4-foot beds with a drip irrigation system built into the bottom. UV lights will be rigged to the bottom of the beds and will be

programmable as well so that the shelving can be used in an area that does not get direct sunlight if the user wishes. The structure will stand at 3 feet high, giving the user easy access to the top shelf. The system will need to be plugged in and hooked up to a water supply to work properly.

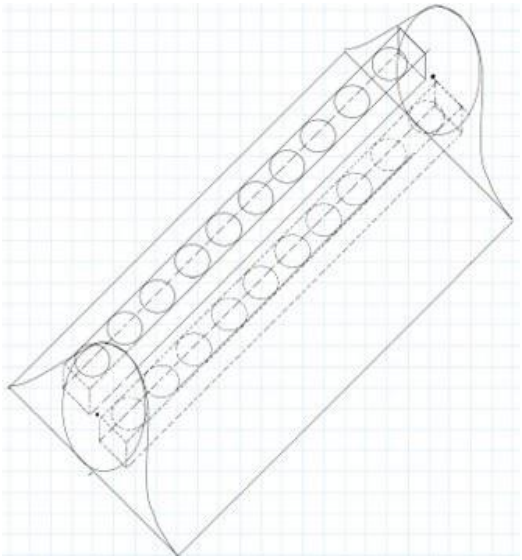


Figure 17: Final Design Sketch

2.6 Module 2 Summary

In this module, we focused mainly on the basics of creating a design proposal, as well as developing prototypes for the team's design concept. What we learned from this module was basically how to outline a design process, which includes identifying stakeholder needs that our team needed to address, as well as identifying existing solutions in order to generate an original idea. Through prototyping, as well as presenting our design, we learned how there are several steps to developing our design including generating our preliminary concepts and presenting ideas to others. This learning is important since it helps give an understanding of how a design process should be organized in a way that is straightforward and concise, since it is important to understand what and how the design will be produced. In our design presentation, for example, we explained what our final prototype would be, and what our design process for the prototype would be. Additionally, we also stated how our design prototype will accomplish the main issue, as well as the impact it can pose on others. This can probably help us in our future careers as we can utilize some of these ideas that we have learned to lay out our design process for our product that can most efficiently solve a specific problem.

Rotating Shelf for Plants:

Rotation Component

Introduction:

The vision of our idea was to provide a way for the elderly to enjoy gardening and growing plants without the risk of injuries and the dire consequences that come with it. Therefore, the idea of a convenient shelf that eliminates the risk of getting injured was born.

Ideas	Viability	Desirability	Sustainability	Feasibility	Originality	Total
Wheelchair that lifts up	6	3	7	8	5	29
Fall detector watch	3	7	7	6	3	26
Balance shoes	7	5	4	3	6	25
Rotating shelves	**8**	**7**	**7**	**9**	**4**	**35**
Dog leash that has a bungee to prevent falls	7	6	6	5	2	26
Automated closet	3	4	4	5	1	17
Kitchen drawers that extend upward	**6**	**7**	**6**	**8**	**6**	**33**
Pantry conveyer belt	3	2	4	3	3	15
back posture corrector to correct stride	**7**	**7**	**6**	**7**	**3**	**30**
Lawn-mower roomba	4	10	4	5	1	24

*Figure 18: Decision Matrix (*Scale: 0-10 (0: Worst; 10: best))

It was determined that, from our potential designs, the rotating shelf could be the one worth putting in our time for due to the versatility and the potential simple building process.

The purpose of my system is to provide the rotation that spins the shelves around, so that the elderly would not feel inclined to move the heavy plants themselves to provide sunlight, increasing the risk of getting injured or even death. To accomplish my task, I will use a Servo motor that provides enough torque to spin the heavier of the plants around on the shelf.

Subsystem Description:

Overall objective of the subsystem:

The main goal is to get the shelf spinning using a Servo motor with the utilization of Arduino board, a bread board and the Arduino idle. The Servo motor will be hooked up to a breadboard and attached to a battery to get power.

Key Subsystems:

Figure 19. The Servo Motor (2.2 x 2.2 x 1.5 inches)

This specific motor takes in 4V-8.4V, which will be supplied by a battery pack.

Figure 20. Battery Pack (Battery – 9V)

```
#include<Servo.h>
#include<math.h>

Servo servoMain;
int servoPin = 6;
int startPos = 90;
void setup() {
  servoMain.attach(servoPin);
  servoMain.write(startPos);
  Serial.begin(9600);
}
void loop() {
  servoMain.write(startPos);
  while (startPos <= 110) {
    servoMain.write(startPos);
    startPos = startPos + 1;
    delay(100);
    Serial.println(startPos);
  }
  while (startPos >= 90) {
    servoMain.write(startPos);
    startPos = startPos - 1;
    delay(100);
    Serial.println(startPos);
  }
}
```

Figure 21. Spinning Script

The script I have written above sets the appropriate speed and the time delay between spins.

The Servo utilizes an Arduino UNO REV3 to carry the script into the motor.

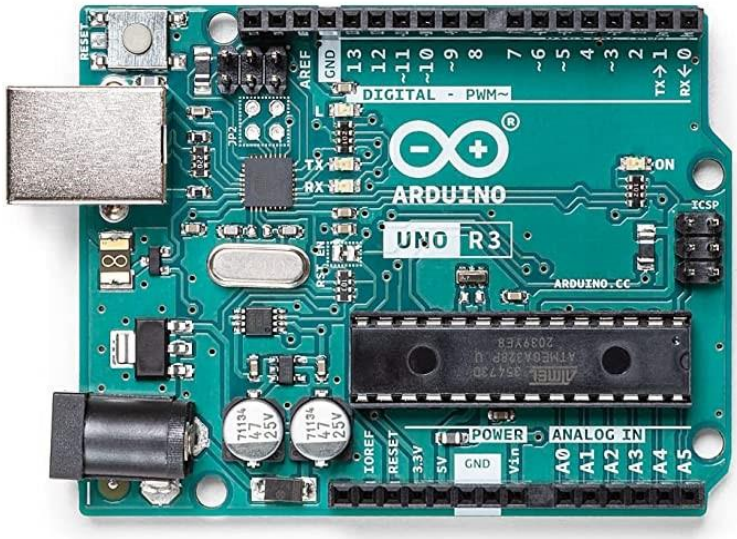


Figure 22. Arduino UNO REV3

The power from the battery is supplied by a bread brown as directed.

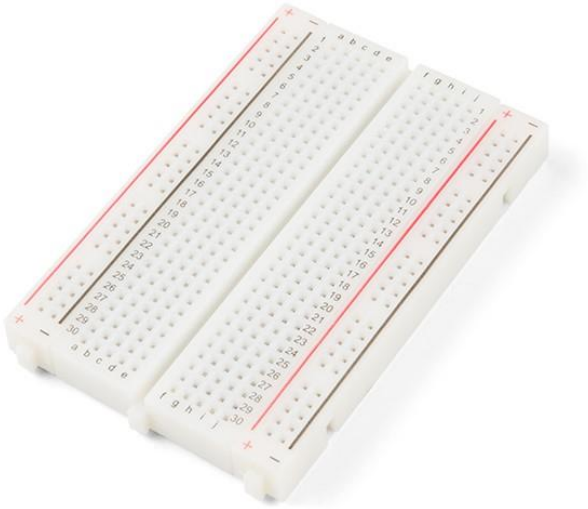


Figure 23. A bread board

How the Sub System Works:

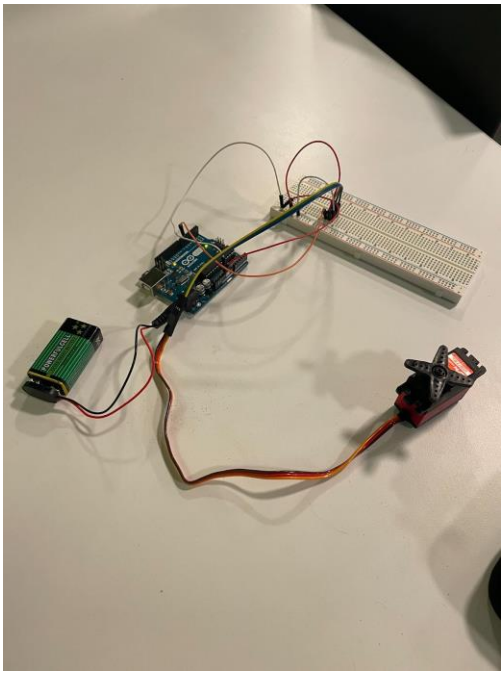


Figure 24. The assembled subsystem.

The power will be given to the motor by a 9V battery pack, and a bread board will be used to power the Arduino board. Then, the Servo will be plugged into the bread board to provide the rotation.

Required Inputs:

Electricity is crucial to get the motor moving. A 9V battery will be used to power the board and the motor. Other than electricity, there is no required input in the subsystem.

Off The Shelf Components:

The Arduino board, bread board, the Servo, the battery, and the necessary wires all have been bought.

Physical Properties:

Items	**Dimensions**	**Voltage**	**Material Type**	**Weight**
Servo	55X20X43 mm	Needs 4V - 8.4V	Metal, plastic	3.4 lbs
Arduino Uno	68.6X53.4mm	Needs 5V	Metal, chips, plastic	1.5 lbs
Bread Board	55X82X8.5 mm	Handles 300V	Plastic	1.2 lbs
Battery	48.5X26.5X 17.5mm	Provides 9V	Metal	2.5 lbs

Figure 25:Physcial Properties of Materials

Idea Generation:

Motors	**Power**	**Ease of Use**	**Weight**	**Total**
Servo	**5**	**7**	**7**	**19(3.4lbs)**
Stepper	**9**	**2**	**0**	**11(10.5lbs)**

Figure 26: Idea Generation

The idea to spin the shelves using servo was made after a stepper motor proved more difficult and complicated to use. The stepper motor was very heavy, proving to be difficult to incorporate in a viable prototype. The use of the Arduino was a no brainer because it is easy to code and set up in our proposed design. The battery is sufficient for now. It could be easily changed if the power provided is not enough.

Validation of Novel and Unique Design Ascept:

Test Results:

https://youtube.com/shorts/viU81Rcuuww?feature=share

The code used in the test result has been modified to show the consecutive spinning capability. The original code will make the shelf spin as we desired, which is every 30-45 minutes.

Analysis and Calculations:

The spinning process in Servo was successful, and the spinning speed seems sufficient and slow enough to accomplish our goal. The power output works well, providing enough torque to spin the shelf.

Secondary Research:

The websites for the Arduino Uno REV3 provided the power needs, dimensions and specific information needed to make the subsystem function correctly. The research of the specific functions and the syntax from the Arduino reference library made it possible to write the script. The incentive to choose a servo motor instead of a stepper motor was solidified by the data provided by a motor reference library.

Stakeholder and Expert Feedback:

A stakeholder was Mrs. Gifford, who is an Occupational Therapist, who complemented the idea of a rotating shelf, indicating that it could really help decrease household injuries for the ageing population.

An expert was my friend Isaac, who is a Mechanical Engineering major and knowledgeable about Arduino, liked the way the script was written for the Servo and gave general advice on how to work the Arduino with the Servo.

Relevant Interfaces and How Each Sub System Works With Others:

Interface descriptions:

The Servo will interact with the lights on the shelf and the irrigation system. The lights will share electricity with the motor, and the irrigation system will open or close the tube depending on if the shelf is spinning or not.

Key interfaces and exchanges:

With the irritation system, there will be an indication that the tube will open when the motor stops to the water will not leave the shelf in an improper way, like rolling off the shelf on the sides. That also will prevent damage to the lights because the water goes out in a proper way.

The shelf will take in enough electricity to share with the tube and the lights.

Citations:

[24] Donna Gifford, private communication, 2022

[25] Isaac Wallen, private communication, 2022

[26] "The components of an Arduino Uno PCB," *Circuit Basics*, 11-Nov-2021. [Online]. Available: https://www.circuitbasics.com/the-components-of-an-arduino-uno-pcb/. [Accessed: 13-Apr-2022].

[27] "Language reference," *Arduino Reference - Arduino Reference*. [Online]. Available: https://www.arduino.cc/reference/en/. [Accessed: 13-Apr-2022].

[28] "Servo Motors, drivers and controllers," *Oriental Motor U.S.A. Corp*. [Online]. Available: https://www.orientalmotor.com/servo-motors/index.html. [Accessed: 13-Apr-2022].

[29] "Arduino Uno Rev3," *Arduino Online Shop*. [Online]. Available: https://store-usa.arduino.cc/products/arduino-uno-rev3?selectedStore=us. [Accessed: 13-Apr-2022].

3.1.1.1 Refer to the Scaled-up Solution

The dimensions of the irrigation system within the beds would be 3 feet long and ¼ inch in diameter. There will be 3 of these components. The tubing running up the structure to the beds will be 3 feet long. The valve is 4inches by 4 inches and attaches to the programmed timer.

3.1.1.1.1 Overall Objective of the subsystem

The key components of this subsystem are the valves (figure 28) and tubes (figure 27). The valve connects to the water source and relies on a timer to turn it on and off to prevent over or underwatering. The tubing allows water to reach the far ends of the beds and ensures that all the plants within the bed will get the proper amount of water. The purpose of this subsystem is to ensure the survival of plants with minimal effort on the consumer's part.

Figure 27. Drip irrigation tubing

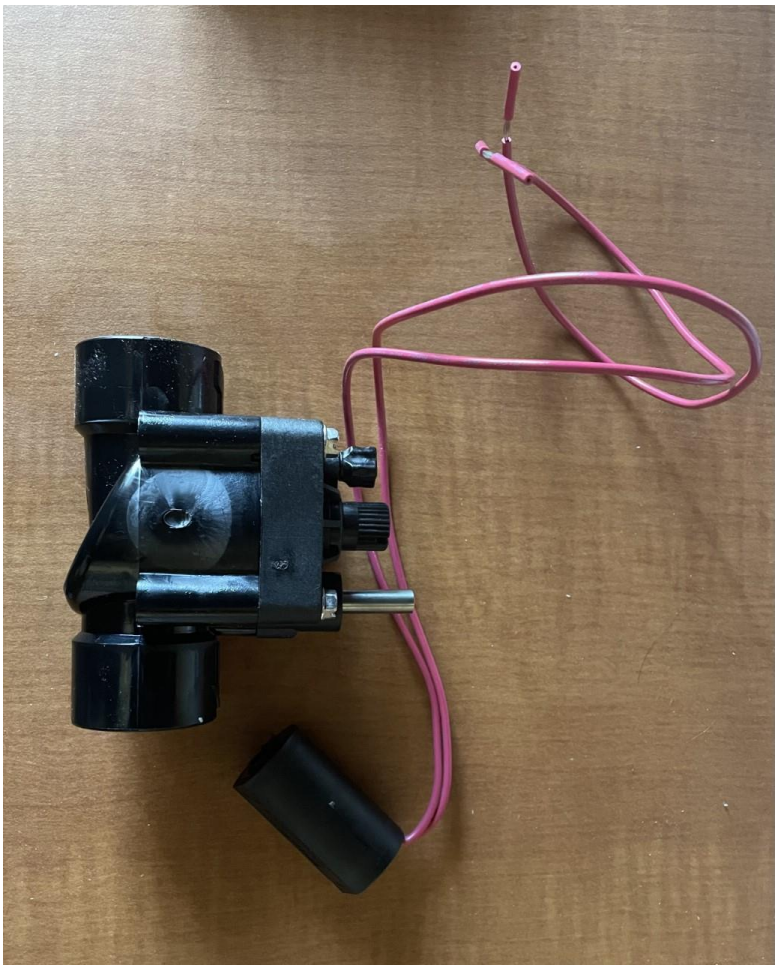


Figure 28. Valve

3.1.1.1.2 How the Subsystem Works

For plants to survive, they need access to water on a consistent basis. This subsystem utilized drip irrigation to evenly distribute water to the root systems of the plants. The irrigation system relies on a programmable timer that opens and closes the valve attached to the water source. The irrigation tubing in use is a ¼ inch tube. In the beds, the tubing has .035” inch holes spaced 1” apart to distribute water within the beds (Figure 31). The tubing outside of the beds has no holes and is ¼ inch tubing. All joints are secured with plumber's putty.

The valve is a professional grade inline irrigation control valve with a 1” connection (Hunter PVG 1” valve). The connection attaches to a 1” standard garden hose connector or faucet. The water pressure within the system is the standard water pressure of faucets or 50 PSI.

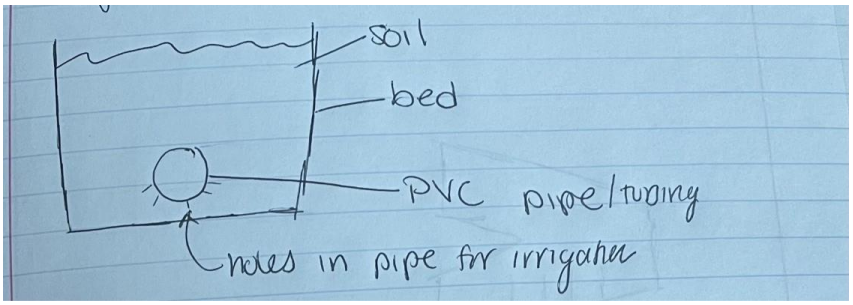


Figure 29. Sketch of inside the beds

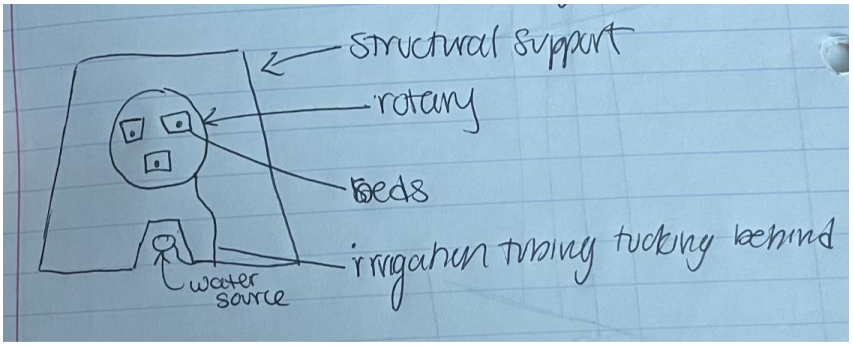


Figure 30. Sketch of irrigation throughout subsystem

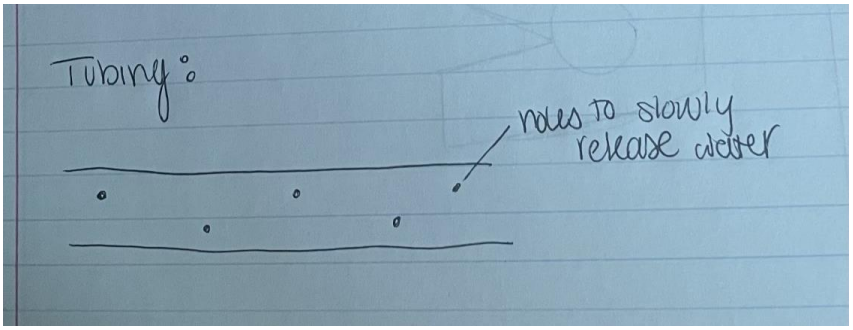


Figure 31. Sketch of irrigation tubing

3.1.1.1.3 Required Inputs

The only required input for this subsystem is water. Water from a spigot is already pressurized, thus making the need for a pump vanish. Electricity is an indirect input as it is required for the timer that turns the irrigation on and off but is not directly necessary for irrigation.

3.1.1.1.4 Key Subsystems

The key components of this subsystem are the valve and tubing. These components are necessary for creating the output of water distribution throughout

the system. These components rely on outside subsystems to function (see section 3.4.1 for more detail).

3.1.1.1.5 Off-the-shelf components

The irrigation tubing (figure 32) in use is the Raindrip 100050211. It comes with 100 feet of tubing and is made from vinyl treated with UV inhibitors. This product is designed for drip irrigation in an agricultural setting and is built for durability.

Figure 32. Irrigation tubing

The valve (figure 33) is a Hunter Industries 1” PGV valve that is used for commercial irrigation and agriculture. This system is made to control the flow of water through it, whether that be shutting it off or lowering the pressure. This system is easily programmed and water-resistant.

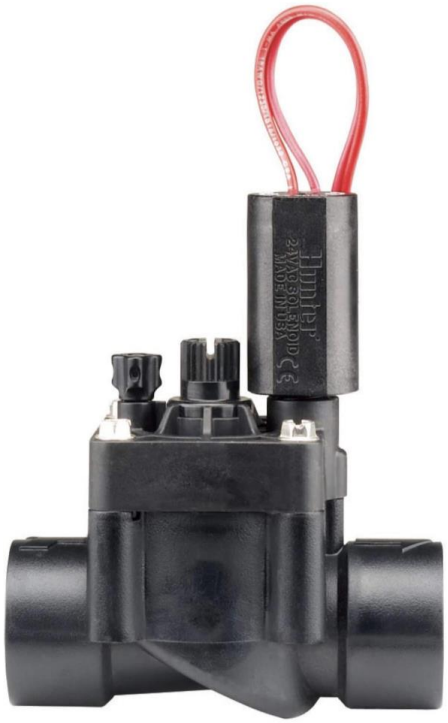


Figure 33. Valve

Plumber’s putty (figure 34) is used to create a waterproof seal. The product used for the irrigation subsystem is the Harvey’s Professional Grade Putty. It is used on all the joints/connections to prevent leaks in the irrigation system.

Figure 34. Plumber’s putty

3.2 Idea Generation

3.2.1: Irrigation

An alternative that was considered was a misting system instead of the drip irrigation system. However, a mist/sprinkler system would require higher water consumption and more maintenance as the consumer would need or clean the excess water. Another considered alternative was using a rain barrel as the source of water. This would require a pump as well to create the necessary water pressure. This would have driven up the price, leading to it being less desirable for the consumer.

3.3 Validation of novel and unique design aspects

3.3.1 Test Results

Irrigation-

The first test of the irrigation subsystem was just testing the tubing's ability to evenly distribute water from an open water source. This test was successful as water did not escape through the end of the tubing that had been sealed with plumbers' putty and went out the desired holes.

https://youtu.be/FUyEuUjrVXg

3.3.2 Analysis and Calculations

When using the standard water pressure that can be found in a faucet or spigot (50-80) PSI, the irrigation subsystem will be successful. It only takes 4.33 PSI for water to travel 10 feet in the air [30]. Thus, the water pressure is more than enough to push the water throughout the system without any additional assistance through a pump.

3.3.3 Stakeholder and expert feedback

Daria Gregg, age 74 years old and an avid gardener, looked over the design of the overall product and subsystem. She agreed that the design would be useful for the elderly as it removed the need to bend over or sit on the ground. She appreciated the self-watering feature and remarked on how it could be helpful for when people go away on vacation as well as aiding those with memory loss.

3.4 Relevant interfaces and how each subsystem works with others

3.4.1 Interface description

Irrigation interacts with nearly every aspect of this product. For proper function, each part must work together perfectly to achieve the end goal of an easily managed garden.

3.4.2 Key interfaces and exchanges

Irrigation interacts with the programming and structure of the product. The program controls both the motor that spins the structure and the timer that turns on and off the water supply. This is vital to irrigation as, without it, there would be no water in the system, rendering it useless. The structure holds the subsystem within it. It also holds the plans and drives the need for irrigation.

3.5 Citations and References

[30] Sprinkler, Big. “How Far Can I Pump Water and Still Have Enough Pressure to Run the Sprinkler?” *Big Sprinkler*, 13 Nov. 2020,

3.1.2 Subsystem description: Potting Beds
Author: Anne Marie Covlin

3.1.1 Scaled-up solution

There will be three potting beds total, each made from pine plywood, and screwed together using wood screws. A short PVC pipe will be glued into the top section of each endpiece. This pipe will then be inserted into the rotating wheel mechanism of the main structure, allowing the beds to rotate vertically with the wheel. The PVC pipe will only loosely fit into the wheel, so the weight of the beds will keep the beds upright as the wheel spins.

3.1.1.1 Overall objective of the subsystem

The purpose of the potting beds is to house the soil, plants, and irrigation units, and allow the plants room to grow and thrive inside a home. The key components of this subsystem include the ½" thick plywood, 1" long wood screws, and Plumbers Putty. When constructed, the beds will provide a sturdy place with plenty of room for plants to send out roots and grow without being overcrowded. Having the potting beds be sturdy enough to hold the plants, yet light enough to not cause excessive strain on the motor is crucial for the functionality of this product.

3.1.1.2 How the subsystem works in order to accomplish the necessary output

The goal of this subsystem is to provide a sturdy and healthy environment for plants to grow. Plants need sunlight, water, and CO2 to thrive. The potting beds will have an open top, allowing sunlight and CO2 from the surroundings to engulf the plants. The beds will also contain a drip irrigation unit to provide the plants with the necessary input of water (See section 3.1.1.4.2). The use of wood as the material of the beds will ensure that they are strong enough to support the soil and plants without caving under the weight, which could potentially cause the beds to collide during the rotating process and could negatively impact the health of the plants. The beds rotate vertically along a programmed belt on the main structure, allowing each bed to sit in the sun for an allotted period of time. Additionally, the rotating of the beds will prevent stakeholders who may struggle with balance to avoid having to bend down to tend to a plant and potentially put themselves at risk of falling during the process.

3.1.1.3 Inputs required in order to make this subsystem work

No unique inputs are required. All are addressed in other subsystems.

3.1.1.4 Key subsystem components needed to accomplish outputs

½ in plywood and 1 in. flathead screws are needed to accomplish the intended outputs.

3.1.1.5 Off-the-shelf components

- **1/2 in. x 2 ft. x 4 ft. Pine Pressure-Treated Plywood**

The frame of the potting beds will be made from ½ in. x 2ft. X 4 ft. Pine Pressure-Treated Plywood. Each bed will require one full sheet of wood, adding to a total of 3 sheets. The wood itself has sanded surfaces across the front and back, and edges have smooth, even cuts, allowing the beds to fit together flush with little room for gaps in the seams. The wood is intended for interior use, but can easily be sealed with a weather-protectant finish if the customer wants to use the product outside.

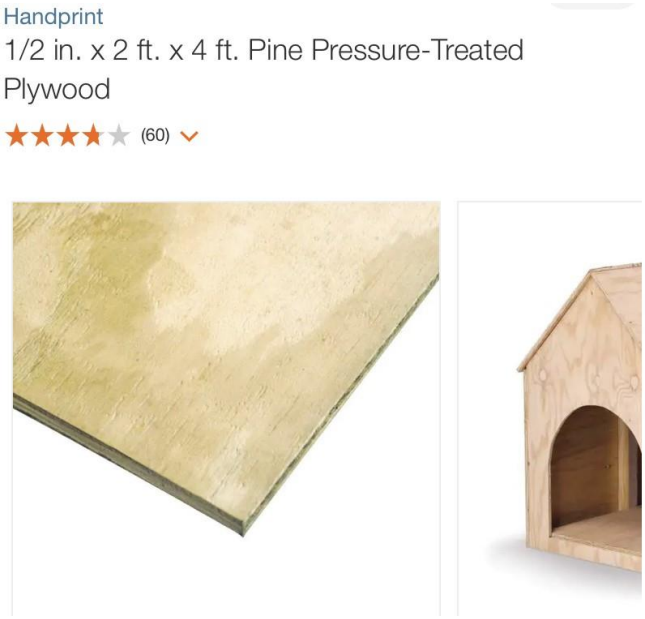


Figure 35: Handprint 1/2 in. x 2 ft. x 4 ft. Pine Pressure-Treated Plywood

- **#8 x 1 in. Zinc Plated Phillips Flat Head Wood Screw**

#8 x 1 in. zinc plated Phillips flat head wood screws will be used for the construction of the beds. Wood screws are designed with aggressive threads to securely grip wood, and are commonly used for fencing, cabinets, and framing. The zinc plated steel material will ensure durability. The flat head top will allow these screws to sit flush with the wood, creating a clean finish.

Figure 36: Everbilt #8 x 1 in. Zinc Plated Phillips Flat Head Wood Screw (100-Pack)

- **1 in. x 24 in. PVC Sch. 40 Pipe**

1 in. x 24 in. PVC pipe will be used to connect the potting beds to the rotating mechanism. These pipes are made from durable PVC sch. 40, so they can easily support the weight of the bed. This pipe is often used for non-pressure, potable water, and drainage uses, but its additional practical uses are endless.

Figure 37: VPC 1 in. x 24 in. PVC Sch. 40 Pipe

- **Plumbers Putty**

Harvey's Plumber's Putty will be used to create a waterproof seal around the edges of the potting beds, preventing any leakage from the irrigation system. This putty formula will not crack or shrink as it dries, making it ideal for long lasting projects. Plumber's putty is often used to seal joints/pipes in sinks, faucets, irrigation systems, etc.

Figure 38: Plumbers Putty

3.1.2 Physical properties of subsystem components

The potting beds will be made primarily out of ½" pine plywood and constructed using 1" long Phillips flathead wood screws. The beds will feature two arched end pieces connecting a large box in between (See Figure 39). The box itself will be 7" x 2'6" x 6" (LxWxH), with the arc on each end piece adding an additional 2 inches to the height (See Figure 40 and Figure 41). The sides of the bed will slant inward at about an 11-degree angle. Plumber's putty will be coated over the interior edges of the box, effectively sealing the beds, and preventing any water leakage. Drip irrigation does not release excess amounts of water, so no drainage holes are needed in the base of the beds. A 1" diameter hole will be drilled into the top section of each end piece, allowing a 2" long, 1" diameter PVC pipe to be glued inside snugly. This pipe will hold the bed in the rotating wheel mechanism as it rotates while allowing gravity to keep it upright (See Figure 42).

Material	Dimensions	Quantity
Pine plywood	½ in. x 2ft. X 4 ft boards	3
Phillips flathead wood screws	1" long	36

PVC pipe	1” diamer, 2” long	6
Plumber’s Putty	3 oz	1 10 oz container

Figure 39: Looks-Like model

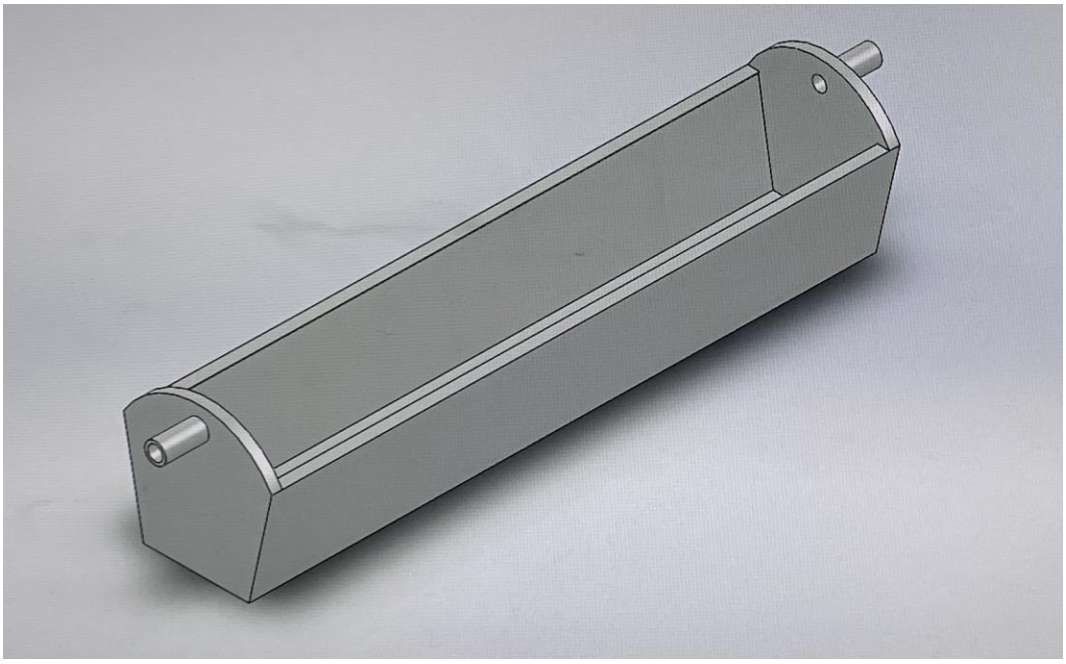


Figure 40: Front Face

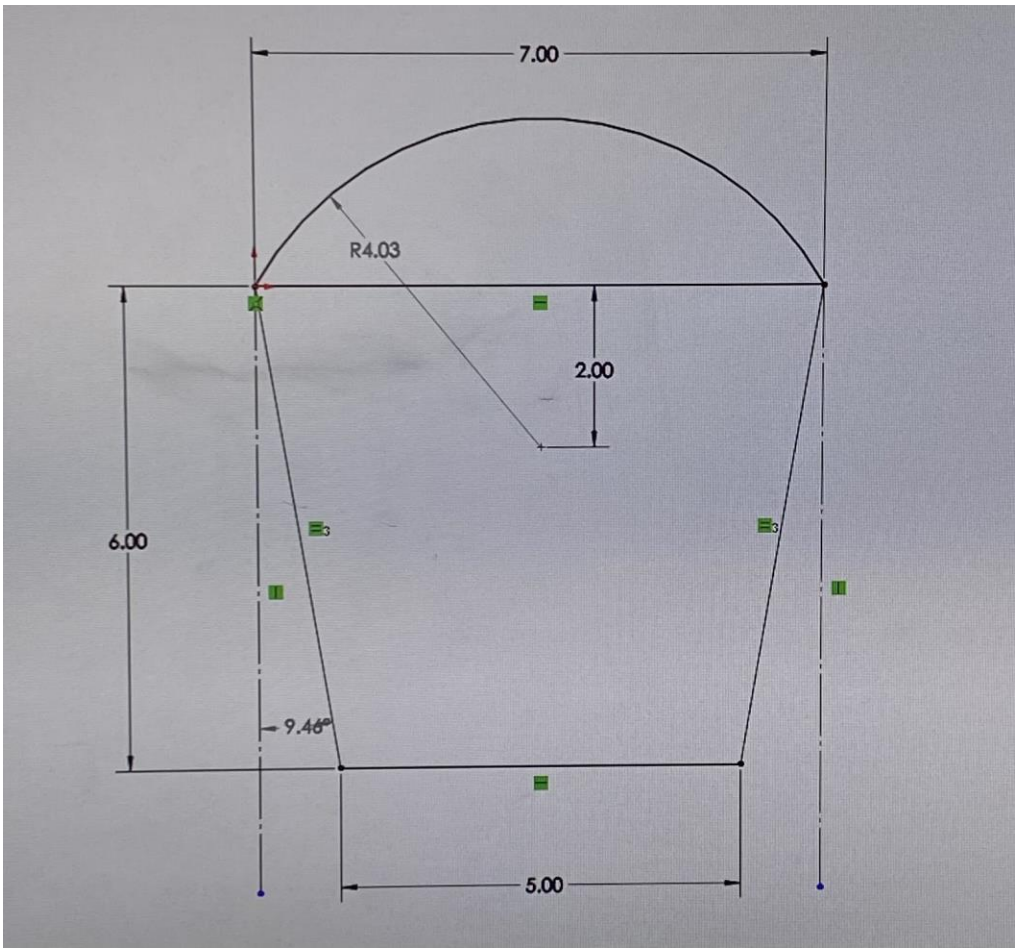


Figure 41: Side face

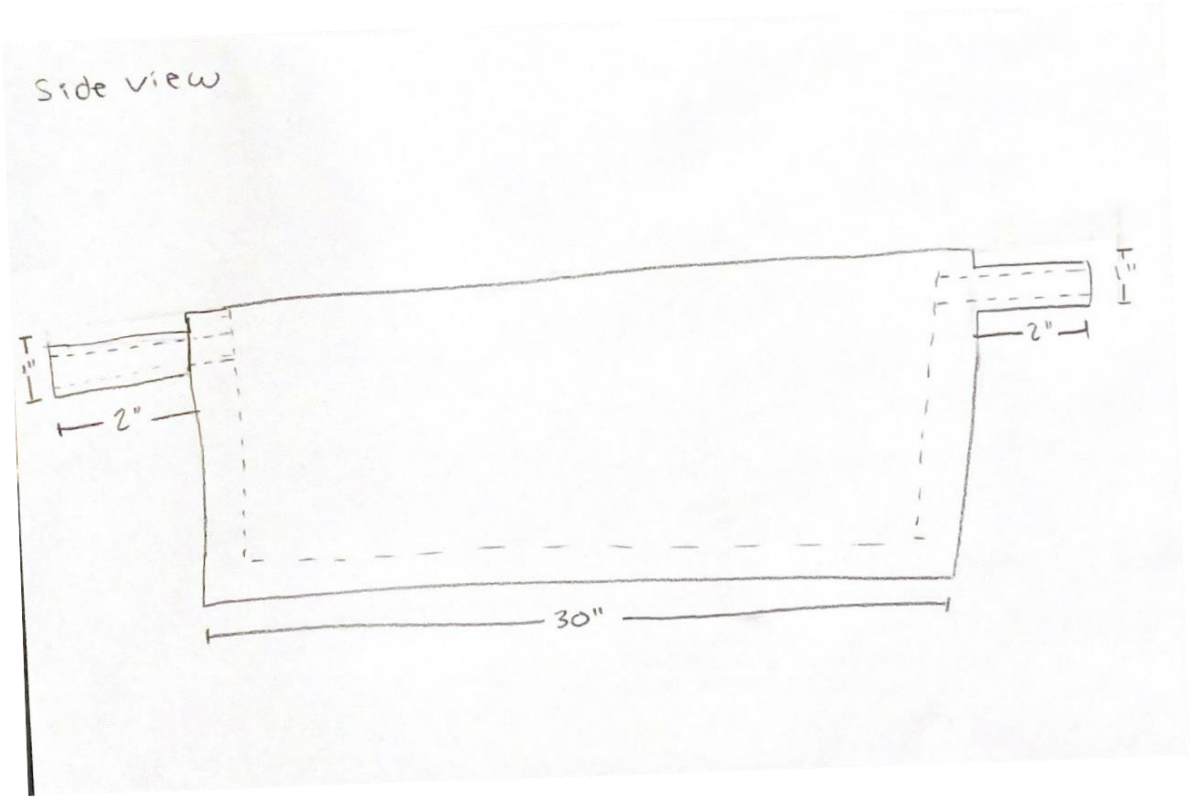
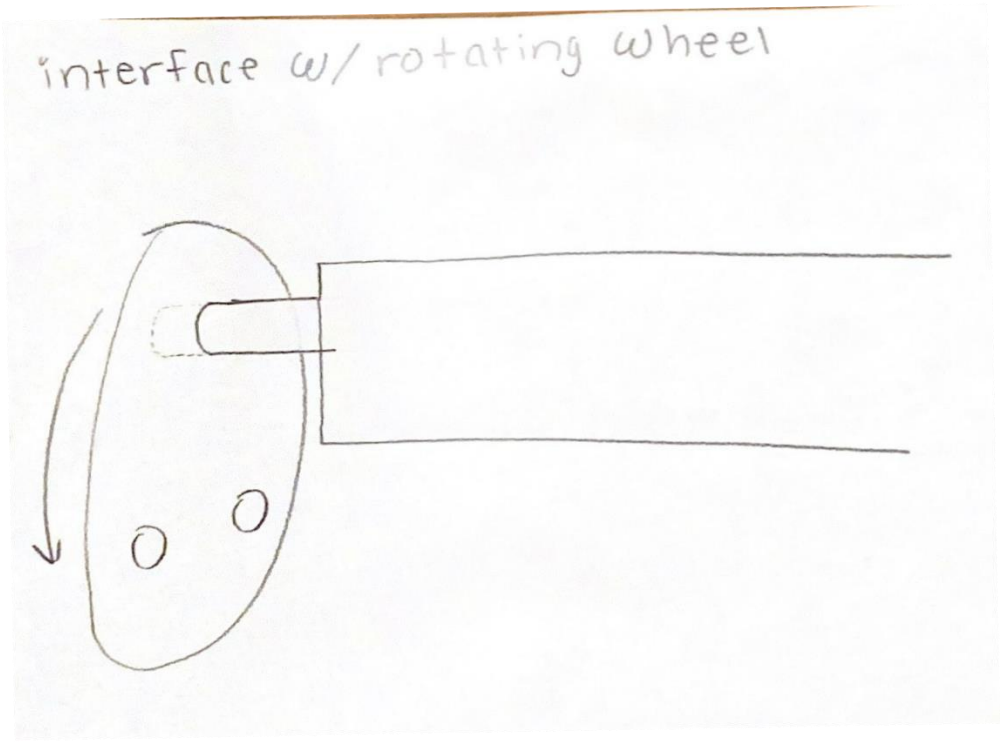


Figure 42: Subsystem Interface with Rotating Wheel



Total Mass: 3.05 lbs (see 3.3.1)

3.2 Decision Making Tools

A decision matrix was used to determine the ideal material to make the potting beds. The results can be summarized below (Figure 5):

Figure 43: Decision Matrix - Material

Material	Cost	Usability	Durability	Aesthetics	Total
Wood	3	8	9	9	21
Metal	4	5	8	7	19
Recycled Plastic	7	5	5	6	18

Figure 43: Decision Matrix - Material (Scale: 1(least practical/worst) - 10 (most practical/best))

Wood was chosen to be the material of the potting bed base. Although it would be the most expensive, it had the highest durability and looks the most aesthetically pleasing. Additionally, metal and plastic would both be hard to work with in comparison to wood, where all the tools necessary for woodworking are available to us.

Additionally, the principle of having a single bed throughout the system as compared to individual holes in a base where plant pots could be inserted was also contested. A second decision matrix was used for this scenario:

Design	Variety of Plants	Cost of Material	Ease of Irrigation	Total
Single Bed	6	7	9	22
Individual Pot Holders	9	5	2	16

Figure 44: Decision Matrix - Usability (Scale: 1(least practical/worst) - 10 (most practical/best))

A single potting bed was chosen to be the final design of the potting bed mostly because it would require an easier irrigation system as compared to individual potholders. A key feature of the Rotating Garden is its ability to water itself. Drip irrigation could be used in a single potting bed, which would produce little waste and effectively water the plants. An alternate irrigation system would be needed to water individual pots, such as misting, which would produce a lot of wasted water and be a very messy procedure. Additionally, a single potting bed is a good option because it would be more versatile and not restrict the size of potential plants by limiting its pot size to a certain dimension. This would allow a wider array of plants to be planted in the beds.

How to connect the different pieces of the bed was also an issue. Wood screws, wood glue, and hot glue were all considered. A test was performed using each of these varied materials, and screws were declared the most practical for long term use (See Section 3.3.1 for more comprehensive test results). This is because of their durability and quick set time.

3.3 Subsystem Validation

3.3.1 Test results from prototyping

When trying to determine which material would be the most suitable for potting beds, I performed a test using small strips of wood and the three contested materials: wood screws, wood glue, and hot glue. I cut small squares of wood with edges slanted at 45-degree angles to mimic the design of the true version.

Figure 45: Wood squares

To test the screws, I first drilled two pilot holes into the wood to make the process of screwing them together much easier. I then screwed them together using a drill and a screwdriver insert.

I then tested the wood glue by coating one edge of a piece of wood with glue, and then sticking the other side on. This same method was used to test the hot glue. The final products can be seen in Figure 46.

Figure 46

After the glue had dried, I tested the strength of each binder by pulling on the two pieces of wood and noting how hard it was to separate the two. The ease of using the material was also evaluated. The results are summarized below:

Material	Ease of use	How hard it was to separate	Total
Screw	4	9	13
Wood Glue	8	4	12

Hot Glue	8	3	11

Scale: 1 (hardest to use, easiest to separate) - 10 (easiest to use, hardest to separate)

Because screws were the hardest to separate and had the most durability, they were chosen to be the binder. This durability shows that the screws will last the longest and be less prone to breakage, which damages our product. Although they were the hardest to use, they didn't require any time to set, which saves a lot of time.

3.3.2 Analysis and calculations

A CAD model was built to simulate the design of the potting beds (See Figure 39 above). By setting the material to "Pine Wood" and using the mass properties tool, the total mass of each potting bed was found to be about 3.05 lbs, which provides an estimate as to how powerful the motor must be to effectively rotate the beds.

3.3.3 Secondary Research

According to Aragão, a plant pot of 6" is about right for most types of common indoor plants, like basil, thyme, and daisies [31]. The potting bed has a depth of 6", so it will be the perfect size for most common indoor plants to send out roots and develop in a healthy environment without being cramped.

3.4 Interactions with Other Subsystems

3.4.1 Interface description

The potting bed interface is responsible for holding the plants and soil, as well as the irrigation tubes and grow-light units.

3.4.2 Key interfaces and exchanges

Rotating Wheel

The PVC pipe ends of the potting beds slide into the rotating wheel of the frame, allowing the beds to rotate along with the wheel.

Irrigation System

The tubes of the irrigation system enter the potting beds through the PVC pipes, and then run along the bottom of the beds, allowing the soil and plants to receive the proper amount of water necessary.

Grow Lights

The bottom of the beds is lined with grow lights, allowing plants to still receive light, even if its potting bed is not at the top where sunlight can reach it.

References:

[31] Obede da Silva Aragão, O., de Almeida Leite, R., Araújo, A.P. *et al.* Effect of Pot Size on the Growth of Common Bean in Experiments with *Rhizobium*. *J Soil Sci Plant Nutr* 20, 865–871 (2020). https://doi.org/10.1007/s42729-020-00172-7

3.1 subsystem description

My subsystem is the frame that brings the entire product together. It is the base that holds all the other components and allows them to function as intended. The objective of the subsystem is to provide a strong and stable base for all the other components to come together and operate as intended to fufil the function of the product.

The subsystem works by taking all the required aspects of the other subsystems and creating a place where each part of the product can come together and work efficiently together. The subsystem relies on inputs from every other subsystem at every step. Each part of the subsystem is dependent on the other subsystems. The subsystem accomplishes this by taking the dimensions of the components of the other subsystems and accommodating for them within the design of the frame.

The only components of the system are the frame itself and the rotating wheel that the shelves and motor attach to (one of each for each side). Both of these components must be custom made pieces specific to the desired dimensions required to house all the components.

3.1.2 physical properties

Material: wood; thickness .25in

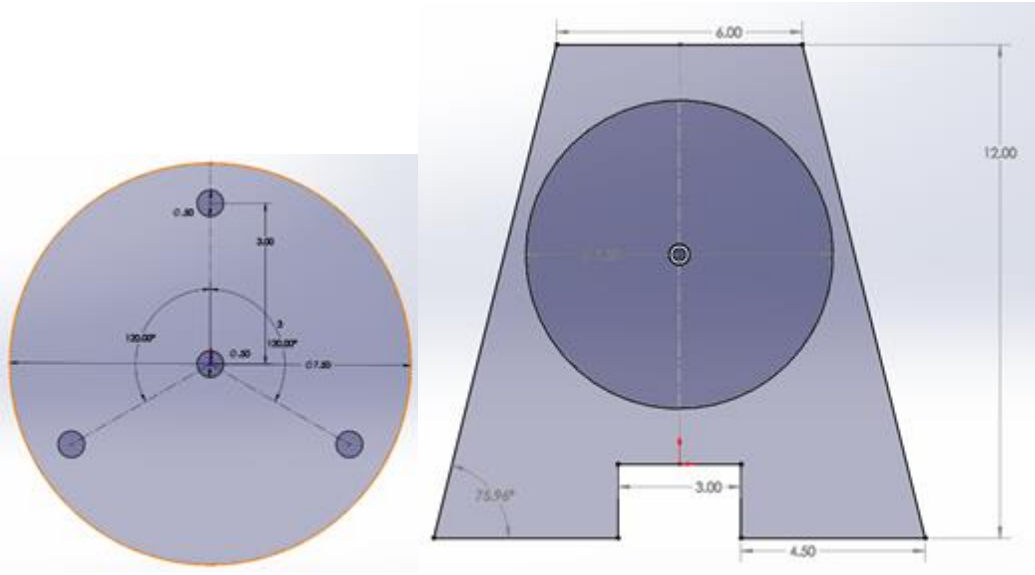


Figure 47:Technical Sketch

Each side has one of each of these components (with minor differences on each side)

The depth of the side piece with the motor is 3in and the side without 1in

3.2 alternate designs

Location of each subsystem within the frame.

Decision to put electrical and water on different sides to prevent problems with water leaking onto electrical components.

My initial design had all the other subsystems on the same side (apart from the shelves themselves which are not held within either end piece). This left me with unused space in the other end piece. I then thought of ways that this space can be used, and it then occurred to me that the drip irrigation system can be held within this space, and it would be beneficial as it would prevent the failure of other (electrical) systems in the event of a leak.

I also ended up changing the diameter of the wheel from 8in to 7.5 in due to a stakeholder's concerns that the thinnest points of the frame would be too weak to support much weight placed on top of it. As designed, there is no additional weight being placed on these points however, in real life there may be a situation where there is a heavy object placed atop one of the end pieces creating additional strain on these weak points.

3.3 validation

3.3.1 test results

I used solid works to build a 3D model of each component of my system so I could dimension the frame properly to hold each subsystem. This testing has resulted in the following models.

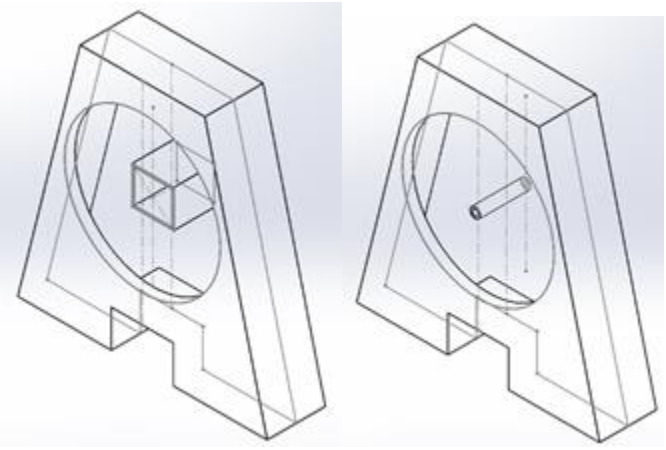


Figure 48

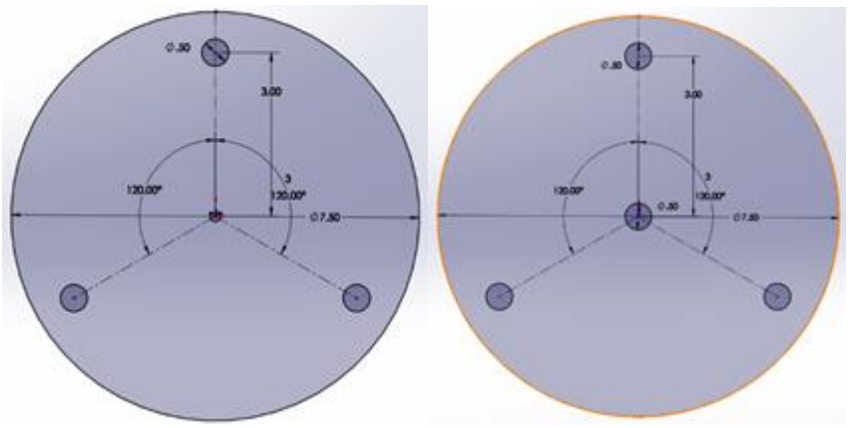


Figure 49

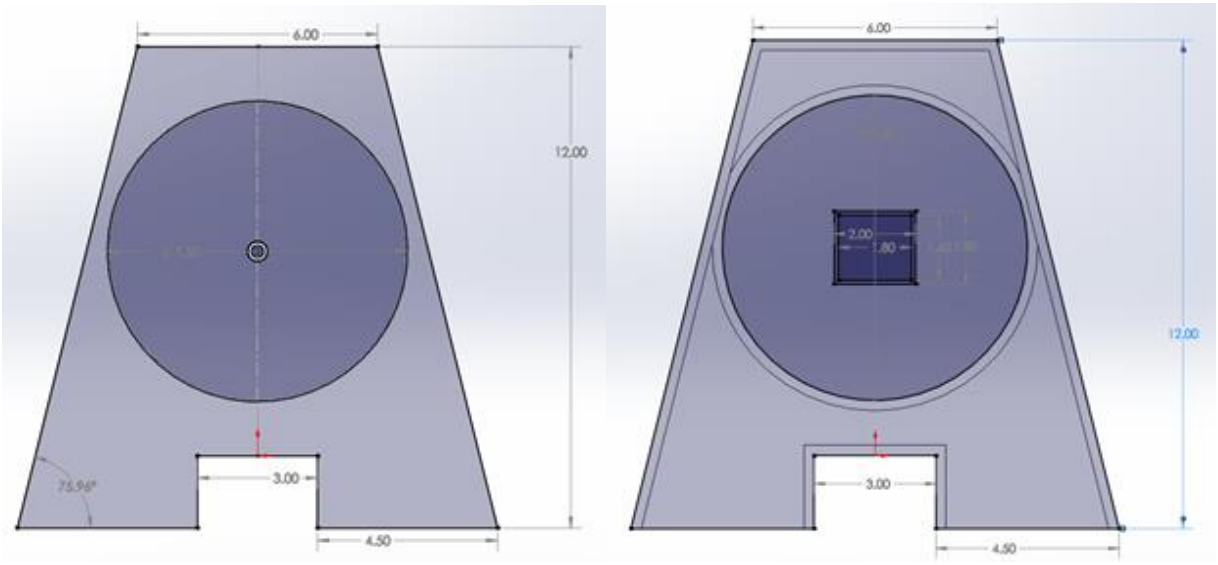


Figure 50

3.3.2 Analysis and Calculations

Given the dimensions of the components above and the projected dimensions of the other subsystems there is ample room for each system to operate as needed.

The distance from the center of the attachment holes for the shelves to the floor is 2.25in at scale which leaves more than enough room of the projected height of 1 2/3 in of the shelves at the same scale

3.3.4 stakeholder feedback

I had another interview with a stakeholder in which they expressed their concerns with making sure that the frame is strong enough for those two weak points discussed earlier as well as concerns of the wood scratching the floors. I plan to prevent scratching the floors by installing felt padding on the bottom of the frames.

3.1 Electrical Subsystem

Author: Iseah Hasan

3.1 Subsystem Description:

This subsystem focuses on the electrical components of the prototype, which will help power both the motors and the lighting components. Additionally,

3.1.1 Functionality and key components:

The dimensions of the electrical system will comprise of the main AC (Alternating Current) cable being about 8 ft. long, while the internal wiring will be at least a few ft. long.

3.1.2 Objective:

The key components of this subsystem will be the wiring, where the AC cable will connect our prototype with an electrical power source. The AC cable will connect to the internal wiring, where the Arduino will be given a certain amount of voltage to be powered, as well as the lighting and other components. The Arduino will power the mechanical components of our prototype, which will help rotate the shelves at various times of the day. The purpose of this electrical subsystem is to enable electrical power supply to help power the prototype.

3.1.3 How the subsystem works:

To make this product functional, electrical power supply is necessary as it will help run Arduino, while it will also power the lighting component, which will give artificial sunlight to the plants. For Arduino, the wiring will provide about 4.8 volts to the motor, while about 12 volts will be supplied to the lighting component.

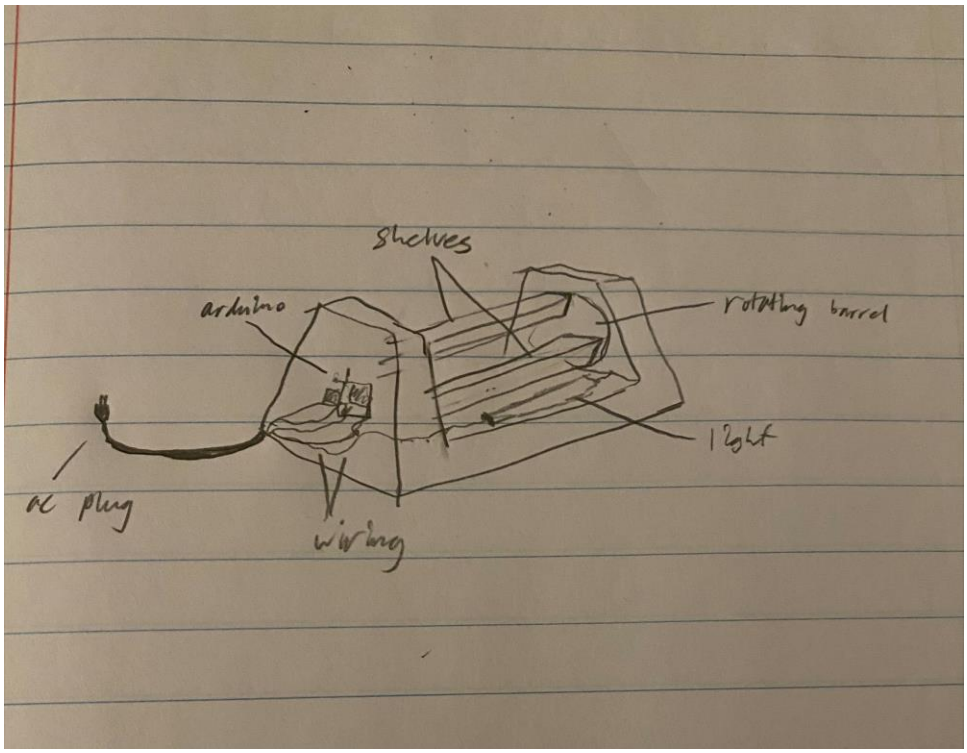


Figure 51: Sketch of wiring throughout the prototype

3.1.4 Required Inputs:

The only input for this subsystem is electricity, which is also the most crucial input. The AC cable will provide the external electrical supply by plugging into a power outlet, which will flow through the wires and provide electricity for the system components. Additionally, the resistors will also help to manage the amount of voltage distributed for each component of the prototype.

3.1.5 Key components:

The main component of this subsystem is the main wiring, which is the AC/DC cable, as well as the internal wiring, which will connect the mechanical, lighting, and irrigation components.

3.1.6 Off the shelf components:

The main wiring that will be used is the AC/DC power cables, along with some 18-gauge silicone copper wires. Additionally, there will be some resistors and other components that will be used to manage the number of volts being distributed. Finally, there will be series of LED

strip light (Figure 53) that will light up the plants as they rotate. Additionally, they will also be provided power by being plugged into an outlet using an external AC power cable (Figure 54).

Figure 52: 18-gauge silicone wire

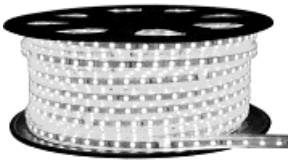


Figure 53: LED strip lights

Figure 54: LED strip light AC plug-in adapter

3.2 Idea Generation:

3.2.1 Electrical:

An alternative for providing power supply that was considered was using a battery instead of plugging in the prototype to an external power source. A possibility of implementing this system would require using something like a 9V battery, while using only low-voltage cables to power the prototype. While this seems more simpler compared to using AC power, it will probably not be enough to power the motors and other components, given the size and weight of the entire product.

3.2.2 Validation:

3.2.2.1 Test results:

I performed a demonstration where I tested out the LED light by plugging it into an external cable, which is connected to a power source. As a result, the light worked as expected.

IMG_8025.mov

3.2.2.2 Analysis and calculation:

With the lights providing about 12 Volts each, it will be sufficient enough to light up the plants within the given scale, as they provide a rough resemblance to daylight which plants usually obtain to grow.

3.2.2.2 Secondary Research:

There were some websites that provided information regarding how much voltage do certain bulbs accept, which in this case, would take around 12 to 24V DC. Additionally, an article from a lighting product website indicate how LED light strips usually "run on low voltage DC, they require a power supply device that converts 120V/240V AC into the voltage signal that LED strips can use" [32], which would address the voltage difference and prevent the risk of short circuiting. This helped guide me into deciding what type of wiring would be necessary for safely distributing electricity to the lights while using an external power source.

3.3 Relevant interfaces:

3.3.1 Interface description:

The electrical subsystem interacts with most of the other subsystems within the product, including the programming of the product. The electrical subsystem will help power the Arduino, which relies on code to control the motor and the irrigation timer, as well as the lighting. While the code executes the actions controlling the other components, the electrical current will be distributed to those components when they get turned on.

Works Cited:

[32] "How to choose a power supply for your led Strip Project," *Waveform Lighting*, 16-Jan-2018. [Online]. Available: https://www.waveformlighting.com/home-residential/how-to-choose-a-power-supply-for-your-led-strip-project. [Accessed: 13-Apr-2022].

4. MODULE 4: SOLUTION DESIGN, VALUE PROPOSITION, RISK, & MITIGATION (BRIEF) – Team Authorship

4.1. Solution value proposition, the comparison of costs and benefits:

4.1.1. Cost and comparison to alternatives

The retail cost of our product will be roughly $550. This price accounts for materials cost, labor hours and any capital going into separate accounts (i.e., insurance, liability, profits). In the retail model, we will utilize aluminum instead of plywood (Figure55). Similar products do not offer the lighting and irrigation aspect of the rotating shelves. Our product is the only product that offers all aspects of the design in a singular product.

4.1.2. Materials list and cost estimation for proposed full scale final product or system shown in a table.

Subsystems	Material	Cost of Material (Actual)	Cost of Material (Prototype)	Cost of time and labor
Rotating Component	Arduino	$36	$23	1 hour - $13
	Bread Board	$20	$10	1 hour - $13
	Servo	$35	$6	0.5 hour - $6.5
	Battery	$20	$10	1 hour - $13
	Wires	$16	$8	2 hours - $26

Potting Bed	Plywood Sheet (x2)	$40	$18	3 hours - $39
	PVC Pipe	$5	$3	
	Screws	$6.30	$2	
End Frames	aluminum sheet 48'x 48'x 1/8' (x2) | Plywood Sheet (x3)	$174.76	$27	4 hours - $52
Irrigation	Connectors	$3	$10	2 hours- $26
	Adaptor	$1	$2	
	Plumbers Putty	$6	$7	
	Valve	$35	$20	
	Tubing	$10	$15	
Electrical Component	16-gauge DC Wires	$14	$14	2 hours - $26
	Lighting component	$17	$17	0.5 hours - $6.5
	Resistors	$10	$10	0.5 hours - $6.5
	Total:	$449	$206	$227.50

Figure 55: Table of costs regarding prototype and retail product

4.1.3. Real benefits, both quantified and unquantified

Our product can decrease depression amongst the elderly and decrease injury among the elderly. Plants are scientifically proven to increase serotonin levels and decrease loneliness, which would greatly improve the quality of life for the elderly. Gardening can also prove to be hazardous for those with decreased mobility and balance issues. Thus, the rotating garden prevents potential harm, decreasing medical costs. Our product will also be made from aluminum that does not rot, making it so we can ensure that it is built to last.

4.2. Risk and mitigation discussion and table:

4.2.1.

	Likelihood	Impact	Mitigation	Mitigation Plan
Flooding	5	3	Low	seal all edges/joints and use waterproof equipment
Mold	8	3	Low	Proper drainage
Fire Risk	4	6	Medium	proper wiring/ preventative materials (aluminum)
Trip Hazard	3	6	Medium	avoid hanging wires
Impacted Vision	7	7	High	provide a warning
Motor Malfunction	3	8	Medium	Warranty

Structural Integrity	3	3	Low	Warranty
Product Defect	3	5	Medium	Warranty
Electrical Risk	5	9	High	ensure proper wiring and waterproofing

Figure 56: Risk Mitigation Matrix

4.2.2. Risk Mitigation Plan:

The benefits of our product will outweigh the risks because most of these risks can be solved with simple caution or a warning and warranty. The only real risk we have is the possibility of the water interfering with the electricity that powers the rotation motor and the UV lights. To combat this, we will ensure that there is no faulty wiring, and that the irrigation subsystem has proper waterproofing. Overall, the injuries and the harm that will be prevented by our products easily overshadow the risks.

4.3. Citations and References:

[34] Turbert, David. "The Sun, UV Light and Your Eyes." *American Academy of Ophthalmology*, American Academy of Ophthalmology, 19 June 2020

[35] Vigstol, Derek. "Electrical Safety around Water." *NFPA*

Conclusion: (Feedback from judges)

- Consider alternative designs, like a lever instead of the motor.
- Good idea to tackle 2 big problems
- Good spread of skills in the team
- Think about the economic side a bit more, specifically profit