Happy Garden: Easy Gardening Tools

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Augmenting Human Dexterity – Spring 2022

Term Project: Gardening Assisting

Abstract

Gardening is commonly regarded as a hobby among people. For older people with underlying conditions, gardening can pose additional problems of hand fatigue or user injury. Thus an assistive device is needed for those who encounter such problems during gardening activities. Hypotheses were made based on literature research, and an in-depth interview was held with a need-knower who was a gardening enthusiast. Two main criteria of safety, ease of use, and a specific task of pruning were confirmed to be our direction for the design. Based on the information learned from the research, we designed and prototyped an assistive pruning shear that helps save effort and prevent user injury with a motor-driven grasper to hold the pruned shears. A human subjects study was also proposed to test the effectiveness of the device, while approval from IRB is required prior to the study.

I. Introduction

Gardening is an activity with different types, aims, and benefits. When regarding gardening as a household activity, it has the benefits of building self-esteem, reducing stress mentally[1], and is able to provide substantial human health benefits [2]. These years, the world horticulture market is worth more than two hundred billion and growing at the rate of 10% [3]. It is hard to tell how large the affected population is since it is a process of dynamic growth. With the importance of sustainable development being considered much more compared to the past, with more and more people starting to pay more attention to their physical and mental health, gardening is now acting an important role for the whole world beyond doubt.

At the same time, the abundance of the injured from gardening cannot be ignored. In 2020, LawnStarter's data analysis showed that "in the past decade, U.S. emergency rooms reported an estimated 3,195,333 injuries tied to lawn and gardening equipment. That amounts to an average of 319,533 per year or a little over 875 per day. Injuries include amputations, burns, nerve damage, broken bones, cuts, and bruises [4]." One of the reasons for the injuries was like Dr. Peter Mace, the assistant medical director of BUPA said, "Anyone planning to spend time gardening or decorating should remember they may be using muscle groups and joints they haven't exercised in a long while [5]."

In order to improve the experience of gardening and reduce the negative effects resulting from the activity, especially for those who may put them at a higher risk of such injuries, our team planned to design an assistive gardening tool for a specific task.

A. Background

We searched papers online at the beginning of the project. Some papers discuss the relationship between gardening and physical mental health.[6] [7] Those papers all point out that gardening activities are accompanied by exercise and careful cultivation, which will be enjoyed by gardeners. So the gap is a tool that can improve both gardener's health and gardening efficiency. However, there may be safety hazards in the process of gardening such as fatigue and stab wounds. Thus, the tool is also needed to guarantee users' safety.

B. Overview

We hypothesize that an assistive gardening device that guarantees safety and ease of use increases mental and physical health and efficiency of gardening in older adults who enjoy gardening.

In section II, we motivate the design of a specific assistive technology platform from an interview with an older adult who used to garden frequently but feels fatigued during certain tasks. Also, in tasks such as pruning roses or other prickly plants, he would get injured by the thorns. In summary, safety is a critical factor for prospective devices.

In section III, we introduce the pruning shears, a set of shears that (1) improve safety by griping cut objects to prevent dropping on the person and (2) motorized the cutting action to reduce hand fatigue. We will discuss it from three aspects - mechanical, electrical, and assembly. A study that evaluate this device is also proposed.

Section IV describes the intellectual merits, compare traditional shears with our prototype. And section V describes broader impacts, including the future work and applications in broader areas.

C. Study Plan

- search and study literature online.
- recruit a gardening lover who is in his or her mid age.
- develop an investigation plan and schedule a time with the gardening lover for the interview.
- determine the project direction
- have CITI training but would need IRB approval prior to conducting this work.
- build a prototype
- give the gardening lover the shears and provide instruction and practice with the device for 30 minutes. They will be asked to use the device while gardening for 1 month. We will then survey the gardening lover to get their attitudes and opinions on the device.
- keep improving the prototype

II. Preliminary results

In order to guide the design of a specific device for testing, we reached a need-knower, a male in his mid-age who takes gardening as his greatest hobby. We interviewed him to get more information about his experience and thoughts on gardening.

During our interview, there were some impressive quotes and moments that strongly influenced our direction. The interview was 60 minutes long and conducted over Zoom. Through this application, we were able to visually see his movements and record a transcript of the conversation for analysis.

A. Criteria: Safety

Our need knower described the safety of his current weeding machine detailedly. Though he is not an expert neither in gardening nor in engineering, he could still list the designs on the weeding machine that make it easier to use without referring instructions and prevent user injury. We believed that his safety awareness made him notice these functions of the wedding machine. Like he said later, “safety is always the most important criterion of a product”.

B. Criteria: Ease of Use Entertainment

One thing our need-knower mentioned was that though there were a large amount of high-tech gardening machines produced by Germany, he had no interest in them at all. In his opinion, machines with high technology are too complicated to be used by a non-expert. Another reason that impressed us was that by his understanding of the machine did all the work instead, no more fun would be left for humans. This quote reminded us of the information shown in the literature that gardening was regarded as a moderate to high-intensity physical activity that does well for human health. That information indicated the importance of considering the criteria of entertainment and ease of use in our design, which could keep us on the right track to designing a gardening helper rather than a substitution.

C. Task: Pruning

When asked about the trouble encountered during gardening, and the most important task for our need-knower, the answer cohered to the same task, which was pruning. As he said, pruning was what he did daily for gardening, and was also where he got tired and even hurt the most frequently among all the gardening tasks. Injury would happen when he pruned the plant with thorns on the stem such as the rose. And he would feel a great score on hands after pruning for some while.

Above were the triumphs of the interview which helped us confirm the most important criteria that we need to consider and meanwhile point to some specific tasks that we could focus on.

As our extracted primary needs, they went along with the order of “Be totally safe to use”, “Be easy to use”, “Include electric parts to save manual strength”, and “ Focus on the task of helping with cut the branch with sufficient protection and efficiency” and “Bu fun to use”. In particular, given the prior experience of the need-knower during pruning, we decided to investigate a device capable of supporting this activity.

Summary

Based on the information gathered from the interview with a need-knower, we confirmed to address the needs above with our product design. In summary, two criteria of safety and ease of use and a specific task of pruning were considered as the primary needs of our product. These three needs will also be considered in our proposed study on testing and refining.

III. Methods

We investigated existing pruning shears. Though there are various designs of blades and grips and some of which are ergonomic-labeled, there are no specific designs that help users save effort or prevent user injury. Besides, A. B. Tebben and J. J. Thomas conclude that ergonomic-labeled tools may not produce better hand positioning [8]. A more detailed user experience of an existing pruning shear can be found in Appendix B.

After analyzing and using the existing pruning shear, we set our prototype goals to be effort saving and injury prevention. Considering that many gardeners keep roses, which have thorns on their stems, an improved pruning shear with a grasper that holds the stems could help reduce the risk of user injury. The grasper also eliminates the need for gardeners to pick up those pruned branches.

A preliminary concept of the assistive tool (see Figure 1) was generated to address the significant needs of the need-knower and be a prototype basis. Other than the pruning function, the tool grasps the pruned

stems and branches in order to prevent the thorns from hurting the gardeners. A rubber grasper located above the blade grasps the plant tightly during the pruning process and remains to hold them after they were pruned due to the spring and slot mechanism. Then when reaching the place to properly deposit the pruned plants, the gardener can release the shear and deposit the branches by pressing the button again. A motor is also integrated to help reduce hand fatigue so as to grant more continuous pruning activities. The figure below shows the rendering pictures of the concept tool.

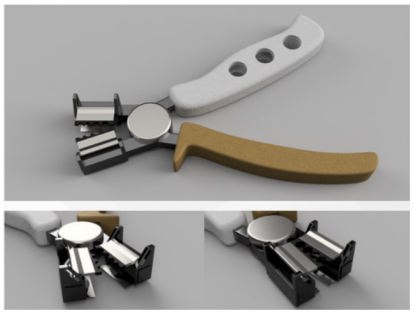

Fig. 1: Assistive pruning shear concept

Then a prototype (see Figure 2) was made based on the concept. 3D-printed grasper helped realize the ”cut and hold” function, and a sponge was used to increase friction. Driven by Arduino, a motor could help gardeners save effort. Figure 3 shows the time when the shear grasped the pruned branch during the test. The detailed design methodology is documented in Appendix C.

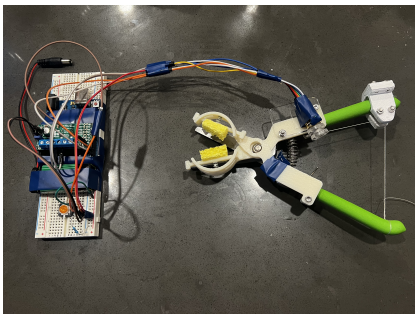

Fig. 2: Prototype of assistive pruning shear

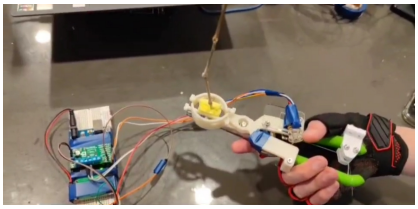

Fig. 3: Pruned branch in the grasper

To test the effectiveness of the device, we proposed a human subjects study, which is documented in Appendix D. All of the team members have received CITI training, but we will not run this study prior to acquiring IRB approval.

IV. Intellectual Merit

Compared to the assistive pruning tool introduced in this paper, traditional pruning shears are similar to scissors, which do not have any additional design to provide user protection. Current manufacturers only focus on designing blades and frames that help cut plants more quickly and efficiently, but not other needs from gardeners other than just pruning. This assistive pruning tool may provide an alternative improvement path for pruning shears for current manufacturers. The proposed study will also inform future work and understanding of the potential of assistive gardening tools to produce positive outcomes for older adults at risk of injury.

V. Broader Impact

In summary, this assistive pruning tool further enhances the user experience of gardeners by preventing injury and saving effort. Meanwhile, it is simple and easy to be operated similarly to the traditional pruning shears which are familiar to the consumers and maintain the entertainment and the chance to have the exercise for the users.

This design is not something full of high tech, which means everyone can easily understand how it works. Think more broadly, the designer and the engineer can be inspired and create more devices that associate with the labor force without damaging the user experience, the consumers would thus have more choice of products to fit their requirements. The Horticulture industry can further develop related industry chains and expand market shares to drive industrial development. What's more, as an activity relates to agriculture, the development of the device chain can even promote the balanced development of the agricultural structure.

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APPENDIX A
DISCOVERY DECOMPOSITION

Topic of the interview: everyday manual activities with hemiparetic stoke.

1) A Survey on Smart Irrigation for Home Gardens: [9].

- Background/Hypothesis: This paper is about Green household automation,a home watering system. Some plants may be left in danger of environment changes. If owners leave them for a long time, they are hoping for monitoring and controlling a system to irrigate.
- Methods: Microcontroller, GSM module, LCD Panel keypad, solar panel,battery,pump, rain water harvesting system and moisture sensor
- Results: Advantages: The whole unit is powered by solar energy. Due to its advantages like less maintenance, fuel free green electricity generation. Disadvantage: Designed system design is expensive.
- Conclusion:The proposal system is cost effective, feasible which can be applied to the small-scale agriculture and gardens. By using this system, the human intervention is reduced. It consumes less water and less time.
- Test Hypothesis:Raspberry Pi will act as a computer. It is connected to the keyboard, monitor and mouse. It will operate in Linux.

2) Design and Development of an Automated Hand Shovel: [10].

- Background/Hypothesis: Trowels may impose stress and lead to musculoskeletal disorders(MSDs) in the wrist, elbow and shoulder of the user. However, not much work has been done in the field of developing a powered hand shovel.
- Methods: An experiment was conducted to capture the actual trajectory traced by the hand shovel during shovelling. The trajectory is recorded using 3D motion capture cameras (Qualysis Opus 5+). The strain in the aim was measured using eletromyography setup.
- Results: The average of the five best trials of each candidate has been plotted and superimposed along with the other six candidates. The average path obtained is a straight inclined profile at a slope $\theta = 51.14°$. According to the data, the team designed a prototype.

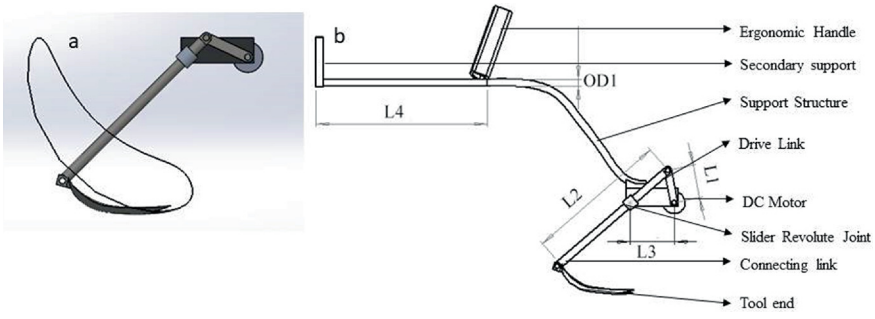


Fig. 4: The hand shovel design image

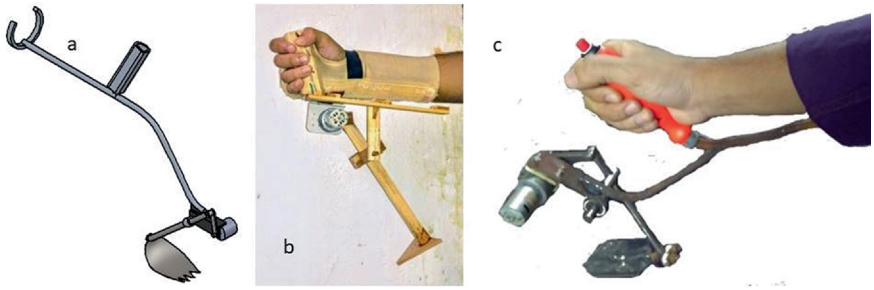


Fig. 5: The hand shovel prototype image

- Conclusion:This device will ensure higher work efficiency and reduce the strain on human arm during garden shoveling.
- Test Hypothesis:The candidate is to sit on one knee whichever suited and perform the shovelling task. Each candidate has to first try for minimum 15 times, and then data for the best five trials are recorded.

3) An SVM Based Irrigation Control System for Home Gardening: [11].

- Background/Hypothesis: It's difficult for beginners in home gardening to use existing agricultural support system, because they assume that users implicitly have expertise in agriculture.
- Methods: propose a support vector machine (SVM) based irrigation prediction control system for beginners in home gardening. The features of all examples are collected from various of sensors.
- Results: the team got the prediction error of the future soil moisture prediction model. And they found out that the error was small enough to ignore
- Conclusion:this paper proposed an irrigation support system for home gardening. And the remaining issues are developing an automatic irrigation control algorithm and evaluating an irrigation support system for home gardening.
- Test Hypothesis:must be based on a huge data set.

4) Gardening Equipment: [12].

- Background/Hypothesis: Garden catalogs and stores are full of gardening tools, many highly specialized; some are very useful, others are nice but not necessary, and some are gimmicks. You can get the best value for the price range you choose by knowing each tool's uses and particular qualities to look for when comparison shopping.
- Methods: taxonomy
- Results: The author divided all gardening equipment into 6 categories: tools for cultivating, pruning tools, carts/ wheelbarrows, pest control equipment, soil monitoring equipment and other equipment.
- Conclusion:The author introduced all equipment for gardening as well as purchasing methods.
- Test Hypothesis:taxonomy knowledge

5) Assistive Technology and Modification of Worksite: Key to Enable the Disabled in Gardening Activities: [13].

- Background/Hypothesis: There are millions of farmers with disability in India. The challenges are especially evident in case of individuals with disabilities involved in agriculture.
- Methods: Literature searching, reach out to farmers with disabilities and observe their daily routines.
- Results: Farmers with disabilities have to consult an occupational therapist for expert advice. Suggestions include: using tape, foam padding, bicycle grips and PVC pipe to improve grip and handle length on tools; finding specific ergonomic (designed to reduce discomfort) and enabling tools - these are available at some hardware stores; using gloves that have a sticky surface or gloves with gripper dots; using of splints and supports; looking for lightweight tools that are easier to handle…

- Conclusion:This article has opened up plethora of options for self-employment of such individuals in agri-business. Vigorous labour intensive-tasks involving the use of two strong arms, legs and back could now be performed easily by them with the help of highly automated machines or scientifically adapted agricultural devices.
- Test Hypothesis:should reach out to farmers with disabilities.

6) Gardening tasks performed by adults are moderate-to high-intensity physical activities: [6].

- BackgroundAssumption: MET is a measure of exercise intensity of physical activity. To benefit adult health, at least 30 minutes of moderate-intensity (3 to 6 MET) physical activity is recommended most days of the week.
- method: 15 college students completed 10 horticultural tasks, and MET values were obtained by pulmonary gas exchange measurements and breath-by-breath analysis using a portable telemetric calorimeter system.
- Results: 10 gardening tasks were identified as subjects' moderate to high intensity physical activity [3.5 ± 0.5 to 6.3 ± 1.2 MET].
- CONCLUSIONS: Adult gardening is moderate-to-vigorous physical activity that may confer health benefits such as reduced risk of chronic disease, improved health, and improved independent living.
- tests the hypothesis: Values ¡ 3 MET indicate low-intensity physical activity, 3 to 6 MET indicate moderate-intensity physical activity, and ¿6 MET indicate high-intensity physical activity.

7) Risk perception in the usage of electrically powered gardening tools: [14].

- BackgroundAssumption: Gardeners can be seriously injured when using power tools designed for cutting and pruning.
- Project Methods: Research methods include observing and recording user activities involving participants' behavior, their awareness of protective and hazard cues, and participants' experiences in the form of situational knowledge.
- Result: Power tools can cause more serious damage than non-power tools and require manual control to keep the trimmer active
- Conclusion: The results of this field study may provide clues for designers to improve the safety of electric garden tools. For example, by emphasizing product features that trigger risk perception, users may be more alert to risks in use.
- Test hypothesis: Epidemiological data provide a global description of the mechanism of harm, while observational studies provide a detailed description of the risk of user-product interactions.

8) Risk Assessment of Musculoskeletal Disorders among Gardening and Landscape Workers of Yazd Industrial Complex: [15].

- Project Background Hypothesis: Exposure to ergonomic risk factors in the workplace is one of the most common causes of work-related musculoskeletal disorders (WMSD).
- method: Analyze workers' job tasks using the Hierarchical Job Analysis (HTA) method. The working posture of 100 horticultural and landscape workers in an industrial park in Yazd province was assessed using the Rapid Whole Body Assessment (REBA) method. Finally, the Nordic Questionnaire (NQ) was used to estimate the prevalence of WMSD.
- Results: A significant relationship was found between aging and the prevalence of WMSD in the neck and wrist regions. In addition, a relationship was found between the severity of WMSD in the elbow region and the type of work activity.
- Conclusion: The working conditions of these workers should be checked and corrected from the perspective of ergonomic issues. It is recommended to understand occupational ergonomic hazards and how to reduce the risk of developing WMSD through the proper use of ergonomic principles.

- Test Hypothesis: This study aimed to assess the risk of work-related musculoskeletal disease prevalence in this group by scoring the rapid whole-body assessment of different gardening tasks.

9) A Review of Ergonomic Tools and Apparatus for the Ageing Population: [16].

- BackgroundAssumption: Population aging is a global phenomenon. Unfortunately, it appears that older adults often face problems dealing with everyday tools and equipment, in part because these devices are not designed with the limitations of older adults in mind.
- Method: Compare and review the target product with other conventional shovels to see if an ergonomic tool is better suited for gardening tasks.
- Result: Target Gardening Product Appel Spade is indeed an ergonomic product with good durability, good design, low maintenance and most importantly, user friendly
- Conclusion: A good ergonomic gardening tool, if used correctly, will reduce the chances of a user suffering repetitive stress injuries or suffering acute trauma while gardening. Also, a good ergonomic garden tool will not only add Efficiency also includes the ability and performance of the work done.
- Test hypothesis: Appel Spade, as the name suggests, is a spade made entirely of stainless steel, designed in a way that is user-friendly for gardeners with arthritis and other disabilities that cause stiff wrists.

10) Ergonomic evaluation of the effects of handle types on garden tools: [17].

- BackgroundAssumption: Traditionally, wood was used for most garden tool handles without taking into account the variety of materials available (Freivalds, 1986a). However, fiberglass has recently become a suitable material for garden tool handles. Fiberglass could be the handle material of the future because it is lightweight, easy to produce,
- Project Approach: Three different gardening tools were evaluated: shovel, rake and hoe, and three different handles: wood, solid fiberglass and hollow fiberglass. The most effective measure of a shovel is shovel performance divided by task effort.
- item result: Hollow fiberglass handles are efficient than wood or solid fiberglass handles. Grip strength and EMG analysis showed similar effects, with solid or hollow fiberglass handles requiring significantly less force than wood handles. Subjective ratings of perceived effort were also the lowest for the hollow fiberglass handle.
- Conclusion: Hollow fiberglass handles exhibit better physiological efficiency and better comfort, tactile feel and reduced subjective acceptance of slip
- Test Hypothesis: Subjective scoring of perceived exertion for overall handle discomfort, lack of tactility, and handle smoothness using the Borg's CR-10 scale. On this scale, lower numbers mean more comfortable or more accepting

11) The value of a gardening service for the frail elderly and people with a disability living in the community: [18].

- Background/Hypothesis: The research was done to explore the significance of gardening services for frail older people and disabled people living in the community. It's hypothesized that the group of people have difficulties and need help managing their own gardens because of their frailness and disabilities.
- Methods: Delivery interviews from both pre-gardening and post-gardening services, and collect qualitative and quantitative data from Housing Enabler.
- Results: Gardening services have a positive impact on the mental health of frail aged people and disabled younger people.
- Conclusion: Gardening service is fundamental for frail older people or younger people with disabilities to stay or return to the community.

- Test Hypothesis: It is important that subsidized gardening service could be provided for elderly and disabled people living in the community.

12) Trowels labeled ergonomic versus standard design preferences and effects on wrist range of motion during a gardening occupation: [8].

- Background/Hypothesis: Two hypothesizes are tested: whether using a trowel labeled ”ergonomic” would produce fewer extremes of deviation and palmar and dorsiflexion than with a standard-design trowel, and whether users will rate the trowel with “ergonomic” label as better and more comfortable.
- Methods: Randomly assign participants into two groups, using ergonomic and standard trowels. Data on wrist ulnar and radial deviation and palmar and dorsiflexion were collected, and participants were asked about their habits and preferences using trowels.
- Results: The t-test for extremes of dorsiflexion was not able to support the hypothesis. The comforts of both trowels were also rated nearly the same by participants.
- Conclusion: Further research is needed. For now, it is not proven helpful to choose garden tools based on the ergonomic label.
- Test Hypothesis: Trowels with ”ergonomic” labels were not able to make participants more comfortable and reduce extremes of deviation and palmar and dorsiflexion than standard trowels,

13) Gardening Adaptations for People with Gripping and Lifting Problems: [19].

- Health problems like arthritis, neurological problems, waning strength could make it hard to grip, grasp, or lift objects. E. Throckmorton and J. Powell give some tips to make gardening easier, like using plastic pots and replacing soil with Styrofoam packing nubbins. Step instruction of making an assisting tool was also given to make gardening easier. Other publications about gardening were also provided.

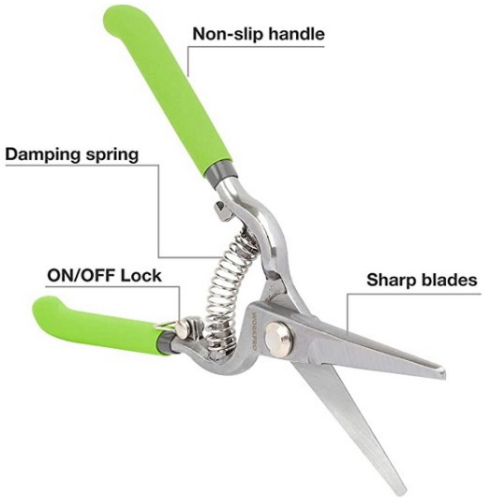
14) Improving Gardening for People with Arthritis: [20].

- Background/Hypothesis: Various forms of arthritis make gardening less accessible. A product is created to make gardening safer and less frustrating to everyone.
- Methods: After user research and product research, the results were analyzed and a concept was generated.
- Results: A detailed CAD model was generated, and a 3D-printed scaled-down prototype was made.
- Conclusion: The product will be able to reduce the pain and mobility issues during gardening, while the users are still able to gain benefits from the exercise.
- Test Hypothesis: This product is the solution to the problem that has been identified. It will solve the negative impacts from arthritis to gardening activities.

15) Getting to the root of the problem: Informing design through the exploration of the gardening experience of older women: [7].

- Background/Hypothesis: To explore the gardening experience of females aged 50+. The perception of the various tasks was mainly focused on.
- Methods: The research is based on an online survey, including a number of different gardening tasks and the motivations for doing gardening activities.
- Results: Questions were answered by participants about their gardening motivation, experience, and comparison of different tasks. Few of the older women choose to move heavy objects in the garden. This is more often done by their spouse/partner.
- Conclusion: Improving the ”moving heavy objects” task will support older women to do such tasks more independently. Improving tools is also important for their gardening motivation.
- Test Hypothesis: Improving on moving heavy object tasks through product design will possibly have positive impacts on older women’s gardening participation, well-being, and consequently health.

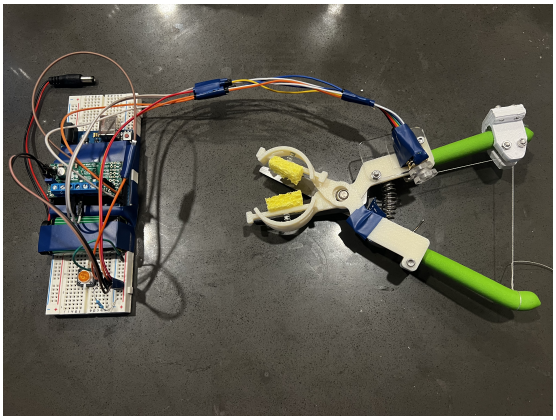
APPENDIX B
EXISTING DEVICE DETAILS



The pruning shear investigated and modified in this project is normally used in gardening activities. There is no protection cover for the blade, and the handles do not have ergonomic design. Having a structure that is similar to scissors, the shear has an extra spring that help it rebound, but taking more force to tighten it.

There are often a lot of branches to prune, so one time of gardening activity can include dozens of uses of pruning shear. We found that the branches that were clipped were all scattered on the ground, and it took extra time to pick them up. Meanwhile, after using the shear multiple times without the protection of gloves, our hands are prone to blisters, because each time we apply force to the shear, the hand and the handle will rub against each other.

APPENDIX C
INVESTIGATIONAL DEVICE DETAILS



A rubber grasper located above the blade grasps the plant tightly during the pruning process and remains to hold them after they were pruned due to the spring and slot mechanism. A button commands the motor to rotate in both directions for grasping and releasing. One button press gives a ”cut and holds” command. Then when reaching the place to properly deposit the pruned plants, the gardener can release the shear and deposit the branches by pressing the button again.

The prototype is made based on the purchased pruning shear discussed in Appendix B. 3D-printed parts and a 6V magnetic encoder motor are integrated onto the shear as the grasper and effort-saving function. The following subsections discuss the detailed modifying methodology.

A. Mechanical

The grasper frame (see figure below) is designed using Autodesk Fusion 360 and 3D-printed at Jacobs Hall. The hollow circle in the middle fits the bolt on the shear. Sponge (black parts) and springs (silver parts) are used to increase grasping force and are attached to the frame (blue parts) using glue.

B.Electronics

A 6V 2W magnetic encoder motor [21] was chosen for smaller size and speed/position monitoring. A string is attached to the motor and will be pulled to tighten the shear, so as to save effort during the gardening process. Arduino is used for controlling the motor for simplicity and universality. The program is able to control the motor with a momentary button and monitor its speed of it during the grasping process. The shear tightens when the button is pressed, and then the shear will release after the button is pressed again.

C. Assembly

Figure 4 shows the final prototype of the tool. The 3D-printed grasper frame (assembly drawing can be found in Appendix E) is clamped on the pruning shear using screws and shares the same center of rotation. The motor is fixed on the 3D-printed grasper frame using tapes and Laser cut boards. The button and micro-controller are wired on a breadboard that is not on the shear. In the future, the button could be integrated into the handles of the shear for easier operation, and the electronics could be attached to a glove.

D. Testing

After modification, the prototype grasps the pruned branches and helps save effort with a motor. During the test, the motor helped tighten the shear, and the grasper was able to grasp the pruned stem without sliding. A strong grip was not necessary to hold the shear since it could be fixed by the motor. The speed of the motor was relatively slow, but the pulley mechanism does not interfere with users so that they can also operate the shear manually like operating a normal one.

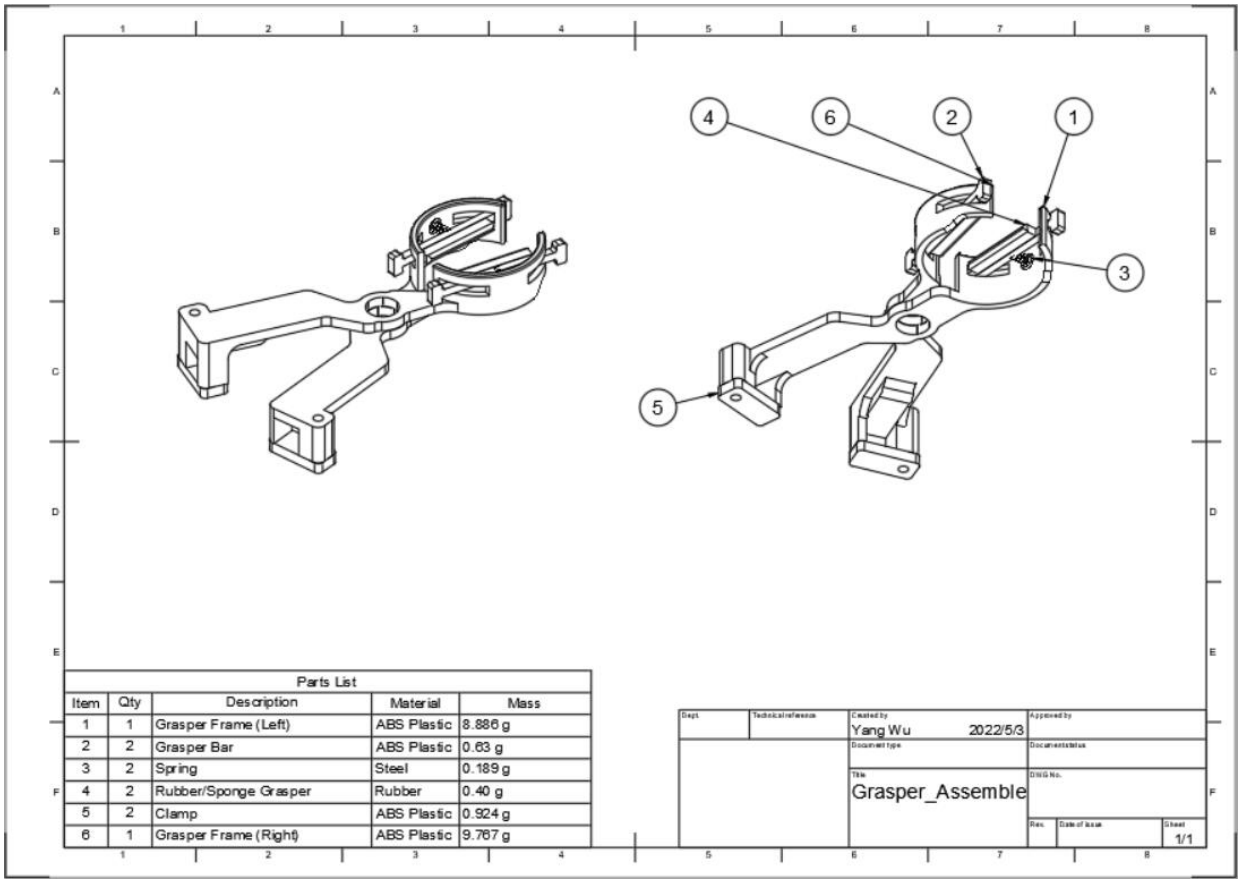
APPENDIX D
STUDY DESIGN

A human subjects study is proposed to investigate the effectiveness of the device. All the team members have already received CITI training. However, to conduct this human subjects study, the team will still need to receive IRB approval.

This device is mainly designed for older adults who do gardening as a daily hobby, and the test subjects should be around the age of 50 to 65. We are anticipating a total of 10 participants. The subjects will be given the shears and provided instruction of using and battery replacement. After around 30 minutes of practicing, they will be asked to use the device as appropriate with normal frequency during two weeks of use (the average using time should be no less than 4 hours per week).

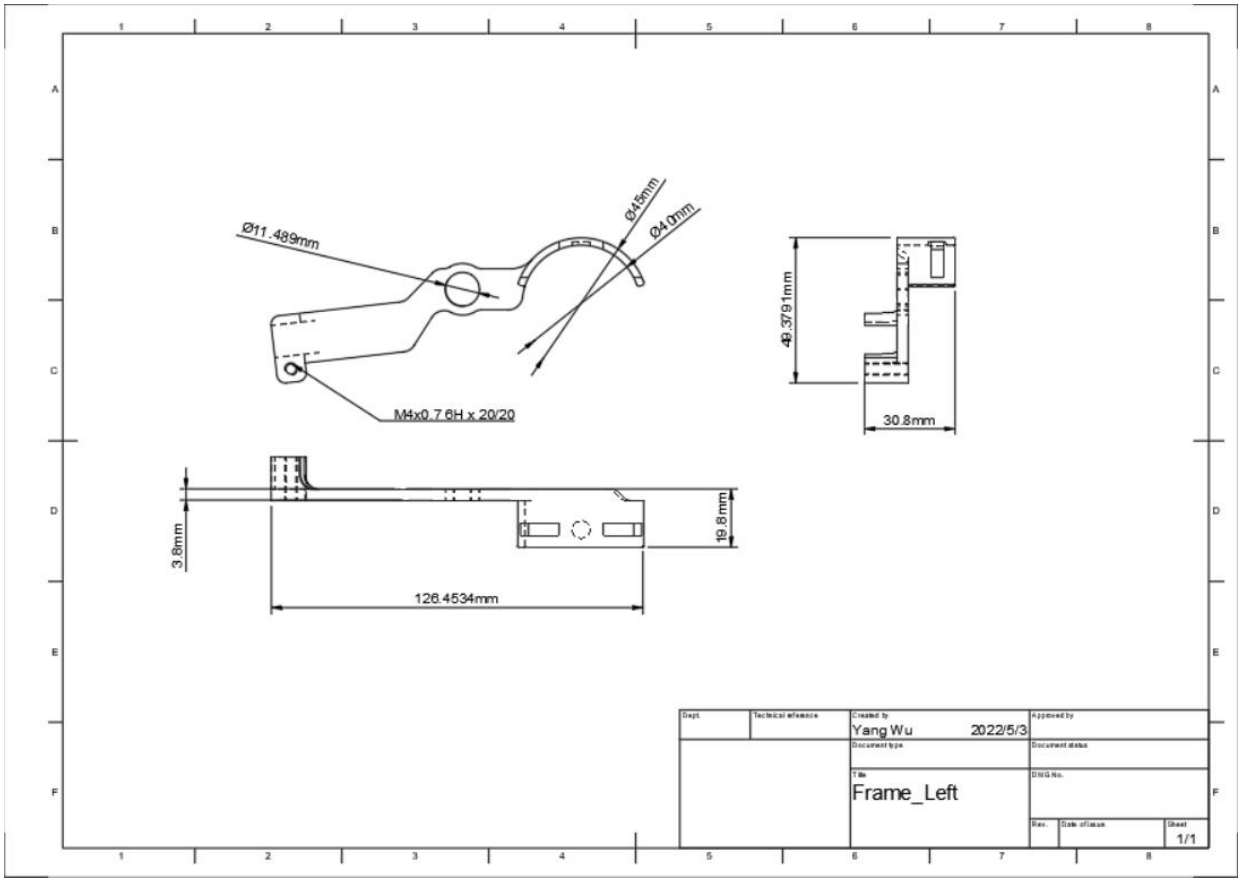
The micro-controller will count the times the motor is actuated (i.e., the shear is closed and released) during the two weeks. Then we will survey the participants to get their opinions about the device. The questions will mainly revolve around the safety and convenience of the item, especially how necessary the grasper and motor are compared with normal shears.

APPENDIX E
ASSEMBLY DRAWING OF GRASPER FRAME



Parts List				
Item	Qty	Description	Material	Mass
1	1	Grasper Frame (Left)	ABS Plastic	8.886 g
2	2	Grasper Bar	ABS Plastic	0.63 g
3	2	Spring	Steel	0.189 g
4	2	Rubber/Sponge Grasper	Rubber	0.40 g
5	2	Clamp	ABS Plastic	0.924 g
6	1	Grasper Frame (Right)	ABS Plastic	9.767 g

Dept. | Technical reference | Created by: Yang Wu 2022/5/3 | Approved by
Document type | Document status
Title: Grasper_Assemble | DWG No.
Rev. | Date of issue | Sheet: 1/1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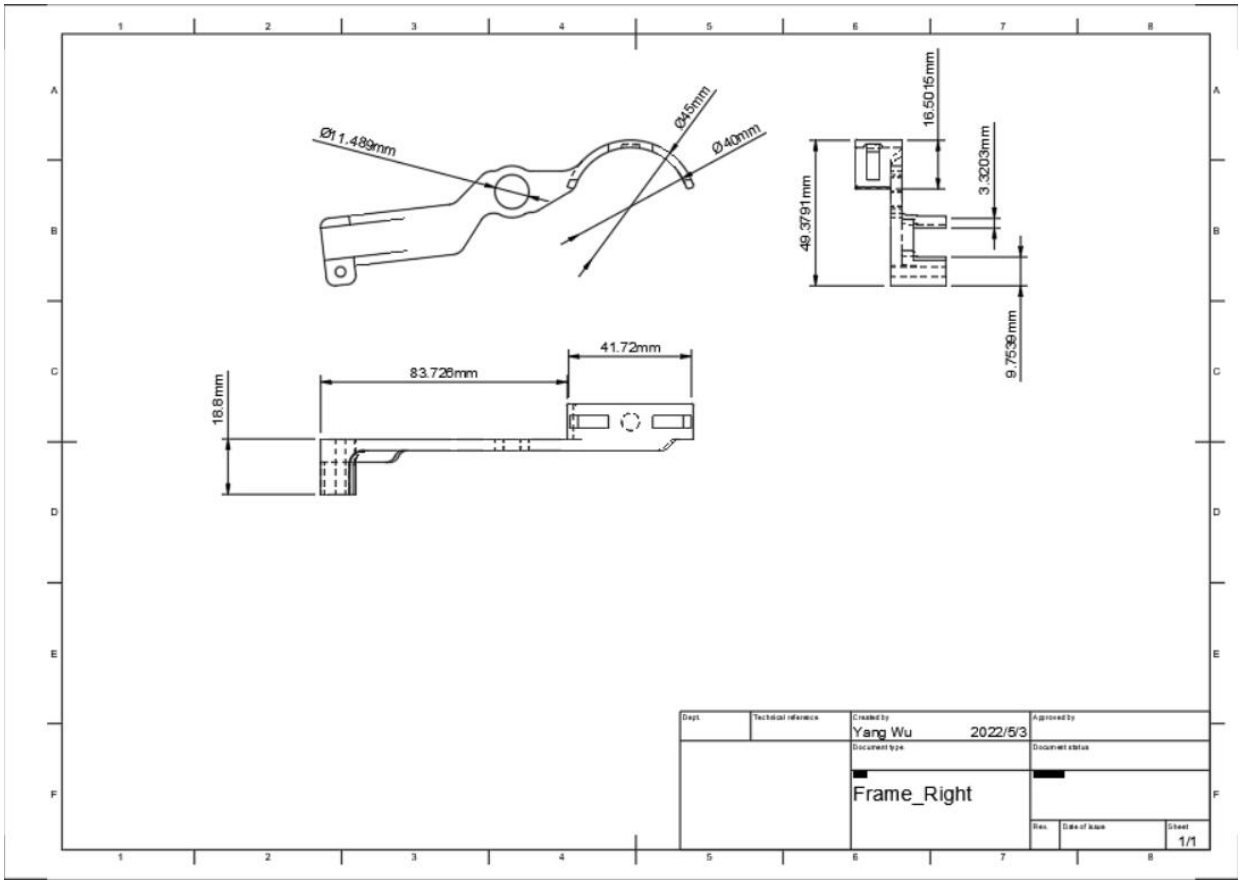
Ø45mm
Ø40mm
M4x0.76H x 20/20
49.3791mm
30.8mm
3.8mm
19.8mm
126.4534mm
Yang Wu 2022/5/3
Frame_Left
1/1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Ø40mm
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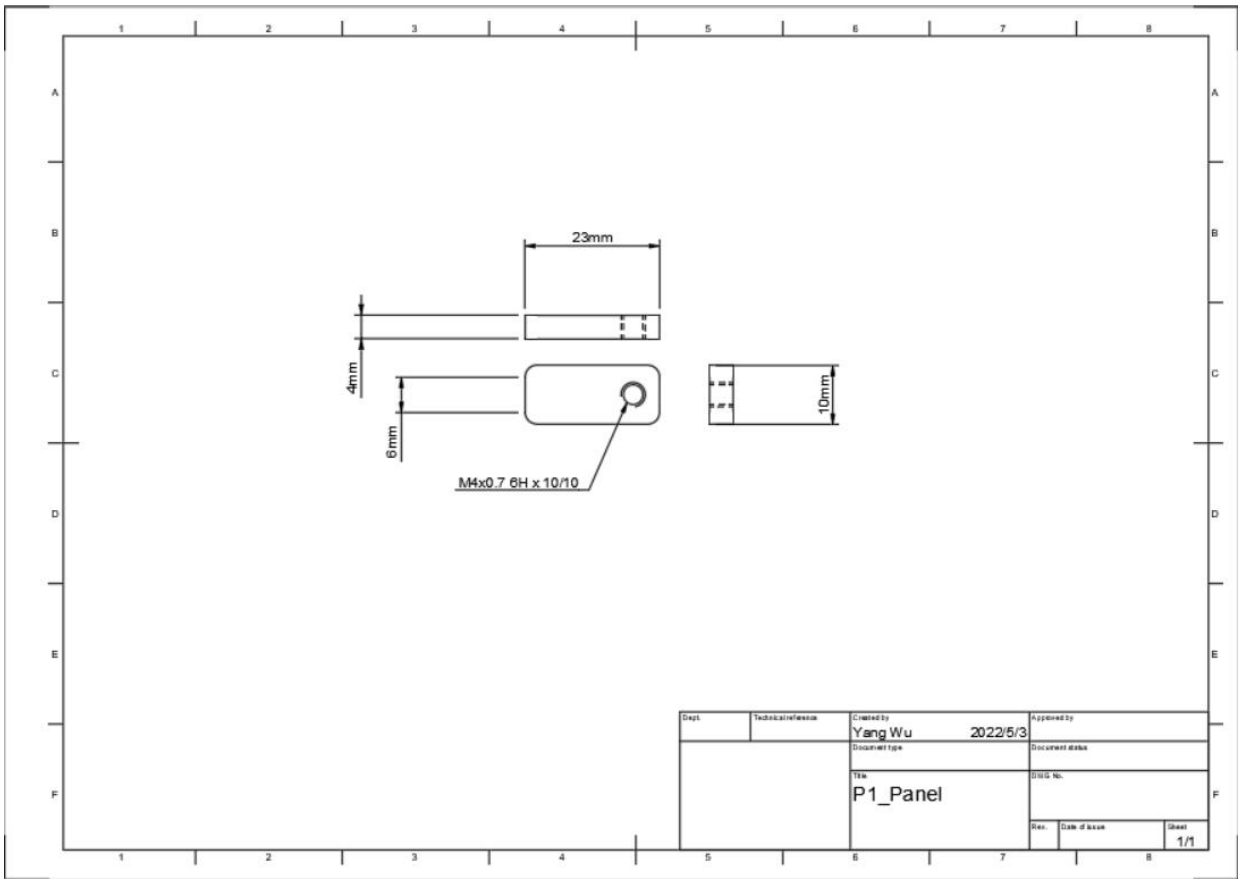
Yang Wu 2022/5/3
Frame_Right
1/1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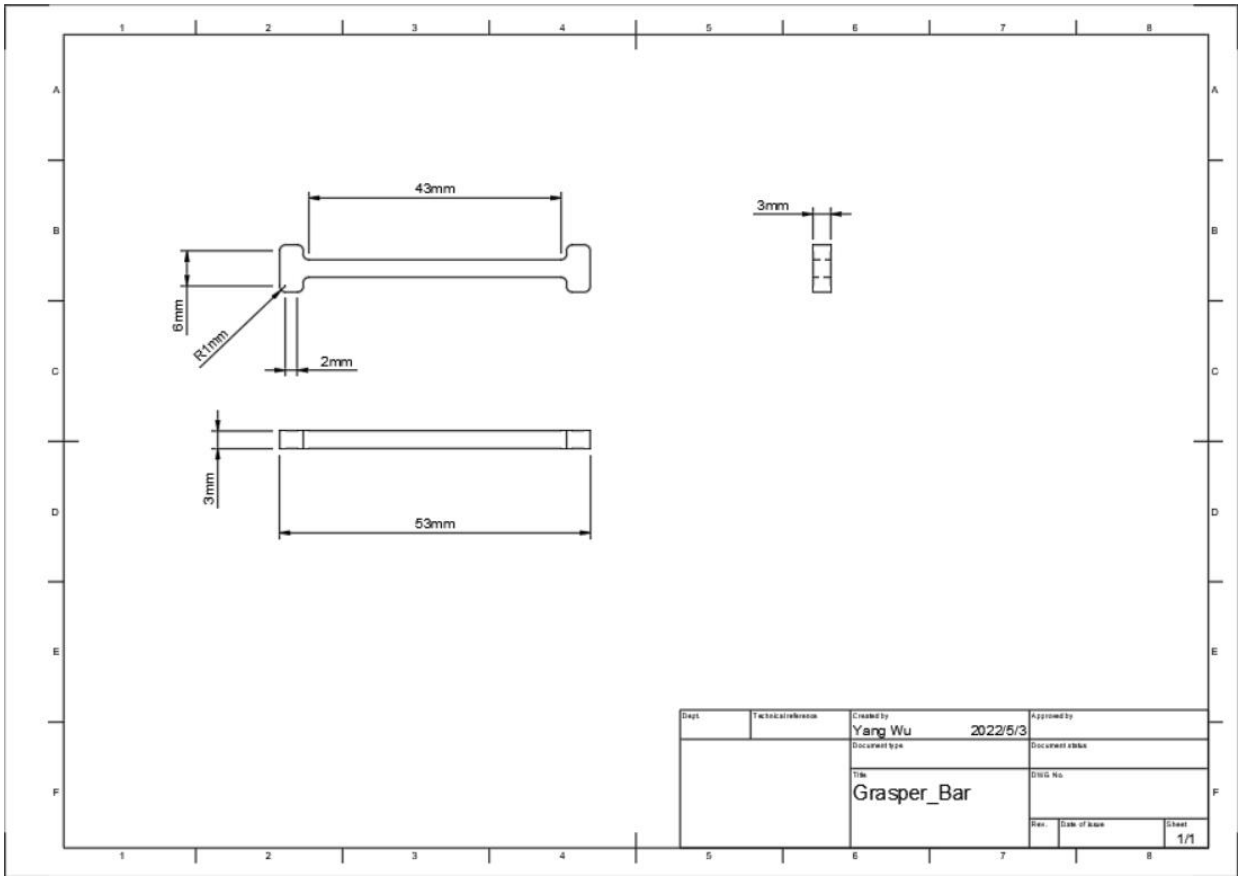
4mm
6mm
M4x0.7 6H x 10/10
10mm
Yang Wu
2022/5/3
P1_Panel
1/1


43mm
3mm
6mm
R1mm
2mm
3mm
53mm
Yang Wu
2022/5/3
Grasper_Bar
1/1