Adaptive Technology Design Report

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Executive Summary

Robots are used every day for a variety of applications in a multitude of environments. Ultimately, robots serve one purpose: to aid and/or enhance human function. Many people live with physical impairments. These impairments can easily make certain everyday tasks challenging. Those who have quadriplegia, which is full paralysis below the neck, have two choices when it comes to dining: they can be fed by a caretaker or by an assistive device. The latter is preferred because it provides the user greater independence. Oftentimes these devices are specialized, very expensive robotic arms costing upwards of $5000. With a budget of $2000, the team set out to utilize readily available technology to create an affordable and easy to use assistive feeding device. Ease and dignity were also primary goals in the design. To achieve these goals, the team decided to implement an eye-tracking based user interface. By using an eye-tracking system the user need only glance at an icon on the LCD screen to select their food choice and commence retrieval. This key feature allows the user to engage in conversations with their friends and family while dining, with the ease and dignity we sought. All work will be made publicly available with the intent that others reproduce and improve upon what we have achieved. Ideally, this will allow the creation of a product that is more affordable than what is currently on the market. This project is a proof of concept and is intended to be passed down to next year's seniors.

Objective

The objective of this project is to develop an assistive feeding device that can be used by someone who is diagnosed with quadriplegia. The objectives that we have set for this project are:

- Commercial Off the Shelf (COTS) Robotic Arm
- Tabletop form-factor
- Mimic natural feeding motion
- Fully user controlled
- User selectable utensils
- User selectable food
- Proximity control/safety interlock
- User Instruction Manual

Background Research

There are two main problems with existing assistive feeding devices. All of these devices are either expensive, up to $5000, or require the user to move in order to control the device. Two of the leading robotic feeding devices are detailed below.

Obi: Identified as the best available consumer product due to price, ability, and design.

- Obi has a retail value of $4,500
- Uses a teaching mode that allows the caregiver to set the feeding motion
- Around the size of a laptop
- Rechargeable battery that allows remote location, feeding
- Detachable spoon
- Collision detection

Meal Buddy: A comparable assistive feeding robot to Obi, not quite as robust but cheaper. Our design takes after Meal Buddy's design.

- Meal Buddy has a retail value of $3,500
- One touch, push-button operation
- Sip and puff option available
- Adjustable feeding operations: random, sequential, and user select
- Carrying case for remote locations
- Battery and charger kit option
- Potential carcinogens are present

To fit our requirements, we must stay under the budget of $2,000 and design the controls to be accessible by a quadriplegic. The only viable options for control would be audio interface or eye tracking. The use of buttons or a joystick the user could use with their head was considered, however many quadriplegics must have their head strapped to their wheelchair making these options near impossible. Since eating is often a social event, multiple conversations could disrupt and cause problems with voice control. For these reasons, the team decided on eye tracking as the control method of choice.

Goal Statement

Design and construct an assistive feeding robot that will allow a person with quadriplegia to feed themselves by using a commercially available robotic arm. This is a design/build project. The user is assumed to be someone with the ability to move their neck and face muscles, but unable to use muscles below the neck. What is unique about our approach from existing technology is that we intend to develop a device than can be fully user controlled using eye-tracking, which is something that has never been accomplished before in feeding devices.

Task Specifications (Constraints & Criteria)

Having crafted the goal statement, specific constraints and criteria may be defined. The constraints and criteria allow for a way to measure the performance and effectiveness of an idea.

Table 1. Constraints and Criteria for Robotic Feeding Device

Constraints	Criteria
• Table-top form factor • Fully-User Controlled • Multiple Selectable Bowls • Within budget of $2000	• Safety • Mimic Natural Feeding Motion • Function with diverse food options

Constraints and Criteria were defined above in Table 1. Constraints were based on what the solution must do, which is informed by the goal statement. Criteria were based on features that are beneficial, but not necessary to the design. These are used later to address the performance of the design presented in Detailed Design.

Detailed Design

Key Components

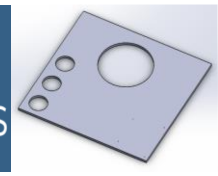
The key components of the device encompass both hardware and software. They consist of the Niryo One kit, Tobii eye tracker, LattePanda development board, Project Iris eye control software, mounting template, and the end effector.

Niryo One [1]

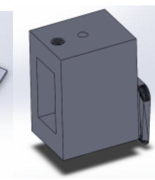
Tobii Eye Tracker [2]

LattePanda [3]

Project Iris [4]



Mounting Template



End Effector

Hardware Summary

- Robot brackets and display stand were 3D printed with ABS
- Mounting template was laser cut out of 0.25’’ acrylic and measures 609mm x 630mm
- Commercially available parts were used when possible
- LattePanda: Quad-Core Intel Processor with 4GB of RAM, 64GB Integrated Storage and a 7-inch eDP Touch Screen.

Software Summary

- Feeding motions were recorded with Niryo One Studio v2.1.1
- Motions were encoded in Python and can be called remotely by executable files
- LattePanda operates on Windows 10 and runs the Tobii Eye Tracking hardware/software
- Project IRIS enables macro and hotkey binding to screen interactors, which then call saved Python motion scripts via SSH to the robot.
- Macro Recorder software which allows any Windows action to be turned into a macro and assigned a hotkey

Mounting Template

The template material is standard 0.25” acrylic which can be bought at Home Depot. Overall dimensions can be seen below in Figure 1. After the acrylic had been laser cut, it had to be further prepared for robot mounting. This preparation included:

- 4mm pilot holes were drilled into the 2.54mm laser cut holes.
- Pilot holes were then tapped with a M4 x 0.7 size tap. This allowed for the robot to be bolted down with four 18mm long M4 diameter screws.

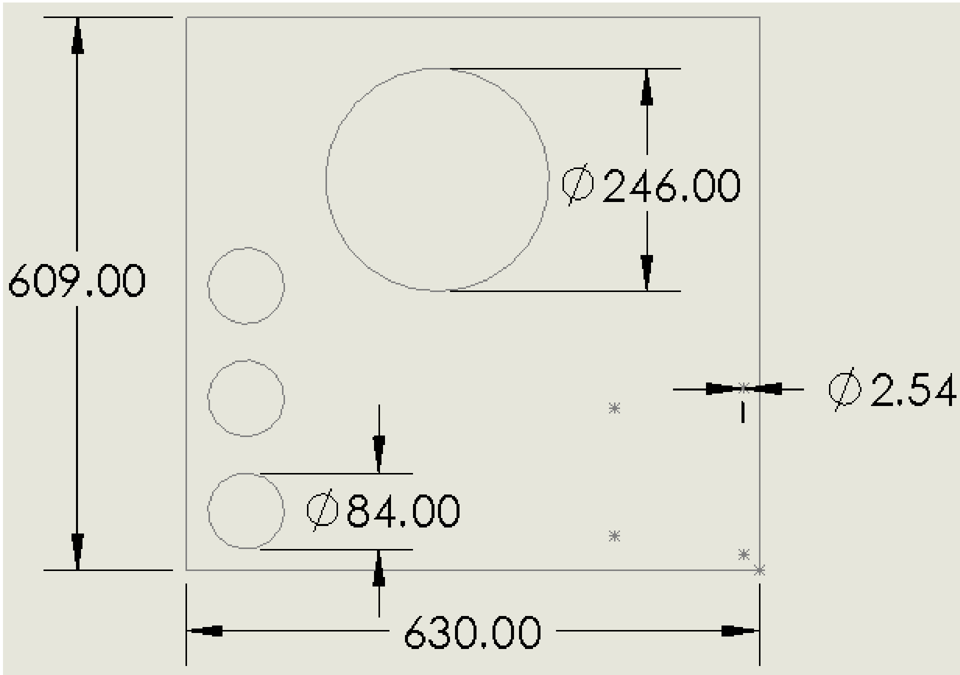


Figure 1: Drawing of mounting template with footprint and diameter dimensions shown in units of millimeters.

The three bowls are placed in a vertical line shown in Figure 2. The suction cup underneath allows the bowls to be held in place and restrict the bowls from moving when any contact is made. The bowls are facing the forward direction to be able to utilize the curve of the bowl to allow for the maximum amount of food to fall naturally on to the spoon.

Figure 2: Bowl placement.

End Effector & Spoon

The spoon that was used is a modified version of a stainless steel household spoon, Figure 3. Using a household spoon allows for the spoon to by washed like any other and is familiar to the user. The following modifications were made:

- Spoon was cut to an overall length of 142mm
- A 4.76mm (3/16 inch) centered hole was drilled at a distance of 10mm from the cut end.

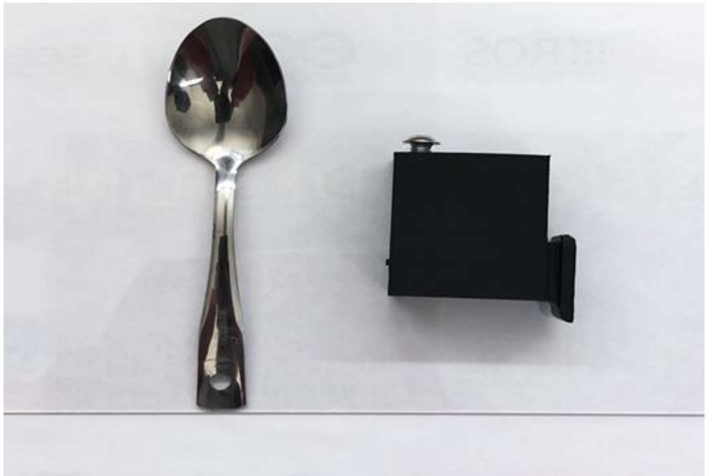


Figure 3: Spoon and end effector side by side.

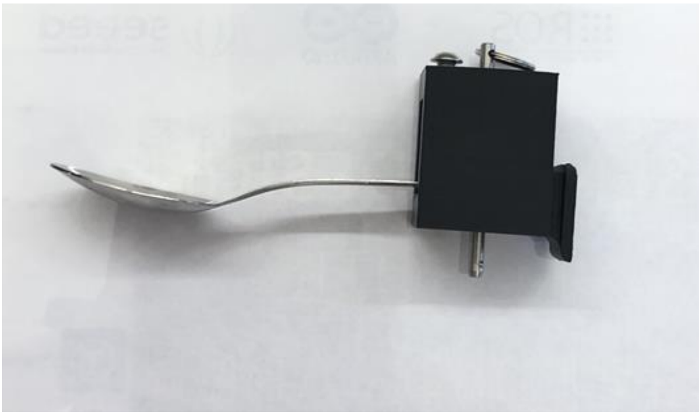


Figure 4: End effector with spoon attached.

LattePanda

The LattePanda is a mini personal computer that runs the Windows 10 operating system, shown in Figure 5. The LattePanda was chosen so that the Tobii eye tracker could be used to communicate with the Raspberry Pi of the Niryo One robotic arm. The Tobii eye-tracker is only capable of communicating with a Windows OS. The LattePanda is able to accept the data output by the Tobii system and use this information to determine which icon is being focused on. Once the correct icon is determined, the LattePanda is able to run an executable file, with the help of

Project Iris binding the hotkey to an icon, which allows SSH (secure shell) communication between the Raspberry Pi and the LattePanda. These SSH commands call a unique Python program, created in the Niryo One Studio, that is stored on the Raspberry Pi. The Python program will then hand off the instructions to the Niryo One arm causing the desired sequence to run.

Figure 5: User interface run on the LattePanda computer.

In order for the LattePanda to successfully run a Windows 10, the Tobii software drivers, and IRIS, improved thermal regulation had to be installed along with operating system tweaks to ensure that one process does not cause the system to become unresponsive. Windows 10 Professional IOT LTSC was used due to its bare bones initial state. All but necessary services were removed or disabled to include:

- Windows Firewall
- Windows Defender
- User Account Control

In addition to these tweaks, PRIO - Process Priority Saver, was utilized in order to provide more granular control of system resources.

- Tobii.Eye.X.Engine
    - Priority Low
    - Affinity – CPU 0
- Tobii.Eye.X.Tray
    - Priority Low
    - Affinity – CPU 0
- IRIS
    - Priority – Realtime
    - Affinity – CPU 1/2/3

Full Device Set-Up

Figure 6 shows the full device setup including all the parts and components mentioned above.

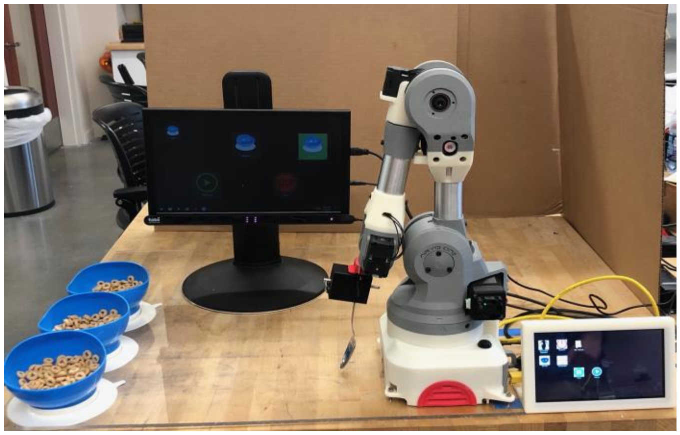


Figure 6: Robotic Feeding Device Set-Up.

Process

The Niryo One Studio has a programming mode called block programming. In this mode, different common programming blocks, such as for and while loops or delays, are accessible as well as saving the current position of the arm as a block. These blocks can be connected into a top down chronological program. Each block symbolizes a line of Python code.. The block code can then be converted into a Python program by clicking the Export to Python button. Once the program is in Python the Raspberry Pi is then accessed remotely through PuTTy. Once access is granted, the command “sudo nano filename.py” stores the Python code onto the Raspberry Pi and allows the filename to be saved as whatever the programmer pleases.

This file created from the “sudo nano” command is the file that is then called by SSH. To SSH the command from the LattePanda to the Raspberry Pi, the router address of the Raspberry Pi, 254.169.200.200, is used to select the Raspberry Pi and the password, “robotics”, is used to gain access. Once the LattePanda has access the executable file has to walk through the Raspberry Pi’s directory until it can properly select the correct Python program to run.

Overview (Successes)

After reviewing the detailed design, we can conclude with an overview of our successes that were based on our constraints and informed by the goal statement. The following list contains the features of the robotic feeding device:

- Completed project under budget (Refer to Table 2 in Appendix)
- User selectable food
- Tabletop form-factor
- Hands-free operation
- Built-in torque-sensing safety interlock
- User may communicate freely during operation

Future Considerations

Suggestions were made for guidance and improvements of our work as if this project were going to be passed on to another team. The considerations that have been given to apply for the future are to:

- Incorporate programmable user height adjustment
- Use antimicrobial materials for robot frame
- Enable fork functionality for a broader range of foods
- Integrate proximity sensors for added safety

References

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Acknowledgments

We wish to thank Mr. Mark Mann for his valuable time and guidance during this project. His expertise allowed us to have a much better understanding of the user as well as existing technology.

We would also like to thank Misumi USA for sponsoring our project through the donation of the hardware used to assemble the robot.

Appendix

Niryo One GitHub: https://github.com/niryorobotics
Niryo One Assembly Guide: https://niryo.com/docs/niryo-one/assembly-guide/assemble-niryo-one/
Niryo One Studio Download: https://niryo.com/download/
Niryo One User Manual: https://niryo.com/docs/niryo-one/user-manual/complete-user-manual/
Adaptive Technology GitHub: https://github.com/AdaptiveTechnology/FEED.ME

Table 2. Bill of Materials Cost

		Item	Source	Qty	Price
Robotic Arm	Arm	Niryo One Robotic Arm	Niryo	1	916.00
	Hardware	Hardware (Bolts, Nuts, Washers, Belts, Drive Gears)	Misumi	1	Donated
	Thrust Bearings	2 Thrust Bearing 8x19x7 Thrust Bearings	Amazon	1	19.66
		Thrust Bearing 20x40x14	Amazon	1	8.35
		90x120x6.5mm Thrust Bearing Washer	Amazon	1	11.46
	Power Supply	12V/10A power Supply	Amazon	1	13.60
	RPi	Raspberry Pi 3 B+	Amazon	1	37.90
	Memory Card	SanDisk Extreme 64GB microSD UHS-I Card	Amazon	1	23.00
	3D Print Filament	Purement Anti-Bacterial Filament	Amazon	2	25.99
Feeding Accessories	Caregiver Display	3.5inch RPi LCD (B) 320x480 Touch Screen Display	Amazon	1	29.99
	Servos for Mount	Annimos 20kg Digital Servo	Amazon	2	17.99
	User Display	Elecro 13.3 inch Raspberry-pi Monitor with Speakers	Amazon	1	145.99
	Utensil	Spoon	Amazon	1	11.44
	Bowls	Ableware Scooper Bowl	Amazon	3	9.82
	Template	Acrylic	McMaster	1	75.00
	Computer	LattePanda	Ebay	1	200.00
	Eye Tracker	Tobii 4C	Amazon	1	169.99
	Heat Sinks		Amazon	2	38.61
	Heat Spreaders		Amazon	1	7.09
	Thermal Epoxy	Arctic Silver Thermal Adhesive	Amazon	1	20.96
	Processor Heat Sink	Enzotech SLF-1 Ultra Forged Copper	Performance-Pcs	1	34.95
	Template	Plexiglass	Lowes	1	63.00
	Extra Drive Belt		Misumi	1	16.70
					1897.49