October 11, 2018

Howdy Dr. Roysam,

This spring you approved of our Makerspace and senior design project, Knuckles, the assistive robotic arm to be exhibited at the 2019 ECEDHA Conference in Tucson, Arizona. I'm glad to report that after our summer of research and study, we've begun our next phase of 3D-printing and ordering parts. We received the Intel RealSense D435 in early October and have started to learn how to use it with ROS, Robot Operating System. This week the ECE department was able to place most of the orders required to complete the build process of the arm. All other arm assembly components will be purchased in-person at Home Depot and reimbursed by the ECE department.

We are still discussing some current needs such as the Intel Voice Enabling Development Kit and a PC. But as they are required at later dates, we are going to seek company sponsorship to lower the overall cost to the department.

If all the arm parts are received and printed before the end of October, we will be on schedule to build and display the MOVEO BCN3D robot in-time for the IEEE Makers' Showcase on November 9th. The robot should be able to be controlled with a physical controller for the event and controlled with ROS within the following weeks.

Thank you for your continued support of our research. If you have any questions or concerns, feel free to contact us.

Sincerely,

Andrew Blanchard
Matthew van Zuilekom
Rym Benchaabane
Paola Hernandez

ADDIE Design Report

Fall 2018 – Spring 2019

Andrew Blanchard

Matthew van Zuilekom

Rym Benchaabane

Paola Hernandez

Purpose

Knuckles is an assistive robotic arm that will hand the user requested objects and tools. It will serve as a convenient assistant that will increase the user's productivity and decrease the risk of dexterity incidents.

Overview Diagram

Deliverables

At the end of the Fall semester, our team will provide the hardware part of the project, which will be the physical robotic arm. The user will be able to use a developed simulation on the computer to manually control the robot through text commands. The simulation will be done through RViz on the Robotic Operating System (ROS). At the end of the Spring semester, our team will provide the software portion of Knuckles, which will include the object detection and voice recognition portion of the project. With the additional help of the software packages, the user will be able to give voice commands to receive requested objects from Knuckles.

Design Considerations

The mechanical properties of Knuckles are divided into two components, the arm and the gripper. The arm's 5-axis movement and mechanics will be developed using ROS on Linux Ubuntu 16.04 LTS. We are connecting the arm's joints with a total of 6 stepper motors (2 for the base). These motors will be processed by ROS and controlled by Arduino. Programming the ability to move autonomously allows the robot to decide how to move without external input beyond voice commands or manual input on ROS. The gripper is a three-finger design; each finger will have a set of tactile sensors to give the robot feedback on the pressure applied to the object it is attempting to grasp. The gripper will be controlled by a DC motor with an H-bridge. The gripper can therefore respond accordingly and autonomously adjust its grip with sensors. Once functioning in conjunction with the software components, it will be able to calculate and complete the best path to the item and its return path to the user. The robotic arm and the gripper will be 3D printed using an AutoCAD design. The design is inspired by the open source robotic arm BCN3D MOVEO (3D printed), with the gripper designed from an IEEE research paper.

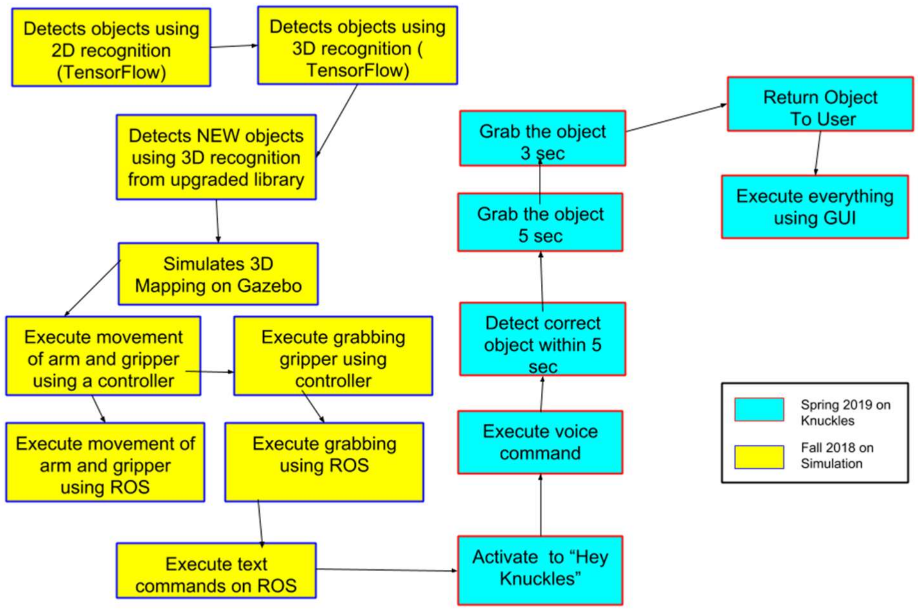
For this project, we are programming in Python 3.5 and C programming. The two main software applications are visual and voice recognition.

The visual processing for Knuckles, including mapping and object recognition will be handled using OpenCV, RViz, and TensorFlow. Knuckles will utilize the Intel RealSense Depth Camera D435 using the mentioned software packages in ROS. OpenCV analyzes the video feed to detect, identify, and log the location of objects as the room is mapped. The recognition features will be executed through TensorFlow. RViz is our 3D visualization application for ROS that will work with the Intel Camera. These libraries will allow us to access and process images, while training with TensorFlow and improving the visual recognition. The user will activate Knuckles with a voice command which will begin the mapping of its surroundings and the execution of the command.

The robot will be able to receive voice commands to perform actions such as handing objects including phones, pencils, etc. The microphone will be incorporated with an Intel Speech Enabling Developer Kit. This add-on module is designed to fit the Raspberry Pi3 board. The Raspberry Pi3+ sends the audio to the Amazon Alexa Voice Service and receives the text request to be processed using a listening script connected to ROS. The command will be translated into the object data detected from the map created via RViz. The robot's arm motors will move and execute the motion command. A voice command will be used to "wake-up" Knuckles from its standby state, which then allows Knuckles to execute commands.

Our main design constraint is the time allotted to develop a gripper that's capable of grabbing a larger range of objects.

Target Objective and Goal Analysis



Test Plan

1. Tests the mobility of the robot: Verifies the arm and gripper motion with a controller.
2. Test robot connection to ROS: Request the robot to position itself in straight up, straight out, and in reaching motions.
3. Test object recognition: Validate that can recognize multiple objects at the same time.
4. Test the ability of the robot to map the environment: Compare map data representation to that of the workspace of the robot.
5. Test the combination of visual recognitions: Measure and compare the accuracy of object tags in ROS and in real space.
6. Test the search function: Use text recognition to have the robot point at objects.
7. Test the retrieval function: Use text recognition to retrieve an object.
8. Tests the voice recognition: Compare voice commands to the text in the ROS terminal.
9. Test the user search function: Upon voice request, have the robot find the user.
10. Test the return function: Have the robot drop the object as close to the user as possible.
11. Test the gripper with the return: Have the robot wait until the user is within range and pulls on the object.
12. Test the timing of the entire process: Have the robot time to complete function.

Schedule

Date	Entire Group	Matthew van Zuilekom	Andrew Blanchard	Rym Benchaabane	Paola Hernandez
October 10th			Get tools		
October 12th	Order Parts	Have robot arm track object in simulation	Submit written report by 5PM. Clean all components.	2D object recognition using RealSense Camera	
October 19th	Build robot.	Get parts from Home Depot.	*Buffer*	2D object detection reliable and working.	
October 22nd (Milestone 1)	Arm and gripper are fully constructed and functional. All parts acquired.		*Buffer*		
October 23rd		*Presenting in senior design*			
October 26th		Gripper and arm in RViz/Gazebo simulation.		Get 3D point cloud video input showing in RViz	*Submit Progress 1 written report by 5PM.* Get 3D point cloud video input showing in RViz.
November 2nd		Print out: final gripper & camera mount Mount gripper & camera on arm		3D object detection	
November 6th	*Ethics assignment due November 6th at 5PM. Group assignment*		*Buffer*	*Presenting in senior design lecture*	
November 9th (Makers' Showcase)	Arm is constructed and moveable	Find and mount tactile pads	*Display built arm at Makers' Showcase*	Train object detection can recognize every object will most likely encounter	
November 16th	Tactile pads respond as expected and recognize when an object has been sufficiently grasped	*Submit Progress 2 written report by 5PM.*	Order voice kit and microphone.	Fully functional object detection simulation with RealSense working on RViz. Saves 3D position of the object	
November 20th (Milestone 2)	Simulate the arm design in RViz. Arm has all hardware attachments. Camera works and provides locations Get response from tactile pads.		*Presenting in senior design*		
November 21 - 25	*Thanksgiving holiday*	*Buffer*			
November 27th	*Facilitator meetings*	*Buffer*			
November 30th		Physical arm fully follows simulation seen in RViz		Arm properly responds to text commands	

<table>
<tr><th>Date</th><th>Entire Group</th><th>Matthew van Zuilekom</th><th>Andrew Blanchard</th><th>Rym Benchaabane</th><th>Paola Hernandez</th></tr>
<tr><td>December 1 - 12</td><td>Final exams, no classes</td><td colspan="4">Buffer</td></tr>
<tr><td>December 7th</td><td></td><td colspan="2">Manual control of robotic arm using a controller</td><td></td><td></td></tr>
<tr><td>December 14th</td><td>Microphone can take audio input and convert to text for voice commands</td><td></td><td></td><td></td><td>Buffer</td></tr>
<tr><td>December 21st</td><td>Arm can remember path made when controlled and duplicate the motion when given the text/voice command</td><td></td><td>Buffer</td><td></td><td></td></tr>
<tr><td>January 4th</td><td>Arm can create 3D map of its environment</td><td></td><td></td><td></td><td></td></tr>
<tr><td>January 11th</td><td>Arm can properly locate requested object (via voice command), pick it up and present requested object to user</td><td colspan="2">Redesign base of arm to consolidate and accommodate microphone</td><td></td><td></td></tr>
<tr><td>January 14th</td><td>First day of spring semester</td><td colspan="2">Mount microphone on arm.</td><td></td><td></td></tr>
<tr><td>January 18th</td><td>Arm can be given an object, and place that object in an empty spot on the table</td><td></td><td></td><td></td><td></td></tr>
<tr><td>January 20th (Milestone 3)</td><td>Implement 3D mapping using RealSense. Simulate object detection and implement on the physical robot. Robot will be able to locate and pick up objects in its environment</td><td></td><td></td><td colspan="2">Fully trained object detection can recognize every object will most likely encounter. Responds to voice commands</td></tr>
<tr><td>February 15th (Milestone 4)</td><td>Improved object recognition and user position recognition. Implement voice recognition software to accept voice commands</td><td></td><td></td><td></td><td></td></tr>
<tr><td>March 8th (Milestone 6)</td><td>Implement final voice commands reference library. Robot arm needs to be 100% done!</td><td colspan="4">Display arm at IEEE Chili Cook-Off</td></tr>
<tr><td>March 11th - 17th</td><td>Spring Break. Prep Robot for travel</td><td></td><td>Buffer</td><td></td><td></td></tr>
<tr><td>March 26th (ECEDHA)</td><td>Demonstrate arm at ECEDHA Conference</td><td></td><td>At Conference</td><td></td><td></td></tr>
<tr><td>April 15th (Milestone 7)</td><td>Fine tuning based on feedback from IEEE National Conference</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Capstone conference date?</td><td></td><td></td><td></td><td></td><td></td></tr>
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Budget

Table 1:List of MOVEO BCN3D parts, associated cost/unit, and status of each order

BOM ID	Part	Quantity	Single Price	Status
1	Stepper Motor SM42HT47	1	23.22	Ordered
2	ARDUINO MEGA 2560	1	14.86	Ordered
3	Stepper Driver TB6560	6	43.99	Ordered
4	Power Supply 24 [V], 320[W]	1	72.89	Ordered
5	RAMPS V1.4	1	12.50	Ordered
6	Power Converter 24[V] to 12[V]	1	41.94	Ordered
7	Servo Motor 180 55G	1	29.00	Ordered
8	Gear Ratio 5:1 Planetary Gearbox Nema 17 Stepper	1	42.00	Ordered
9	Nema 23 flat shaft	2	45.50	Ordered
10	Nema 14 36 [mm]	1	19.99	Ordered
11	Nema 17	1	12.99	Ordered
12	Chrome steel smooth bar-134[mm]	3	4.29	Verified
13	Chrome steel smooth bar-114[mm]	1	0.00	Verified
14	Chrome steel smooth bar-80[mm]	1	0.00	Verified
15	Ball Bearing 608ZZ 8[mm] x 22[mm] x 7[mm]	1	9.99	Ordered
16	Ball Bearing 625ZZ 5[mm] x 16[mm] x 5[mm]	1	14.72	Ordered
17	Ball Bearing 624ZZ 4[mm] x 13[mm] x 5[mm]	1	8.45	Ordered
18	Ball Bearing 623ZZ 3[mm] x 10[mm] x 4[mm]	1	7.38	Ordered
19	Brass insert M4	1	18.00	Ordered
20	Brass insert M3	9	0.00	Verified
23	Rod Bar M8 [mm]	1	6.90	Ordered
24	Coupling Steel 5 to 8[mm] rigid	1	6.84	Ordered
25	Axial Fan DC 24[V] 80[mm] x 80[mm]	1	4.95	Ordered
26	Axial Fan DC 24V 50x50[mm]	1	4.93	Ordered
27	Power Supply cable IEC 1.8[m]	1	15.95	Ordered
28	Cable USB 2.0 AM/BM 1.8[m]	1	10.92	Ordered
29	Zip ties	1	5.95	Ordered

BOM ID	Part	Quantity	Single Price	Status
32	Wood Base	1	0.00	Verified
33	Breco Belt T5	7	1.88	Verified
34	High Torque Geared Motor DC 12[V]	1	13.99	Ordered
101	Dimension A: M-3 Dimension B: 10 mm	10	0.48	Verified
102	Dimension A: M-3 Dimension B: 12 mm	6	0.00	Ordered
103	Dimension A: M-3 Dimension B: 16 mm	13	0.00	Ordered
104	Dimension A: M-3 Dimension B: 20 mm	1	10.98	Ordered
105	Dimension A: M-3 Dimension B: 25 mm	5	0.00	Ordered
106	Dimension A: M-3 Dimension B: 30 mm	2	0.00	Ordered
107	Dimension A: M-3 Dimension B: 40 mm	7	0.00	Ordered
108	Dimension A: M-4 Dimension B: 12 mm	2	9.99	Ordered
109	Dimension A: M-4 Dimension B: 10 mm	2	0.00	Ordered
110	Dimension A: M-4 Dimension B: 16 mm	8	0.00	Ordered
111	Dimension A: M-4 Dimension B: 40 mm	4	2.23	Ordered
112	Dimension A: M-4 Dimension B: 45 mm	6	0.00	Verified
113	Dimension A: M-4 Dimension B: 60 mm	4	0.00	Verified
114	Dimension A: M-5 Dimension B: 14 mm	8	0.00	Verified
115	Dimension A: M-5 Dimension B: 20 mm	8	0.00	Verified
116	Dimension A: M-8 Dimension B: 65 mm	1	0.00	Verified
117	Dimension A: M-4 Dimension B: 25 mm	4	0.00	Ordered
118	Dimension A: M-3 Nut	30	0.00	Verified
119	Dimension A: M-4 Nut	4	0.00	Verified
120	Dimension A: M-4 Locknut	18	0.00	Verified
121	Dimension A: M-5 Locknut	16	0.00	Verified
122	Dimension A: M-8 Locknut	2	0.00	Verified
123	Dimension A: M-4 Dimension B: 20 mm	3	0.00	Ordered
124	Dimension A: M-3 Dimension B: 8 mm	4	0.00	Verified
125	Dimension A: M-4 Dimension B: 30 mm	8	0.00	Ordered
126	Dimension A: M-3 Dimension B: 35 mm	4	0.00	Ordered
127	Washer M-3	10	0.00	Verified

BOM ID	Part	Name	Quantity	Single Price	Status	Print Location
202	**Articulation 1**	1M1	1	0.00	Printed	Robotics Lab
203		1M2	1	0.00	Printed	Robotics Lab
204		1M3	1	0.00	Printed	Robotics Lab
205	**Articulation 2**	2M1	1	0.00	Printed	Robotics Lab
206		2M2M	1	0.00	Ordered	Robotics Lab
207		2M2H	1	0.00	Ordered	Robotics Lab
208		T2M1BD	1	0.00	Printed	IEEE Makerspace
209		T2M1BI	1	0.00	Printed	IEEE Makerspace
210	**Articulation 3**	3M1	1	0.00	Ordered	Robotics Lab
210A		3M2C	1	0.00	Ordered	Robotics Lab
211		3M2	1	0.00	Ordered	Robotics Lab
212		T3M1C	1	0.00	Printed	IEEE Makerspace
213	**Articulation 4**	4M1	1	0.00	Ordered	Robotics Lab
214		4M2	1	0.00	Printed	Robotics Lab
215		4M2C	1	0.00	Printed	Robotics Lab
216		T4M1	1	0.00	Printed	IEEE Makerspace
217	**Machine - tool**	Top plate	1	0.00	Printed	IEEE Makerspace
218		Bottom Plate	1	0.00	Printed	IEEE Makerspace
219		Cylinder	2	0.00	Printed	IEEE Makerspace
220		Pivot Arm	2	0.00	Printed	IEEE Makerspace
221		Gripper Left	1	0.00	Printed	IEEE Makerspace
222		Gripper Right	1	0.00	Printed	IEEE Makerspace
223		Idol gear	1	0.00	Printed	IEEE Makerspace
224		Servo gear	1	0.00	Printed	IEEE Makerspace
228	**Base**	Stand	4	0.00	Ordered	IEEE Makerspace
229	**Cover**	Tapa 2M1	2	0.00	Printed	IEEE Makerspace
230		Tapa 3M1	2	0.00	Ordered	IEEE Makerspace
231		Tapa 4M1	2	0.00	Ordered	IEEE Makerspace
232		Tapa TBB	1	0.00	Ordered	IEEE Makerspace
21	**Other**	Pulley T5, bore	3	0.00	Ordered	IEEE Makerspace
22		Pulley T5, bore	2	0.00	Ordered	IEEE Makerspace
30		Specialty Bearing	8	0.00	Printed	IEEE Makerspace

Table 2: List additional technologies, associated cost/unit, and status of each order.

BOM ID	Part	Quantity	Single Price	Status
35	Intel RealSense D435	1	160.00	Received
36	Intel Speech Enabling Development Kit	1	499.00	Verified
37	Raspberry Pi 3B+	1	34.99	Verified
38	Raspberry Pi 3B+ USB 3.0 Expansion Shield	1	29.59	Verified
39	Mini PC	1	~800.00	Pending
40	PS3 Controller	1	59.99	Verified

Current Expenditures	**$953.18**
Total Expenditures	**$2407.58**

Summary

By the end of the Fall semester, the physical robot arm will be constructed, and the user can use a simulation in RViz to control the robot through text commands. By the end of the Spring semester, the object detection and voice recognition of the project will be completed, and the user will be able to give voice commands to request objects from Knuckles. We will accomplish our target objective by following a modular test plan, allowing us to develop the hardware and software in tandem. We have ordered all the necessary components to build the robot arm and will pick up the remaining fasteners from Home Depot. Through the IEEE Makerspace and the Robotics Lab, we have almost completed printing out the parts of the robot arm and prototype gripper. We are on track to complete our project by the end of the Spring semester.