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

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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

Andrew Zuilekom

Blanchard

Rym Benchaabane Paola Hernandez

October 10th Get tools

October 12th Order Parts

Have robot arm Submit track object in

simulation

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

Submit Progress 1 written report by 5PM. Get 3D point cloud video input showing in RViz.

November 2nd

Gripper and arm in RViz/Gazebo simulation.

Get 3D point cloud video input showing in RViz

Print out: final gripper & camera mount Mount gripper & camera on arm

3D object detection

November 6th

Presenting in senior design lecture November 9th (Makers’ Showcase)

Ethics assignment due November 6th at 5PM. Group assignment

Buffer

Display built arm at Makers' Showcase

Train object detection can recognize every object will most likely encounter

November 16th

Arm is constructed and moveable

Find and mount tactile pads

Fully functional object detection simulation with RealSense working on RViz. Saves 3D position of the object

November 20th (Milestone 2)

Tactile pads respond as expected and

Submit Progress recognize when an object has been

2 written report sufficiently grasped

by 5PM.

Order voice kit and microphone.

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

Andrew Date Entire Group

Matthew van Zuilekom

Blanchard

Rym Benchaabane Paola Hernandez

December 1 - 12 Final exams, no classes Buffer

December 7th

Manual control of robotic arm using a controller

December 14th

Microphone can take audio input and convert to text for voice commands

Buffer

December 21st

Arm can remember path made when controlled and duplicate the motion when given the text/voice command

Buffer

January 4th

Arm can create 3D map of its environment

January 11th

Arm can properly locate requested object (via voice command), pick it up and present requested object to user

Redesign base of arm to consolidate and accommodate microphone

January 14th First day of spring semester Mount microphone on arm.

January 18th

Arm can be given an object, and place that object in an empty spot on the table

January 20th (Milestone 3)

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

Fully trained object detection can recognize every object will most likely encounter. Responds to voice commands

February 15th (Milestone 4)

Improved object recognition and user position recognition. Implement voice recognition software to accept voice commands

March 8th (Milestone 6)

Implement final voice commands reference library. Robot arm needs to be 100% done!

Display arm at IEEE Chili Cook-Off

March 11th - 17th Spring Break. Prep Robot for travel Buffer

March 26th (ECEDHA)

Demonstrate arm at ECEDHA Conference

At Conference

April 15th (Milestone 7)

Fine tuning based on feedback from IEEE National Conference Capstone conference date?

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.