CEAT Interdisciplinary Design

Personal Assistive Robot

Dylan Shadoan, Emily King, Hrudhay Jaladi

Dr. Guoliang Fan, *Project Champion*

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Introduction

This system creates a digital map of a one-story living space and then retrieves objects from within that space. It must be able to detect obstacles as well as recognize and locate small objects of interest such as keys, remote controls, glasses, and pillboxes. The system communicates with an Android tablet or mobile device in order to display a graphical user interface with the map, object locations, and labels. The device can retrieve an object as requested by the user and present it to them in a safe, intuitive manner. The objects in question must be laying on a flat surface, unattached, and no more than four feet from floor-level. The objects can weigh up to one pound.

Background

This project is an extension of a CEAT Undergraduate Research Scholars project created by Dr. Guoliang Fan and Dylan Shadoan. The original project investigates the use of smart glasses wearable technology to assist patients of neurodegenerative diseases around their home or living community. The original project proposal can be found in Appendix A.

This project maintains the same goal of assisting users around their home, but focuses on different technologies: robotics and AI. However, the usefulness of this project extends beyond the scope of patient care since its functions are more universally desirable.

Schedule

Week 1: Team introduction. Selection of off-the-shelf components.

Week 2: Prepare lab space. Test prior electronics inventory. Design strategizing.

Week 3: Preliminary design completion. Concept Design Review presentation. Concept Design Report. Hazard Analysis.

Week 4: Familiarization with Robot Operating System (ROS) and TensorFlow. Safety training. Prototyping and Implementation. Identify and design structural and chassis based on requirements.

Week 5: Identify common UI Solutions, development platform, objection detection and localization requirements, and available implementations. Research object detection, robotic arm control, arm design, and grasping mechanism.

Week 6: Identify navigation, open-source SLAM and arm control software. Select actuators, model arm segments and grasping mechanism.

Week 7: Final Design Review presentation. Final Design Report. Custom Part modeling Finalize parts order list.

Week 8: Research and implement SLAM and object detection software. Build and test grasping mechanism and arm control.

Week 9: Continue testing. Custom parts fabrication.

Week 10: Final design implementation. Test SLAM and object localization concurrently. Test grasping with control arm. Interface with Raspberry Pi and base platform.

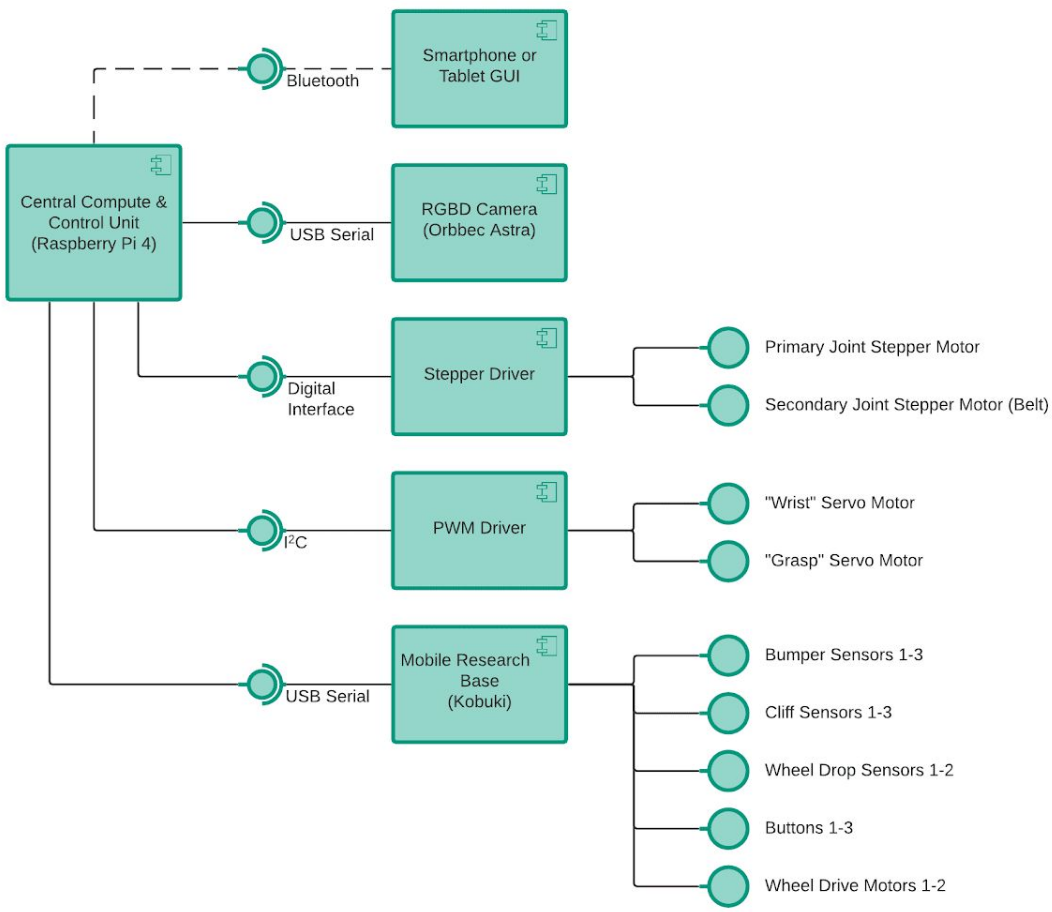
Week 11-13: System integration. Corrections in design and rework.

Week 13-16: Final testing and unexpected fault mitigation. Design Expo.

Gantt Chart provided in Appendix B.

System Overview

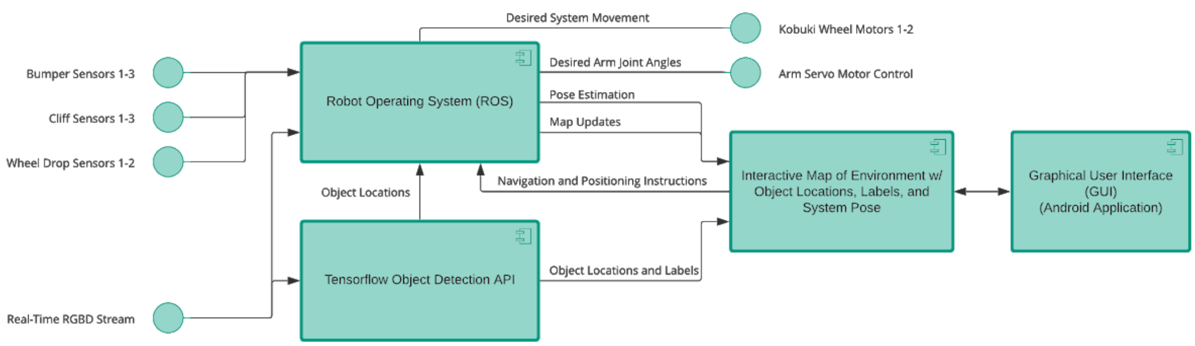
Five subsystems intercommunicate in order to form the overall system. The robot uses a Kobuki mobile research base in order to move around its environment and gather mechanical sensory data. A graphical user interface (GUI) is provided via an Android mobile application connected to the system with Bluetooth. The RGBD camera provides image and depth information to the robot, which allows the Raspberry Pi 4 to collect data for localization and mapping as well as object detection and retrieval. The camera and base interface with the Raspberry Pi via standard USB Type-A connections. Two servos— one that controls the "wrist" and another that controls the "grasper"— interface with the Raspberry Pi through a Pulse Width Modulation (PWM) Driver which is connected via I^2C communication. Using a digital interface, a Stepper Driver will control two, higher torque-rated, servos that control primary arm movement.



Software Overview

The system must operate in two distinct modes: *learn* and *retrieve*. In learn mode, the system navigates through a living space in order to create a digital map of the environment and mark the locations of objects of interest. In retrieve mode, the previously collected map data is used to navigate the system to an object as selected by the user, and then bring that object to the user.

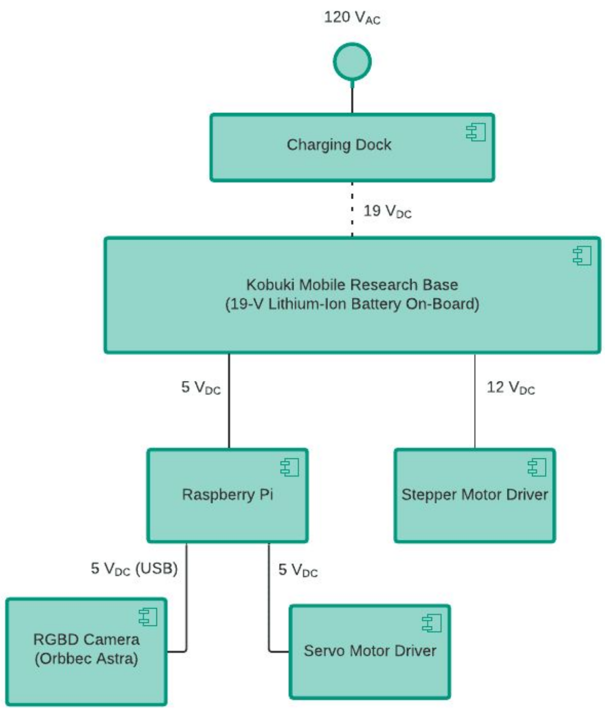
The open-source Robot Operating System (ROS) is leveraged for Simultaneous Localization and Mapping (SLAM) as well as control of the robotic arm. Google's TensorFlow Object Detection API is leveraged to identify and localize objects of interest. Together, ROS and TensorFlow provide the processing necessary to send map and object data to the Android device. They also work to close a feedback loop that ensures accurate navigation and arm control when in retrieve mode. The Android application will handle all GUI-related processing.



Power Distribution

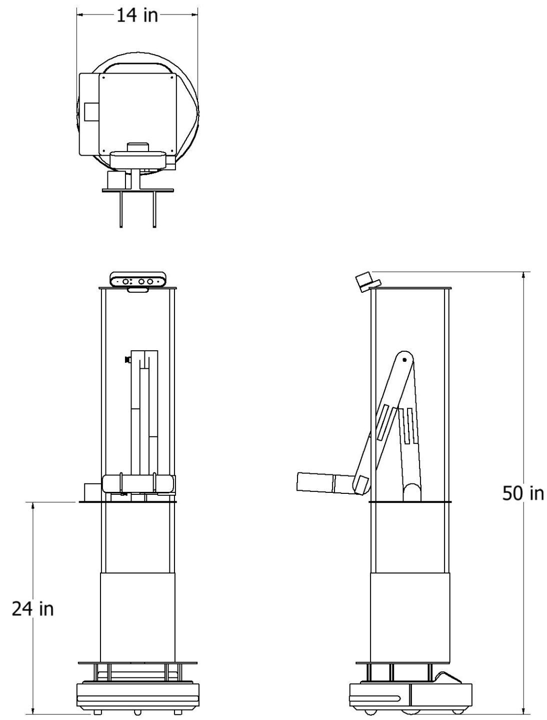
The Kobuki base includes a docking station, an internal 19-Volt Lithium-Ion battery, and various power distribution options. This project uses the 12-Volt DC, 1.5-Amp output on the Kobuki to power all other devices onboard. A buck converter converts the 12 Volt supply to 5 Volts, which allows the Raspberry Pi to operate and distribute resulting power to the RGBD camera and PWM Driver. The Stepper Motor Driver will utilize the 12-Volt DC, 5-Amp output to drive power to the higher torque motors in the arm.

Various electrical safety features are included in the design of the Kobuki base. It is a commercially available unit for educational and research purposes, so all consumer electronics regulations apply. Additionally, the base provides current-limiting for all power supplies, and the system will shut down if 3.3 Amps or more is pulled by the system.



Structural Design

The primary objective of our structural design was to avoid tipping the robot. Excess weight of the robotic arm could cause tipping when reaching for the object. The arm is designed in a way that it would be in a contracted position while in motion to maintain structural stability. The estimated height of the robot with contracted arm position is 40in and the maximum height could be upto 50in in extended position.The robotic arm is situated 2 feet above the ground elevated with four 0.5 inch aluminium rods attached to a base plate with robotic arm and the 3D camera on another base plate located 4 ft high from the kobuki with similar four aluminum rods. The base plate is cut in U shape to situate the arm with more degree of freedom. The stepper motors are located on the base plate along the arm with a pulley mechanism with a GT-2 timing belt to control the arm joint. The pulley mechanism helps reduce weight on the arm, maintains more stability and helps maintain center of gravity on the kobuki with arm extension upto 1.5ft.The center of gravity is estimated to be 4 in away from center of the kobuki base with maximum arm extension of 1.5 ft. The arm movement occuring at rest helps avoid tipping.



Arm Design

The primary objective of the arm design is to design it in a way that it can sustain an additional one pound weight without failure. The arm consists of two one foot and quarter long segments with 4 actuation motors. Two high-torque stepper motors will control the main arm segments. One servo will control the angling of the grasping mechanism and one will control the expansion and contraction of the grasping mechanism. The arm segments would be manufactured using 3D printers to have minimal possible weight. The selection of material for arm segments will depend on the weight and strength of the material. The lightest possible material to sustain the forces would be ideal for the current design. The materials considered for arm segments are carbon fiber and fiberglass using Markforged 3D printers for precision. The total estimated arm weight expected is 4-5lb including the weight of two micro servo motors in the arm.

Applicable Codes and Standards

Non-industrial robotics areas have unfortunately yet to establish comprehensive regulations for system safety and operation. ISO 13482 (Robots and Robotic Devices: Safety Requirements for Personal Care Robots) provides a great foundation for this project's specific area, and the project team plans to develop additional standards which will define their human interfacing strategy. General FCC consumer electronics and household appliance requirements apply to this device as well as best practices as recommended by the CPSC. Known possibly applicable standards under review by the project team are listed below:

- ISO TC-10 (Technical Product Documentation)
- ISO TC-98 (Bases for Design of Structures)
- ISO TC-173 (Assistive Products)
- ISO TC-184 (Automation Systems and Integration)
- ISO TC-199 (Safety of Machinery)
- ISO TC-299 (Robotics)
- ISO/IEC JTC 1/SC 6 (Telecommunications and Information Exchange Between Systems)
- ISO/IEC JTC 1/SC 7 (Software and Systems Engineering)
- ISO/IEC JTC 1/SC 22 (Programming Languages, Their Environments, and System Software Interfaces)
- ISO/IEC JTC 1/SC 29 (Coding of Audio, Picture, Multimedia and Hypermedia Information)
- ISO/IEC JTC 1/SC 31 (Automatic Identification and Data Capture Techniques)
- ISO/IEC JTC 1/SC 35 (User Interfaces)
- ISO/IEC JTC 1/SC 41 (Internet of Things and Related Technologies)
- ISO/IEC JTC 1/SC 42 (Artificial Intelligence)
- OSHA STD 01-12-002 (Guidelines for Robotics Safety)
- ANSI RIA R15.06 (Industrial Robots and Robot Systems)
- IEEE 1872 (Ontologies for Robotics and Automation)
- IEEE 1873 (Robot Map Data Representation for Navigation)

Preliminary Cost Analysis

Component	Estimated Cost
Kobuki Mobile Research Base*	($400)
Orbbec Astra RGBD Camera*	($150)
Platforms and Aluminum Supports**	($100)
Arm Structural Components**	($200)
Servo Motors	2 x $20
Servo Motor Driver	$10
Stepper Motors	2 x $62
Stepper Motor Drivers	2 x $15
Arm Actuator Components	$30
Raspberry Pi 4B w/ 4 GB RAM	$60
Electrical Components	$50
Raw Materials (Aluminum Rods for Supports	$25
Miscellaneous Unaccounted Items	$30
Total Project Cost	$1250
Total Funding Needed	$400

* Visual Computing and Image Processing Lab has generously provided this component at no cost.
** CEAT provides this component at no cost via on-campus fabrication facilities.

Hazard Analysis

Project Name	Personal Assistive Robot	Date	1-31-2020
Author	Dylan Shadoan, Emily King, Hrudhay Jaladi		
Mentor/Faculty Lead	Dr. Guoliang Fan	Mentor/Faculty Lead Approval (signature)	

Risk	Initial PR	Mitigation	Final PR
Electrical Shock	3D	Proper enclosure covering all electrical connections and wiring. All electrical components mounted or tied neatly and tightly. (Kobuki base includes many electrical safety features and certifications.)	3E
Tripping Hazard	3C	Navigation algorithms account for human presence, avoid humans. Halt operation when the only available path must pass closely by a human.	3E
Human Interfacing Issues (when presenting objects to the user)	3C	Arm design indicates when it is safe for a user to grab the presented object. Object is released fully by the grasping mechanism. Grasping mechanism is a simple two-finger clamp design with a soft rubber skin.	3E
Pinching Hazard	3D	Arm design leaves sufficient space between segments. Arm will have a mesh wrap around it to act as a guard against user interaction.	3E

Conclusion

Moving into its second phase, the project now has well-defined objectives and clear methods for achieving them. Some very good points were made by faculty attendees of the Concept Design Review that are to be immediately considered by the team, including the following:

- The RGBD camera needs to be mounted higher in order to achieve the vision necessary for the full 4-foot vertical arm range.
- Human interaction is of great concern. How can the robot safely present objects to the user?
- Consider alternatives to additive manufacturing for larger components.
- Consider stabilization arms--motorized or fixed.

Immediate next steps include consulting with various local experts in robotics and AI, safety standard refinement, design refinement, initial prototyping and development, and arm actuator selection. The team is also continuing to familiarize themselves with ROS, TensorFlow, and robotics best practices.

References

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RD5ARIsAGFygj_fBaOwViObZQlNwj3JOo9A6I9yjKOmEjo_hGYmWPhz-eNJwg abbroaAl7rEALw_wcB&s_kwcid=AL!4223!3!198551352378!!!g!340299749008!.

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"Mirage Camera with Daydream." *Point-and-Shoot VR180 Camera | Lenovo US*, www.lenovo.com/us/en/virtual-reality-and-smart-devices/virtual-and-augmented-reality/lenovo-mirage-camera/Mirage-Camera/p/ZZIRZRCVR04.

"MYNT EYE Standard." *MYNT EYE*, www.mynteye.com/products/mynt-eye-stereo-camera?variant=13183676973079¤cy&gclid=Cj0KCQiA04XxBRD5ARIsAGFygj_eIYOAQ0su3TR_RI_Od81NR6Zw4jbf84X_P0V32Adsdqrly9XfL34aAqN6EALw_wcB.

"Product: RICOH THETA SC." *Product | RICOH THETA SC*, theta360.com/en/about/theta/sc.html.

Appendix A: URS Proposal

A Wearable Object Finding and Localization Tool for Personal Assistive Technology

Dylan L. Shadoan | Electrical, Computer, and Mechanical Engineering | Oklahoma State University

Background and Objective

The struggle against aging is one which every person comes to know. Aging presents us with countless problems that seem impossible to solve—even with many technological advancements at our fingertips. While aging does bring a welcome gain of experience and wisdom, it can also bring with it considerable loss—loss of memory, loss of perception, loss of mobility, etc. It is the medical community who works to treat and prevent these losses, but it is the technological community who can work to give these losses back. This project is a part of that effort, and it aims to take advantage of advancements in computer vision, machine learning, robotics, and wearables to assist persons with impaired memory and awareness—such as victims of neurodegenerative diseases—to navigate their living space, locate lost items, and carry out everyday tasks with greater ease.

Much of this project will build upon two other efforts completed recently in the School of Electrical and Computer Engineering including navigational robots and smart glasses wearables[1]. The idea is to integrate these projects to communicate with an Android smartphone application via a WiFi local area network and then add additional functionality and intuitive controls. The additional functionality includes object location using computer vision algorithms as well as object retrieval using a simple robotic arm. The end goal is to wrap all of this assistive technology into a clean, reliable, and user-customizable package.

System Overview

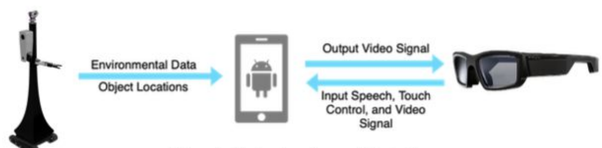

Figure 1: Device Functions and Data Flow

In order to assist individuals with navigating their living space, the system will first need to collect data about how the space is laid out and take note of specific landmark locations within the space (e.g., kitchen appliances, bathroom fixtures, furniture, and doorways). Items of interest—such as keys, wallets, and pill boxes—can also be identified and located for the purpose of recovering lost items. All of this data can be collected via computer vision algorithms using a camera mounted on the robot as well as a camera built into the smart glasses. The robot will initially navigate and scan the entire living space autonomously to form a base map, and the smart glasses' camera will be used to make adjustments to this base map while the user moves about. The robot can also be set to periodically update the map as well to ensure no environmental change goes unnoticed.

An Android smartphone application will act as the brain of this system, storing all of the relevant data and processing the input received from the smart glasses. The robot will process its data locally into a map on its onboard microcontroller, but it will then transmit the map data to the smartphone for storage and further use.

The system will interface with the user through the smart glasses' speech input, touch input, and transparent display. The user will have the following options:

- Navigate to a landmark or lost item with onscreen directions
- Have the robot retrieve a lost item
- Ask a question about the stored data
- Ask for help performing a task

Task assistance can be achieved by two different means: prerecorded instruction and guided instruction. Prerecorded instruction would display step-by-step instructions on the smart glasses' screen either in written form or as a demonstration video. Guided instruction would use the built-in camera and computer vision algorithms to monitor the user's actions throughout the process to account for errors and adjust the displayed instructions accordingly. This could be further expanded to direct the user in a more personal way through augmented reality techniques. This project will investigate both means of task assistance.

A scheduling system will also be integrated to visually remind the user when they are scheduled to perform certain tasks (e.g., take medication, eat lunch, or call a family member) and help them navigate to those tasks if they wish. If the glasses sense an emergency situation like a fall or an emergency phrase, the system can also be configured to contact another individual for help.

Technology

vSLAM (Visual Simultaneous Localization and Mapping) is a potential computer vision technology for the mapping portion of this project. It can use a simple monocular camera to create a map of the environment and determine the camera's location. There are a few vSLAM implementations commercially available, such as the Accuware Dragonfly[2], that provide APIs for easy integration.

In order to perform object detection, a second computer vision technology is required. This can be achieved using a machine learning algorithm which has been trained using sets of reference images to identify similar objects. Google's Tensorflow Object Detection API is a possible candidate for this component as it is trained on the COCO dataset (Common Objects in COntext), which contains 300,000 images of 90 common objects[3].

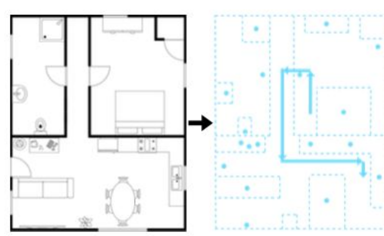
Figure 2: Abstract Mapping of a Living Space

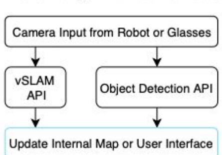

Figure 3: Combined Computer Vision Mapping Algorithm

Other potential technologies for use in this project include:

- 2.4-GHz WiFi for device communication
- Single-board computer or microcontroller for robot control and data acquisition, such as a Raspberry Pi[4]
- Continuous-track propulsion for robot maneuverability on various types of indoor flooring
- 3-axis articulated robotic arm for object retrieval
- 3D printing technology for robot structure
- Motorized gimbal for robot camera control

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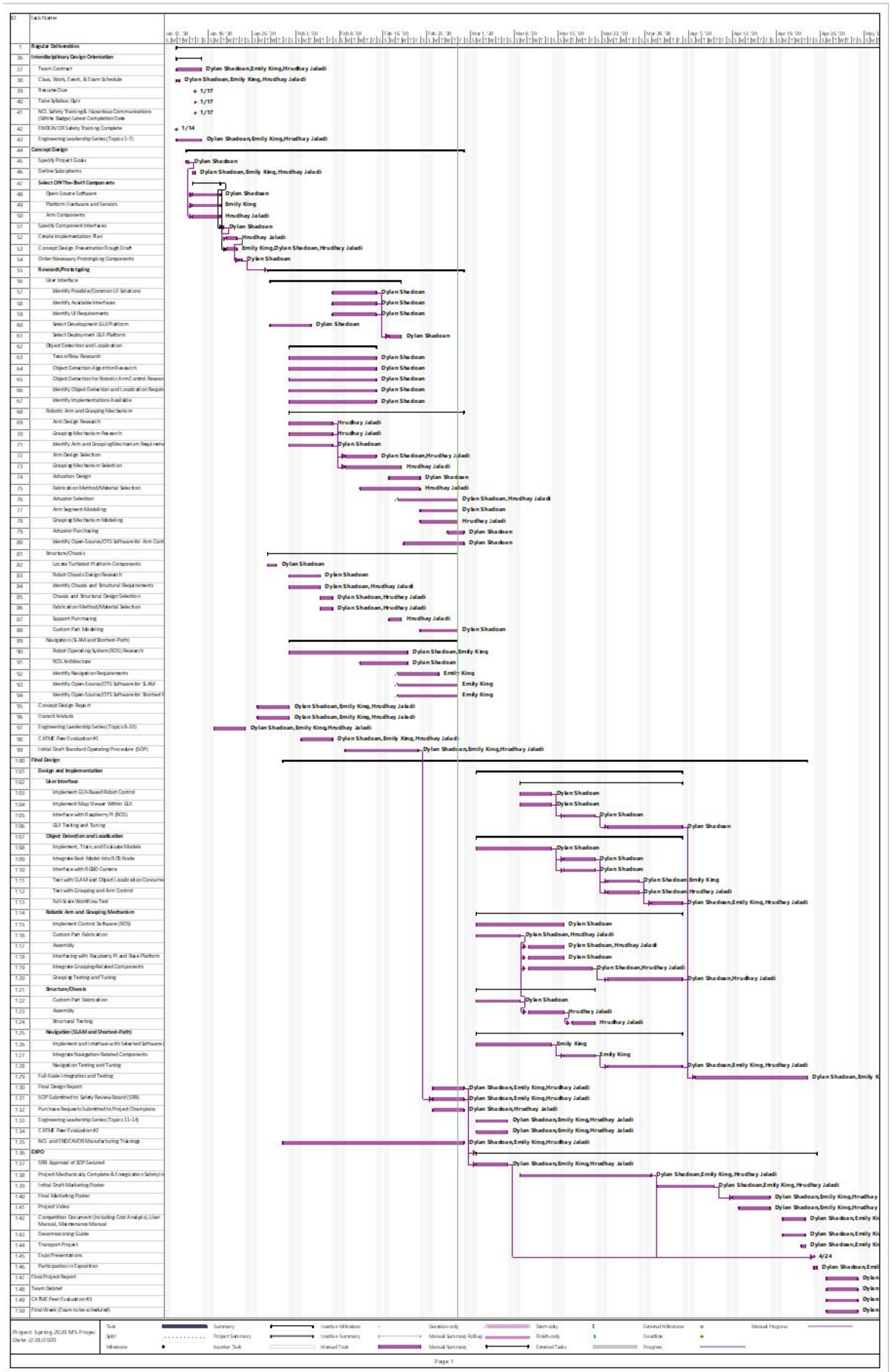
[1] Vuzix *Vuzix Blade® Smart Glasses* https://www.vuzix.com/products/blade-smart-glasses

[2] Accuware, Inc. "What is Visual SLAM?" https://www.dragonflycv.com/what-is-visual-slam/

[3] Google, Inc. *Tensorflow Object Detection API* https://github.com/tensorflow/models/tree/master/research/object_detection

[4] Raspberry Pi Foundation "Teach, Learn, and Make with Raspberry Pi" https://www.raspberrypi.org

Appendix B: Gantt Chart



Appendix C: Off-the-Shelf Component Selection Example (Optical Sensor)

Camera Comparison Table

Product	Cost	Size	Range	FOV	RGB Image Res.	OS	SDK	Other
Orbbec Astra	$0	165mm x 30mm x 40mm	0.6m-8m	60°H x 49.5°V x 73°D	640 x 480 @30fps	Android/Linux/Windows 7/8/10	Astra SDK or OpenNI	2 built-in microphones
Lenovo Mirage	$103	55 mm x 105 mm x 22 mm		180° x 180°	4K/1440P/1080P @30 FPS			IMU Sensor (6 Degrees of Freedom)
								2 microphones
MYNT Eye 3D	$179	165 mm x 31 mm x 30 mm	0.5m-18m	146° D - 122° x 76°	752x480 @ 60 fps	Windows 10, ROS, Android 7.0 +,		non-IR
	$239					Ubuntu 14.04/16.04/18.04		IR Light quad module
Ricoh Theta SC 360	$200	45.2 mm x 130.6 mm x 22.9 mm		360°	3840 x 1920, 29.97fps			
QooCam	$389	30.5x25x198.5mm		216°	3840*1920@30fps			
					3840*1920@60fps			
					1920*960@100fps			
					1920*960@120fps			
Insta360 Evo	$420	98.4mm×49mm×26.27mm		180° or 360°	5760*2880@30fps	IOS/Android		No video stitiching, gyro-stable
					3840*1920@50fps			
					3840*1920@30fps			
					3008*1504@100fps			
Intel RealSense D435	$194	25.4mm x 25.4mm x 88.9mm	7.9in min	69.4°H x 42.5°V	1920 x 1080 @ 90fps			IR Laser projector
OpenMV Cam H7	$65	2.8mm			640x480 @60fps	MicroPython		STM32H743VI ARM Cortex M7 processor

Criteria	Weight	Options															
		Orbbec Astra		Lenovo Mirage		MYNT Eye 3D		Ricoh Theta SC 360		QooCam		Insta360 Evo		Intel RealSense D435		OpenMV Cam H7	
		Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total
Cost	5	5	25	4	20	3	15	3	15	2	10	1	5	4	20	5	25
Size	2	3	6	4	8	3	6	3	6	3	6	5	10	5	10	5	10
Range	4	4	16	1	4	5	20	1	4	1	4	1	4	4	16	1	4
FOV	5	3	15	4	20	4	20	2	10	5	25	4	20	3	15	1	5
Resolution	4	2	8	4	16	2	8	2	8	5	20	5	20	2	8	2	8
OS	3	4	12	1	3	5	15	1	3	1	3	3	9	1	3	2	6
SDK	3	3	9	1	3	1	3	1	3	1	3	1	3	1	3	1	3
Other	1	2	2	3	3	3	3	1	1	1	1	3	3	2	2	2	2
	Total:		93		77		90		50		72		74		77		63

Key:	1	2	3	4	5
Weight	Not at all Important	Slightly Important	Important	Fairly Important	Very Important
Cost	$400+	$300-$400	$200-$300	$100-$200	$0-$100
Size	unknown	300mm+	150-250mm	100-150mm	100-50mm
Range	unknown	0m-5m	5m-10m	10m-15m	15m-20m
FOV	unknown	360° 2D	0°-90° 3D	0°-180° 3D	0°-270° 3D
Resolution	unknown	1 option	2 options	3 options	4 options
OS	unknown	1 platform	2/3 platforms	4 platforms	5+ platforms
SDK	unknown	1 platform	2/3 platforms	4 platforms	5+ platforms
other	none	1 item	2 items	3 items	4 items

Appendix D: Interdisciplinary Design Project Proposal (Problem Assignment)

CEAT Interdisciplinary Project Application and Approval Form

Interdisciplinary Project Name	Personal Assistive Robot
Semester	Spring 2020
Form Prepared by	Dylan Shadoan
Date Submitted	22-Oct
Date Approved by Interdisciplinary Project Review & Selection Team	

Project Description/Scope

A continuation of a Undergraduate Research Scholars project tasked with exploring personal assistive technologies and developing a system to help persons with neurodegerative diseases with everyday tasks at home. This project will develop an indoor autonomous robot with the following capabilities:
- navigate to all areas of a single-story occupied home or living space
- return to its docking station when its battery is low
- create a digital map of the living space while navigating (perform Simultaneous Localization and Mapping algorithm)
- detect and recognize a set of important objects within the home (keys, phone, medication, appliances, furniture) and note their locations on the map
- retreive small objects as requested by the user
- provide an interface for users to input commands
- communicate its intentions with the user (sound, visual, etc.)
- notify the user in a failure situation (robot is stuck, cannot find the specified object to retrieve, or cannot find docking station)

The team is encouraged to consider off-the-shelf components and open-source software for many of the relevant project areas.

Other Information That may be relevant to*Project Selection* Team	The Personal Assistive Technology project is particularly exciting because of its potential to help the millions of people around the world who are living with neurodegenerative diseases. The functions of the robot itself can be useful even outside the scope of the UR project. The technologies and deliverables are highly scalable and relevant to many applications within the areas of IoT, robotics, machine learning, and control systems.

Key Deliverables

Hardware and software for traversing a living space autonomously (robot platform, actuators, onboard power, camera(s), etc.) across various common surfaces (carpet, flooring, small thresholds)	Hardware and software for detecting and recognizing a given set of objects to note landmarks on digital map
Hardware and software for grasping small objects and carrying them to another location within a living space (robotic arm, etc.)	Hardware and software for creating a digital map of a living space (SLAM implementation) at regular intervals (update map one per day, every four hours, etc.)
Charging dock and the functionality to return the robot to its dock when needed	Hardware and software to interface with the user (audio, visual, smartphone interface, etc.) for configuration, communication, and user input
Hardware and software to notify user and take appropriate action in a failure condition	

Leading College	CEAT
Leading Department(s)	ECEN
OSU Project Champion(s)	Professor Guoliang Fan
Project Administrator	Professor Gard
Project Fabrication and Production Location(s)	OSU Visual Computing and Image Processing Lab (ATRC 233)
Installed Project Location	
OSU Mentors	

Sponsor(s)/Client and Funding

Organization/Company	
Sponsor Representative(s)	
Team Travel Required	
Location if Travel Required	
Source of Funds*	
Funding Approved (Y/N/Pending Project Acceptance)	

Discipline (& College if not CEAT)	Number of Students Required	Discipline (& College if not CEAT)	Number of Students Required
ARCH - Architecture		FPST - Fire Protection & Safety Technology	
ArchE - Architectural Engineering		IEM - Industrial Engineering and Mgmt.	
AE - Aerospace Engineering		ME- Mechanical Engineering	2
ChemE - Chemical Engineering		MET - Mechanical Eng. Technology	
CivE - Civil Engineering			
CE -Computer Engineering			
CET - Construction Eng. Technology			
EE - Electrical Engineering	2		
EET - Electrical Engineering Technology			
		Total	4

Approximate Project Costs		**Notable Project Safety Considerations**	**Y/N**
Materials/Eqpt for Project		High Voltage (> or = to 110 VAC or 60VDC)	N
Materials for Marketing/Communications		High Pressure (> 100 psig)	N
Outside Services		Working at Heights (>6 ft)	N
Transportation & Travel		Dropped Objects	N
Miscellaneous		Lasers involved	N
		Hazardous Materials (chemicals, fumes, etc.)	N
Total	$0	Working in Excavations	N

Other Notable Project Safety considerations not listed above:

Special Student Requirements/Considerations:

Students are expected to be able to perform physical tasks that are common within their disciplines, however if the project is deemed by the project Champion or discipline Mentor to require skills and abilities that are not common to their disciplines, they should be listed here (i.e. color-blindness if color recognition is a key aspect of the project, or if traversing difficult terrain as part of data gathering or project installation, etc.)

** Projects requesting Interdisciplinary Design funding from Foundation Account must meet the following criteria: To access the $10,000 per project maximum, must involve students from at least three departments and ten students. Other funding requested from the Interdisciplinary Design budget, must be reviewed and secure approval from Director of Interdisciplinary Design.*

inputs in cells shaded this color

Appendix E: Individual Contributions to Final Design

Student	Contribution Areas	Effort
Dylan Shadoan	• Project description • Base and software selection • Implementation strategy • Subsystem interfacing • Modeling/drafting • Budgeting • Hazard Analysis	20 hrs
Emily King	• Codes and Standards • OTS component selection methodology • ROS familiarization • ECE departmental communication • Project Planning Training Session	20 hrs
Hrudhay Jaladi	• Arm design • Grasping Design • Structural design • Physical stabilization • Safety code • Project Planning	20 hrs

Appendix F: SOP

OKLAHOMA STATE UNIVERSITY
NCL STANDARD OPERATING PROCEDURE

This document is for use by the Project Team to develop a Standard Operating Procedure (SOP) and sent to the NCL Safety Review Board. **The completed SOP should be shared with all the members of the team.** The SOP should be revised whenever a significant change to the location or scope of work occurs. The NCL Safety Review Board (SRB) is available to assist in completion or review of the SOP. For questions, please call (405) 744-5915 or email ceatncl@okstate.edu. Submit the completed SOP to the NCL SRB by emailing an electronic copy to ceatncl@okstate.edu with the subject heading: SOP_<Team/Group name>. Save the file name in the following format (<team/group name>_<date-of-submission> Ex: ImpactTester_2018-01-31). Please allow at least two business days for approval or requested revisions. Hand written documents will not be approved.

The following SOP generally follows under:

☐	SOP is for a general lab operation/process that could apply to several chemicals
✓	SOP is for a specific protocol/experiment/procedure
☐	SOP is for a specific chemical or class of chemicals with similar hazards

Section I.

Project Title:	Personal Assistive Robot		
Principal Investigator/Project Manager:	Dr. Guoliang Fan	Department:	ECE and MAE
Email:	guoliang.fan@okstate.edu	Phone:	405-744-1547
Project Duration:	January 14^{th} - May 1^{st}		

Location of Fabrication/Testing Include room number(s) as appropriate

CEAT North Labs		UAFS	
ATRC	ATRC 233 (VCIPL)	Richmond Hills	
Other			

OSU Contact Person:	Dr. Guoliang Fan	Phone:	405-744-1547
Local (Field) Contact Person:		Phone:	

Group/Project Members (Attach separate sheet of paper if necessary)

Name	Email	Team Leader	Team Member
Dylan Shadoan	dylan.shadoan@okstate.edu	✓	☐
Emily King	emily.n.king@okstate.edu	☐	✓
Hrudhay Jaladi	hrudhay.jaladi@okstate.edu	☐	✓

Section II.

Procedure Overview: Provide a brief description of the project and/or procedure.
(Attach separate sheet of paper if necessary)

The project involves development of an indoor autonomous robot to be marketed as a personal electronic assistance device. The device's goal is to map a single-story indoor space, detect and store the locations of small objects as specified (keys, phone, remote control, pillbox, etc.), and retrieve those objects individually as requested by the user. The device conforms to all safety codes and standards which apply to such consumer electronic devices.

When the device is not in operation, it automatically returns to its charging base or notifies the user that it cannot find its base. All active modes of operation involve traversal of the living space according to either mapping or shortest-path algorithms. Whenever the device is in motion, there exists a potential tripping hazard. The device does not move silently, so most users would be notified by light noise that the robot is approaching. However, it is recommended that users do not attempt to move about their living space while the device is in motion. All user control is handled via a wireless mobile application.

Section III.

	Hazards Inherent to the Project (Check all that Apply)	
	☐Extreme Temperature ☐Electrical Hazard > 50 volts or high current ☐Noise Generated > 85 dBA ☐Sharp Edges ☐Flying Debris or Impact ☐Pressure Vessel/Compressed Gas ☐Bungee Cables/Elastic Energy Storage ☐Fire Hazards (open flame, welding, cutting) ☐Handling Hazardous Materials	☐Heights (roofs, lifts, towers, catwalks, etc.) ☐Potential for Oxygen Deficiency or Other Atmospheric Hazard (i.e. gas, vapor) ☐Storage of Hazardous Materials on site ✓ Lithium Batteries ☐Transportation of Hazardous Materials ☐Other:_____ **Equipment Used**

	☐Dusts/Other Particulate Hazards	☐Golf Cart/ATV
	☐Work in Confined Space (natural or man-made)	☐Forklift
	☐Falling Objects	☐Tractor
	☐Trenching/Excavating	☐Other _____
	☐Explosion	

Health and Safety Information: Briefly describe the hazards associated with the materials or equipment used during the procedure. (Attach separate sheet of paper if necessary)

This device utilizes a Kobuki mobile research base. Below are the basic performance specifications.

Maximum translational velocity: 70 cm/s
Maximum rotational velocity: 180 deg/s (>110 deg/s gyro performance will degrade)
Payload: 5 kg (hard floor), 4 kg (carpet)
Diameter : 351.5mm / Height : 124.8mm / Weight : 2.35kg (4S1P - small) (Update this to include the Turtle-deck if it is installed)
Cliff: will not drive off a cliff with a depth greater than 5cm
Threshold Climbing: climbs thresholds of 12 mm or lower
Rug Climbing: climbs rugs of 12 mm or lower
Power connectors: 5V/1A, 12V/1.5A, 12V/5A
Battery: Lithium-Ion, 14.8V, 2200 mAh (4S1P - small), 4400 mAh (4S2P - large)
Recharging Adapter: Input: 100-240V AC, 50/60Hz, 1.5A max; Output: 19V DC, 3.16A

Section IV. (NOT APPLICABLE)

Personal Protective Equipment or Clothing Required: All activities require basic protection including appropriate clothing, hand protection, safety shoes/boots, and eye protection. Any additional PPE requirements based on the hazards identified as part of minimizing risk of exposure, injury or illness. (Check all that Apply)

☐Face Shields/Safety Glasses	☐Respirator	☐Emergency Shower
☐Hearing Protection	Type:_____	☐Extraction Equipment (Confined Space)
☐Hard Hat	Cartridge/Filter Type: _____	☐Other: _____
☐Gloves	☐N95 Particulate Mask	
☐Fall Protection	☐Portable Eye Wash	

Safety Training Required

☐ Advanced First Aid	☐Confined Space

☐CPR	☐Laser Safety
☐Emergency Action and Preparedness	☐Forklift/Other Heavy Equipment
☐Project Specific Hazard Communication	☐N95 Particulate Mask Disclaimer
☐Compressed Gasses	☐Respiratory Protections
☐HotWorks (Welding, Torch/Plasma Cutting)	☐Fire Extinguisher
☐Ladder	☐Other:_____

Section V.

Method Procedures: Give a step-by-step instruction for the procedure. (Attach separate sheet of paper if necessary)

The device has two modes of operation: **mapping/map updating** and **retrieving**.

Mapping Mode (Device Set-Up and Update)

1. Check that robot is on charging base
2. Open Mobile App
3. Select “Update Map”
4. *Without interfering with robot, wait for robot to traverse entire room
5. Allow robot to return to charging base
6. View map of living space and on mobile app
    a. Objects of interest will be highlighted in corresponding location on map

*If user wishes to stop mapping process, select “Abort” on mobile app

**If user wishes to pause mapping process, select “Pause” on mobile app

Retrieving Mode (Regular Use)

1. Tap on desired object in mobile app
2. Wait for robot to move to object location
3. Wait for robot to successfully grasp object
4. Wait for robot to move to user location and deliver object
5. Take requested object from robot

Section VI.

Waste Disposal Procedure: Give a step-by-step instruction for the procedure (if applicable). (Attach separate sheet of paper if necessary)

1. If any LiPo cell in the pack has been physically damaged, resulting in a swollen cell or a split or tear in a cell's foil covering, do NOT discharge the battery. Jump to step 5.
2. Place the LiPo battery in a fireproof container or bucket of sand.
3. Connect the battery to a LiPo discharger. Set the discharge cutoff voltage to the lowest possible value. Set the discharge current to a C/10 value, with "C" being the capacity rating of the pack. For example, the "1C" rating for a 1200mAh battery is 1.2A, and that battery's C/10 current value is (1.2A / 10) 0.12A or 120mA. Or, a simple resistive type of discharge load can be used, such as a power resistor or set of light bulbs as long as the discharge current doesn't exceed the C/10 value and cause an overheating condition. For LiPo packs rated at 7.4V and 11.1V, connect a 150 Ω resistor with a power rating of 2 watts (commonly found at Radio Shack) to the pack's positive and negative terminals to safely discharge the battery. It's also possible to discharge the battery by connecting it to an ESC/motor system and allowing the motor to run indefinitely until no power remains to further cause the system to function.
4. Discharge the battery until its voltage reaches 1.0V per cell or lower. For resistive load type discharges, discharge the battery for up to 24 hours.
5. Submerse the battery into bucket or tub of salt water. This container should have a lid, but it does not need to be airtight. Prepare a bucket or tub containing 3 to 5 gallons of old water, and mix in 1/2 cup of salt per gallon of water. Drop the battery into the salt water. Allow the battery to remain in the tub of salt water for at least 2 weeks.
6. Remove the LiPo battery from the salt water and place it in the normal trash.

Above instructions from: http://manuals.hobbico.com/sup/supz1030-lipo-handling.pdf

Section VII.

First Aid Procedures: Give a step-by-step instruction for the procedure. (Attach separate sheet of paper if necessary) This section should also contain the address and location(s) that the SOP will be used.

All incidents require that as soon as possible the Instructor of Record and Profession Staff over lab be notified.

Location:

Oklahoma State University

ATRC 233, Athletic Ave

Stillwater, OK 74075

Location of Nearest Hard Phone Line: VCIPL Lab, south wall on table

Nearest Location of a solid Cell phone signal: All Areas on campus

Emergencies:

- One person is assigned to stay with the injured personal
- One person should be assigned to call 911, this person will stay on the phone and state the following
  - Location of the accident (This should include building and room)
  - Type of injury
- One person should be assigned to escort the emergency response crew to the location

Specialized First Aid Procedures as related to this project:

In the event of a burn from a lithium ion battery fire, call the local emergency medical services.

Section VIII. (NOT APPLICABLE)

Spill/Release Containment, Decontamination, and Clean-up Procedures: Give a step-by-step instruction for the procedure (if applicable). (Attach separate sheet of paper if necessary)
Not applicable to this project.

Section IX.

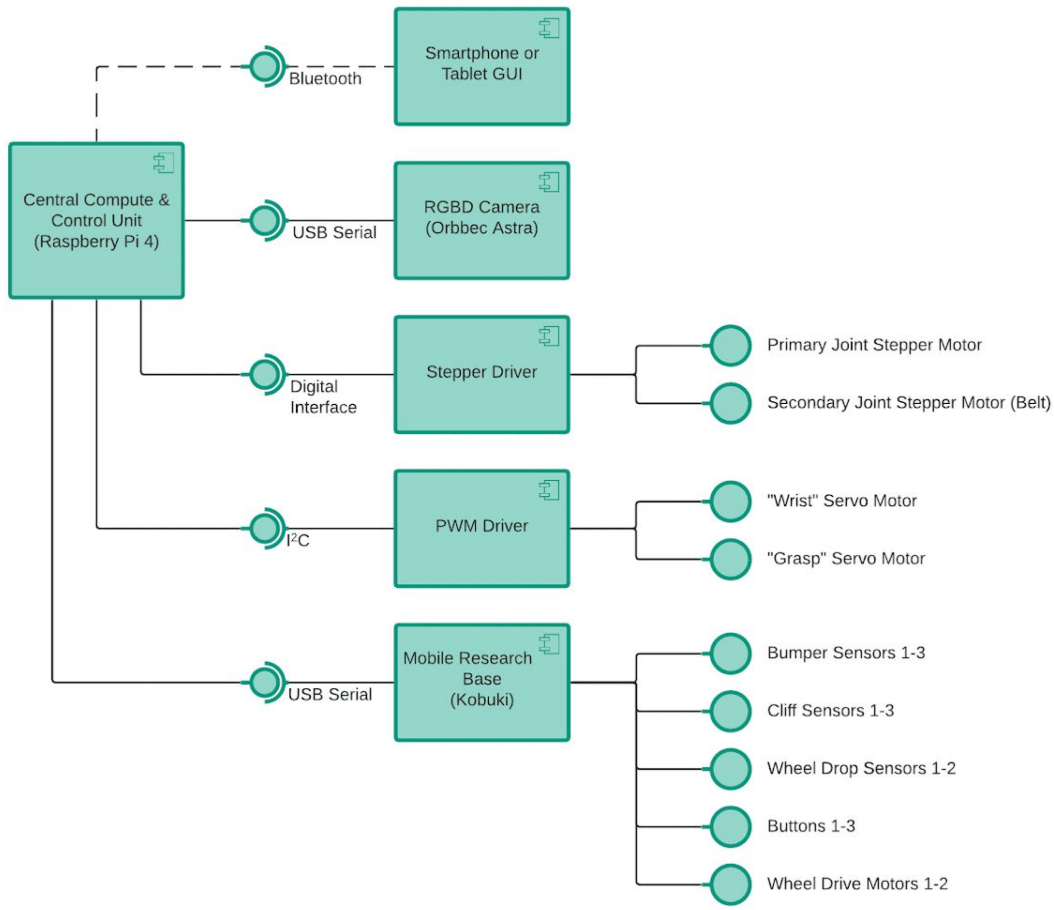
Approvals Required: Describe any special approvals required before conducting this work such as approval by Principal Investigator or lab supervisor before beginning work (if applicable). (Attach separate sheet of paper if necessary)
Not applicable to this project.

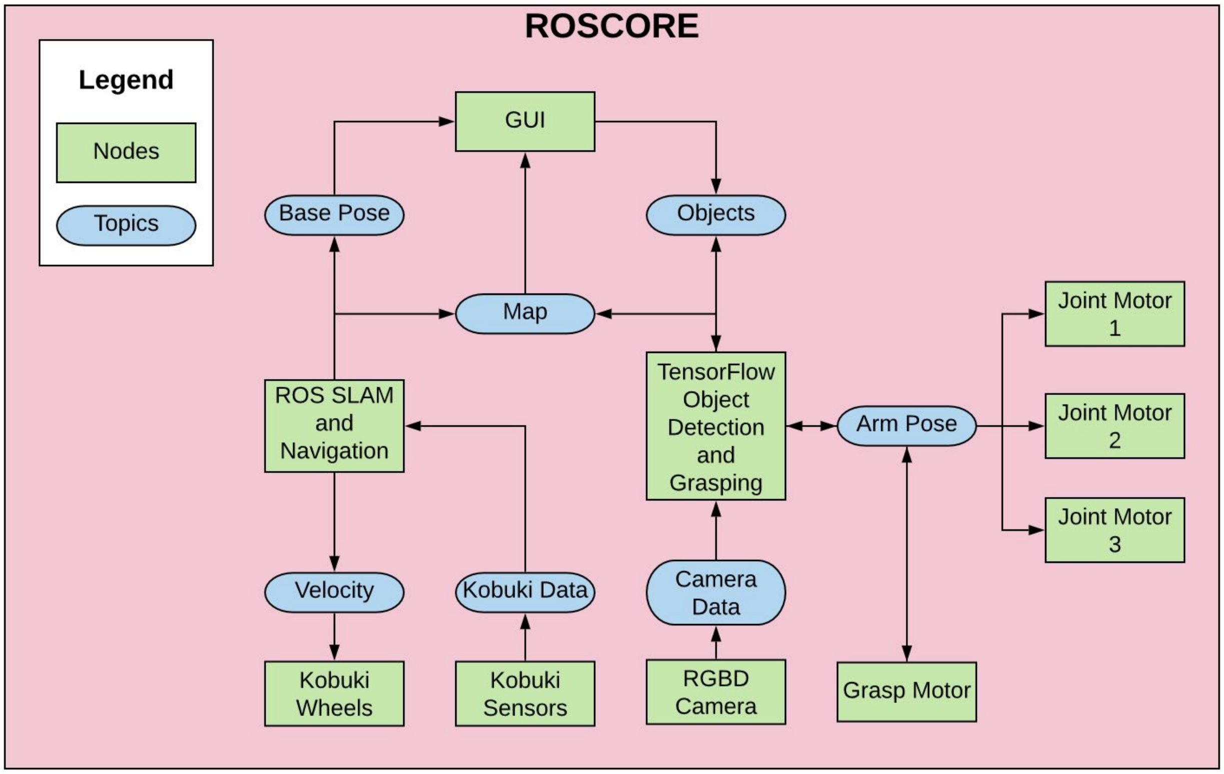
Section X.

Designated Area/Communications: (For work involving particularly hazardous dangers, identify the area where the work will be conducted and to where it will be confined; identify any communication that will be done to assure others know the hazards and location of this work.) (if applicable). (Attach separate sheet of paper if necessary)
Team meeting and design area ATRC 233, requires special access to lab area. Address: Room 233, ATRC, Athletic Ave, Stillwater, OK 74075

Section XI.

Piping, Wiring, and Instrumentation diagram: (This should include a detailed schematic illustrations of the functional relationship of piping, instrumentation and system equipment components. (Attach separate sheet of paper if necessary)

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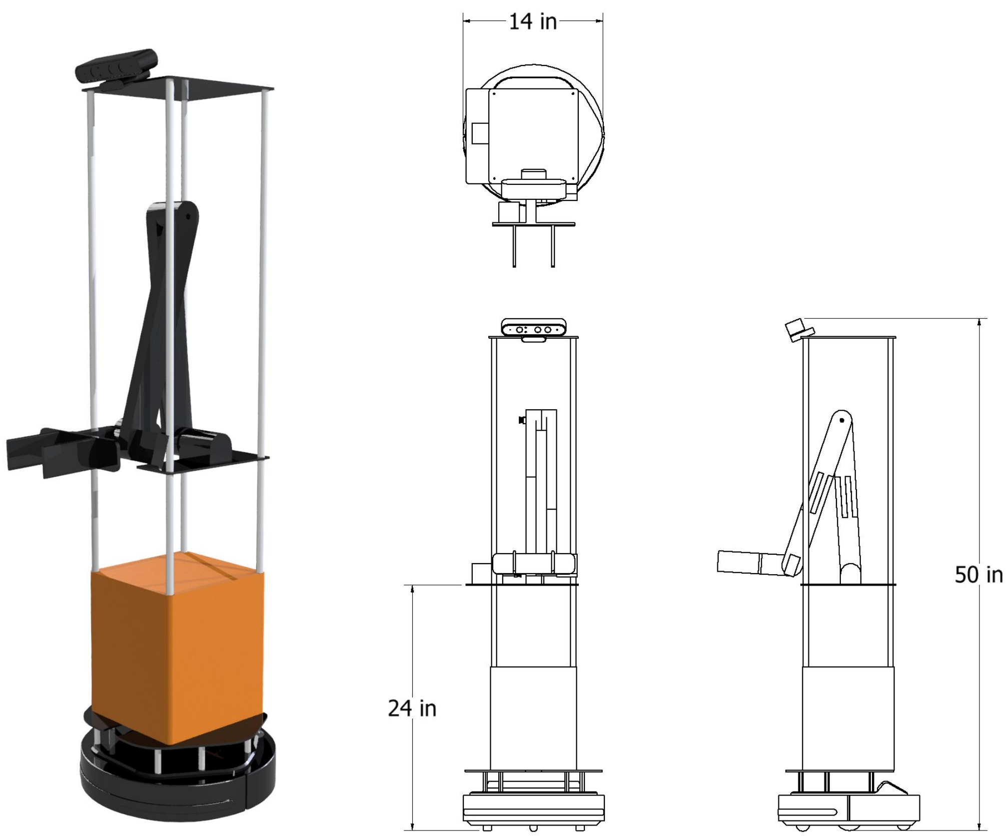
Kobuki Sensors
RGBD Camera
Grasp Motor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Once the SRB has approved the document, all team members will be required to electronically sign the document below.

By signing below, I certify that I have read the Standard Operating Plan (SOP) and agree that all listed participants and I will abide by the SOP and adhere to all OSU policies and procedures as well as any local policies, procedures or guidelines.

PI Signature: ______________________________

Participants:

____

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SRB:

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