Carnegie Mellon University

16-682

Robotic Systems Development Project Course II

Test Plan Report
COBORG

Team C:
Gerald D'Ascoli | Jonathan Lord-Fonda | Yuqing Qin | Husam Wadi Feng Xiang

Sponsor:
Biorobotics Lab

September 22, 2021

Table of Contents

1. Introduction

This document describes the various tests to be performed on the COBORG system (and subsystems) throughout the fall semester in order to validate and verify that the system and subsystems meet the stated requirements and perform as expected. The various tests are aligned with the high-level goals of the project for this semester to demonstrate incremental improvement as various features are wrapped into the full system, as well as a "use case" simulation at the end to show the end-to-end capability of our system.

2. Logistics

All tests will take place in Newell-Simon Hall Lab B512. In the interest of time, only the Fall

Validation Demonstration will be performed live, while the other tests will be run by the team and the results reported during their respective Progress Reviews. All team members will be required to be present during the Fall Validation Demonstration, but only the section lead and at least one other team member are required to be present for all of the other validation tests. Most tests will require use of the COBORG system. Additionally, revalidations will require the equipment used during the corresponding validation test in the spring.

3. Schedule

Identifier	Capability Milestone(s)	Associated Test(s)	Associated System Requirements
Progress Review 7	Run spring software on Jetson Xavier.	F1 - Jetson Xavier Baseline Functionality	None

Progress Review 8	Ensure that updated mechanical and vision subsystems will sufficiently cover the task space.	F2 - Mechanical and Vision Task Space Sufficiency	PM 7.1 PM 7.2 PM 7.3 PM 8.1 PM 8.2 PM 8.3
Progress Review 9	Revalidate the new mechanical subsystem.	F3 - Mechanical Subsystem Revalidation	PM 2 PM 3.2 PM 6
Progress Review 9	Revalidate the new vision subsystem.	F4 - Vision Subsystem Revalidation	PM 1.1 PM 1.2 PM 1.3 PD 1.1 PD 1.2 PD 1.3
Progress Review 10	Ensure that obstacle avoidance is sufficient and doesn't hinder previous performance capability.	F5 - Obstacle Avoidance Capability and Integration	PM 1.2 More TBD
Progress Review 10	Ensure that the cosmetic overhaul does not prevent system functionality.	F6 - Cosmetic Baseline Functionality	None
Progress Review 10	Ensure that the smart manipulation system achieves associated requirements.	F7 - Path Planning and Stabilization Validation	PM 3.1 PM 3.2 PM 5 PM 6
Progress Review 11 / FVD	Demonstrate that the system achieves the desired results.	FVD - Full Use Case	All requirements

4. Test F1 - Jetson Xavier Baseline Functionality

Objective: Ensure that the current software system will run on the Jetson Xavier after installation.
Elements: System Equipment: COBORG Backpack
Location: NSH Lab B512 Personnel: Yuqing Qin and Jason Xiang
Procedure: -Start up all of the nodes used in the spring's integrated test demo. -Hold a hand up in front of the COBORG system, in view of the camera. -Command the COBORG to move to the target.
Verification Criteria: -The COBORG will successfully have passed this test if it responds to the voice command and reaches out its end effector to touch the user's hand. This is an abbreviated version of the integrated system test that still runs through each node and subsystem.

5. Test F2 - Mechanical and Vision Task Space Sufficiency

Objective: Ensure that the plans to update the mechanical subsystem and vision subsystem will result in a system that can theoretically meet all of the task space requirements.
Elements: Mechanical and Vision Subsystems Equipment: Laptop with ROS, MoveIt, etc.
Location: None Personnel: Yuqing Qin Jason Xiang, and Jonathan Lord-Fonda

Procedure:
-Create a URDF file representing the plan for both the new mechanical subsystem and the new vision subsystem.
-Run the mechanical task space checking program for the URDF and analyze its outputs. The number of runs and other settings defined should ensure sufficient coverage of the task space.
-Run the vision task space checking program for the URDF (or camera configurations) and analyze its outputs.

Verification Criteria:
-The mechanical subsystem will be sufficiently capable of performing in the required task space if more than 85% of the points tested in both the task space and the stability task space are successful.
-The vision subsystem will be sufficiently capable of performing in the required task space if the vision cones of the camera(s) entirely envelop the spherical section(s) of the task space, as well as the increased dimensions related to hand offsets.

6. Test F3 - Mechanical Subsystem Revalidation

Objective: Ensure that the mechanical subsystem will continue to meet its associated requirements even after being overhauled.
Elements: Mechanical subsystem Equipment: COBORG Backpack, Board
Location: NSH Lab B512 Personnel: Jason Xiang and Other
Procedure: -Run through the mechanical validation test performed during the spring semester (see below). 1. Send arm to compact mode 2. Measure furthest point from base motor 3. Send target position to robot 4. Allow robot to actuate 5. Measure arm error 6. Repeat for two different target positions 7. Repeat test 8. Hold representative part above Coborg 9. Send Coborg to the part 10. Release part and allow Coborg to support it against another panel
Verification Criteria: -The actuated manipulation subsystem will successfully have passed this test if it achieves the same verification criteria required of it last semester (see below). ● Euclidean distance error to target is less than 6” in ≥ 60% of trials ● Point of arm furthest from base motor will be ≤ 20” in compact mode ● Coborg is able to successfully hold representative part overhead

7. Test F4 - Vision Subsystem Revalidation

Objective: Ensure that the vision subsystem will continue to meet its associated requirements even after being overhauled.
Elements: Vision subsystem Equipment: COBORG Backpack, Board
Location: NSH Lab B512 Personnel: Yuqing Qin and Other
Procedure: -Run through the vision validation test performed during the spring semester (see below). 1. Set up board and camera with known relative orientation 2. Have assistant place hands in designated locations 3. Get target goal from camera 4. Time previous step 5. Repeat for two different hand locations 6. Shift board to matte side and repeat

Verification Criteria:
-The vision subsystem will successfully have passed this test if it achieves the same verification criteria required of it last semester (see below).

- Euclidean distance error to target is less than 6” in ≥ 60% of trials
- Target is received less than 5 seconds after command issue

8. Test F5 - Obstacle Avoidance Capability and Integration

Objective: Ensure that the obstacle avoidance feature(s) are sufficiently functional and do not hinder system performance.

Elements: Software subsystem Equipment: COBORG Backpack, Obstacle, Panel, Board

Location: NSH Lab B512 Personnel: Gerry D’Ascoli and Yuqing Qin

Procedure:
-Start the COBORG system with obstacle detection.
-Measure the frame rate of the vision subsystem.
-Hold up a part ala the integrated system demo from the Spring.
-Return the COBORG to compact position.
-Move an obstacle into the path the arm would have to take so that it cannot reach the target position and hold up the part again, commanding the COBORG to reach it.

Verification Criteria:
-The vision system’s frame rate must not be too low.
-The system must be able to hold the panel while obstacle avoidance is running. -The system must be able to error out after successfully identifying that there is no acceptable path around given obstacle(s).

9. Test F6 - Cosmetic Baseline Functionality

Objective: Ensure that the current software system will run even after the cosmetic overhaul.

Elements: System Equipment: COBORG Backpack, Panel, Board

Location: NSH Lab B512 Personnel: Husam Wadi and Other

Procedure: -Start up all of the nodes used in the spring's integrated test demo. -Hold a panel up on the board, in front of the COBORG system. -Command the COBORG to move to the target. -Release the panel. -Return hands to the panel. -Command the COBORG to return home. -Weigh the COBORG by having a user stand on a scale and taking the difference between their weights with and without the COBORG in hand.
Verification Criteria: -The COBORG will successfully have passed this test if it responds to the voice command and reaches out its end effector and holds up the panel. This is the integrated system test that runs through each node and subsystem. It is also assumed that all cosmetic changes to the

COBORG system will have been applied before this test. -The COBORG must also weigh less than the 40lbs stated in the requirements.

10. Test F7 - Path Planning and Stabilization Validation

Objective: Ensure that the smart manipulation node provides sufficient path planning and stabilization capability so that the system can successfully meet its actuated manipulation requirements.	
Elements: Software and Actuated Manipulation subsystems	Equipment: COBORG Backpack, Panel, Board
Location: NSH Lab B512	Personnel: Jonathan Lord-Fonda and Jason Xiang
Procedure: -Start up all of the nodes used in the spring's integrated test demo. -Hold a panel up on the board, in front of the COBORG system. -Command the COBORG to move to the target. -Release the panel. -Rotate and translate the user's body in various directions as specified by the stability space. -Return hands to the panel. -Command the COBORG to return home. Verification Criteria: -The COBORG will successfully have passed this test if it can successfully hold up the panel, despite motions from the user to the contrary.	

11. FVD - Full Use Case

Objective: Ensure that the entire system functions as expected and can sufficiently perform the described use case for an "average user" under normal circumstances
Elements: System Equipment: COBORG Backpack, Panel, Drill, 4 Screws, Testing Setup, Measuring Tape, Protractor
Location: NSH Lab B512 Personnel: All
Procedure: 1. During the test an assistant will record successes, failures, measure errors, and time procedures 2. User will put on Coborg backpack 3. User will hold a matte panel overhead in one corner of the task space and say, "Coborg, move to target" 4. Coborg will operate 5. User will move 6 inches in cardinal directions 6. User will rotate 90 degrees to the left, followed by returning to the center, rotating 20 degrees to the right, and returning to the center again 7. User will screw in the panel and say, "Coborg, go home" 8. User will place hands on panel and say, "Coborg, move to target" 9. Coborg will operate 10. User will unscrew panel and say, "Coborg, go home" 11. User will flip panel to shiny side and repeat previous steps for a diagonal corner of the task space 12. Test will be repeated as time allows
Verification Criteria: ● Panel is successfully screwed into the board all times without interference from the user ● Euclidean distance error to target is less than 6" in ≥ 60% of trials ● Target is received less than 5 seconds after command issue ● End-effector will shift less than 6" during screwing process ● The robot is able to hold the part overhead without dropping it ● The percentage of all commands correctly identified (out of all true/false positives and false negatives) is ≥ 60% ● Both the number and length of commands are inherent to the test ● Release of part takes less than 5 seconds ● Point of arm furthest from base motor will be ≤ 20" in compact mode ● User will be unharmed during test, also inherent to system (e-stops, torque limits, etc.) ● User does not have difficulties, automation works as intended ● Robot battery performs for at least 20 minutes or less than a corresponding percentage of the battery has been used during the whole test ● A number of NM requirements are inherent to the system ● The speaker is audible to all present

12. Appendix - Requirements

category	Requirement Type	Mandatory/Desir	#Req Name	Requirement Description

		abl e		
	FUNCTIONA L		F..	
vision	Functional	Mandato ry	1 F.M.1	Shall detect intended object in 3D space.
ma l		Mandato ry	2 F.M.2	Shall move end effector to intended object in 3D space.
ma l		Mandato ry	3 F.M.3	Shall maintain object position in 3D space.
voice	Functional	Mandato ry	4 F.M.4	Shall respond to preconfigured voice commands.
ma l		Mandato ry	5 F.M.5	Shall release control of object at current position.
ma l		Mandato ry	6 F.M.6	Shall compact the arm to the “home” position.
manipulati on /vision manipulati on /vision manipulati on /voice	Functional Functional Functional	Mandat ory Mandat ory Desirabl e	7 F.M.7 8 F.M.8 .. 1 F.D.1	Shall successfully reach points within a good working range. Shall account for spread of user's hands, error, and movement v F.M.7's "good working range." Shall re-orient the object based on the voice command by user.
voice	Functional	Desirabl e	2 F.D.2	Shall communicate state to user
			..	
	PERFORM AN CE		P..	
vision	Performance	Mandato ry	P.M.1. 1.1 1	(Detect indicated parts) Will have 60% accuracy of detecting inc 6" in 3D space, and always within 12".
vision	Performance	Mandato ry	1.2 P.M.1.	(Calculate object) Will detect intended object within 5 seconds o

			2	command is issued.
vision	Performance	Mandato ry	P.M.1. 1.3 3	(Pose Detection) Shall detect the surface normal of the part with than 45°.
	Performance	Mandato ry	2 P.M.2	(Move to object) Will reach within 6 in of the planned target posi and always within 12 in.
	Performance	Mandat	P.M.3. 1	(Hold object) Will maintain target's spatial position with less thar
	Performance	Manda	P.M.3. 2	(Hold object) Will be able to hold a representative part overheac
voice	Performance	Mandat	P.M.4. 1	(Voice command) Will be able to understand the voice commanc
voice	Performance	Manda	P.M.4. 2	(Voice command) Will be able to understand at least 2 unique v 8.
voice manipulati on /voice manipulati on /vision manipulati on /vision	Performance Performance manipulation Performance Performance Performance	Mandator 4.3Manda y Mandat Mandator 7.1Manda y 7.2	P.M.4. 3 5 P.M.5 6 P.M.6 P.M.7. 1 P.M.7. 2	(Voice command) Will be able to understand commands of at lea up to 8. (Release object) Will release object within 5 seconds of when th is issued. (Compact arms) Will bring full robot arm to within 20" of the poir the backpack. Will reach targets within 1.5 feet and 3 feet of the user's chest. Will reach targets within 30 degrees (in the horizontal plane) on of perpendicular to the user's chest.
manipulati on /vision	Performance	Manda	P.M.7. 3	Will reach targets between 10 degrees below horizontal up to ve
	Performance	Mandat	P.M.8. 1	Will stabilize part, even if user moves 6" in any cartesian directic their body up to 90 degrees to the left or 20 degrees to the right.
vision	Performance	Manda	P.M.8. 2	Will detect user's hands, even if one or more hands lie outside o 25 degrees in the horizontal plane and/or 10 degrees in the vert

vision	Performance	Mandato ry	P.M.8. 8.3 3	Will detect user's hands if they are in an approved location with hand's facing the user (no under-handed grips).

			..	
vision	Performance	Desirabl e		(Detect occluded parts) Must be able to detect part while 20% of
vision	Performance	Desirabl e	1.2 P.D.1.2	(Texture Invariant) Must be invariant to part texture, specifically gloss finish.
vision	Performance	Desirabl e	1.3 P.D.1.3	(Pose Detection) Shall detect the surface normal of the part with than 45°.
voice	Performance	Desirabl e		Speaker will alert user to state changes with an 80% success rat
			..	
hardware	NON-FUN CTI ONAL Non-		N.. 1 N.M.1	Will be ergonomic for spinal comfort. Will be comfortable to wea consecutive minutes.
hardware	Non-			Will weigh less than 40 lbs.
hardware hardware hardware hardware hardware	Non-Functiona Mandatory Non-Functiona Mandatory Non-Functiona Mandatory Non-Functiona Mandatory Non-Functiona Mandatory			Will be aesthetically pleasing. Will operate safely. Will be simple to operate. Will be able to perform untethered for 20 minutes. Will require minimal part modification to assisst with assigned task
hardware	Non-			Will be operable on a portable computer.
voice	Non-		..	Audio feedback will be clearly audible in representative work envi
hardware	Non-Fu		1 N.D.1	Will be able to operate standalone (no WiFi)