Operating Room Bot

Team I - Fall Test Plan

Team Members
Gaurav Sethia
Jinkai Qiu
Robert Kim
Siddharth Ghodasara
Tanmay Agarwal

September 18, 2024

Carnegie Mellon University
The Robotics Institute

Introduction

This document provides a comprehensive overview of the testing methodologies for the OR BOT project during the Fall 2024 semester. The system will be evaluated by testing individual components and subsystems, progressively moving towards more complex integrations. This approach is designed to ensure thorough verification at each stage, culminating in a fully functional robot capable of efficiently managing OR inventory and autonomously delivering medical items.

It is important to note that our team has shifted the focus from inventory tracking to restocking supplies. This change was driven by additional onsite visits and interviews with OR clinicians during the summer, where we identified greater value in restocking supplies rather than merely inspecting them. The outlined schedule includes the specific functionalities targeted in each test phase, detailing their contribution to fulfilling the overarching system requirements.

The final system will be showcased in our Fall Validation Demonstration, highlighting the autonomous system's advanced capabilities in navigating the on-campus testbed and manipulating objects to restock and retrieve medical items.

Logistics

Personnel

No additional personnel are required for testing other than 5 team members.

Location / Equipment

All tests are going to be conducted in AI Makerspace at Tepper. The AI Makerspace will be set up with shelves to mimic a hospital supply room. All tests will be conducted on the Fetch robot.

Schedule

The following tables summarize the schedule until the FVD

Date	Identifier	Capabilities	Test	Requirements
09/11/2024	Progress Review 7	- Fetch's CPU does not overload and has fewer unpredictable errors. - ROS1 Bridge does not drop ROS topics due to throttling	1	M.N.4
09/25/2024	Progress Review	- Curobo motion planner plans	2, 5	M.F.6

	8	trajectories for sim+real Fetch. - Grasp pose is generated using RGBD data from Fetch's PrimeSense camera.		
10/09/2024	Progress Review 9	- Perception system segments objects of interest placed in a box and on a shelf. - Vacuum gripper is fitted onto the Fetch and picks up items from a table.	3, 4, 5, 6	M.F.6, M.F.3, M.F.5
10/30/2024	Progress Review 10	- Collision object modeling is satisfactory for the arm to reach into a shelf. - Grasp pose is correctly generated by using the perception subsystem. - GUI has a button for switching between restocking and retrieving items.	7, 8. 10	M.F.6, M.F.3, M.F.5, M.N.3
11/13/2024	Progress Review 11	- GUI commands Fetch to either restock or retrieve an item from a shelf - Fetch plans and executes path to a restocking position - Fetch plans and executes manipulator trajectory to an item on a shelf upon - Fetch picks an item from a box and places on to a shelf using its vacuum gripper	9, 11	M.F.3, M.F.5, M.N.3
11/18/2024	Progress Review 12 (FVD)	- Fetch plans and executes path to a restocking position upon receiving the GUI command - Fetch plans and executes arm trajectories to its target pose within 5 seconds - Fetch picks up an object using its end-effector with 90% success rate - Fetch transports a requested item to a designated hand-off zone. - GUI can alert the user of malfunctions/errors	12, 13	M.F.3, M.F.5, M.F.6, M.N.1, M.N.2, M.N.5, M.N.6

Tests

Test 1: Compute Throttling

Objective	
Validating Fetch robot's reliability with compute load and ROS1 bridge	
Requirements	Prevent ROS1 from throttling in a 30 minute run
Equipment	PC, Monitor, Jetson Xavier AGX
Elements	Compute Subsystem
Personnel	Gaurav Sethia
Procedure	
1. SSH into Fetch using Jetson Xavier with ROS1 bridge-enabled ROS2 2. Open RVIZ on both Fetch and Jetson with RGBD image topics bridged 3. Open htop in Terminal 4. Observe Fetch and Terminal for more than 1 hour	
Verification Criteria	
1. CPU load on both Fetch and Jetson are under 50% utilization on average 2. Real-time ROS1 topics from Fetch, such as TF and PointClouds, are not dropped and are correctly updated in ROS2	

Test 2: Motion Planning

Objective	
Validating the capability to plan and execute a point to point trajectory on Fetch	
Requirements	Setup and configure motion planning pipeline on Fetch
Equipment	Fetch, Jetson Xavier AGX, PC(optional)
Elements	Motion Planning Subsystem

Personnel	Robert Kim, Siddharth Ghodasara, Tanmay Agarwal
Procedure	
1. Power up Fetch and the onboard pc 2. Launch the motion planning scripts 3. Feed the desired end-effector pose of the robot	
Verification Criteria	
1. Carefully monitor the movement on the real robot 2. Monitor feedback from the motion planning pipeline 3. It should successfully plan and execute a point to point planned path	

Test 3: Perception - Segmentation

Objective	
Validating the capability to segment the desired object	
Requirements	Segment out a desired object to grasp
Equipment	Fetch, Jetson Xavier AGX, PC(optional)
Elements	Perception Subsystem
Personnel	Gaurav Sethia
Procedure	
1. Teleop the fetch near the objects of interest 2. Launch the perception pipeline 3. Visualize the results	
Verification Criteria	
1. Produces a message that encompasses a segmentation mask for 90% of instances of the desired object, that is visible 2. The segmentation masks shall be visually clean with a confidence score above 70%	

Test 4: Perception - 3D Pose Estimation

Objective	
Validating the capability to estimate the 3D pose of the desired object	
Requirements	Get the 3D pose of the desired object using the segmentation mask
Equipment	Fetch, Jetson Xavier AGX, PC(optional)
Elements	Perception Subsystem
Personnel	Gaurav Sethia
Procedure	
1. Teleop the fetch near the objects of interest 2. Launch the perception pipeline, to get the segmentation mask 3. Use the segmentation mask and depth images to compute the 3D location of the object of interest 4. Visualize the results	
Verification Criteria	
1. Generates a message that specifies a 3D point within the boundaries of existing objects in a point cloud. This point will be visualized by plotting its coordinates onto the point cloud for verification.	

Test 5: Perception - Suction Pose Estimation

Objective	
Validating the perception stack's ability to generate a pose given a segmentation mask	
Requirements	Gripper should be attached and able to produce grasp with command
Equipment	Fetch, Computer
Elements	Perception Subsystem
Personnel	Jinkai Qiu

Procedure
1. Teleop Fetch near the object of interest 2. Get a segmentation mask for using point-based prompting 3. Get depth information from the fetch's camera 4. Given depth information and segmentation mask, produce a pose 5. Visualize the pose on Rviz
Verification Criteria
1. The provided pose is within 30 degrees of the surface normal and within the bounds of the object

Test 6: Suction Gripper Attachment and Communication

Objective	
The suction gripper can be attached to the robot and can be commanded by the robot	
Requirements	Gripper should be attached and able to produce grasp with command
Equipment	Suction Gripper, Fetch, Computer
Elements	Manipulation Subsystem
Personnel	Siddharth Ghodasara; Robert Kim
Procedure	
1. Physically touch the gripper to make sure it is attached rigidly to Fetch 2. Send commands through ROS2 demanding vacuum suction and release	
Verification Criteria	
1. Gripper cannot be moved by bare hand movements 2. Gripper is able to produce suction via ROS2 commands within 10 seconds 3. Gripper is able to release suction via ROS2 commands within 10 seconds	

Test 7: Restocking - Single Item from a box close to the shelf

Objective	
Validating capability of the robot to restock items when the robot is static	
Requirements	Robot restocks an item from an opened box to the shelf
Equipment	Fetch, Suction Gripper, Opened Source Box, Shelf, Computer
Elements	Manipulation Subsystem; Perception Subsystem
Personnel	Gaurav Sethia; Tanmay Agarwal
Procedure	
1. Setup items in an open box 2. Teleop fetch to next to the open box and shelf 3. Executes restocking-only behavior tree 4. Robot grasps an item from the open box 5. Robot plans and executes a collision-free path with the item from the box to the shelf 6. The robot drops the item in the desired location	
Verification Criteria	
1. Robot grasps an item from the open box within 5 attempts 2. Robot plans and executes a collision free path with the item from the box to shelf within 1 minute 3. Robot drops the item in desired location	

Test 8: Navigation

Objective	
Validating capability of the robot to autonomously navigate shelf and a desired drop off pose	
Requirements	Robot navigate autonomously within the workspace
Equipment	Fetch, Computer
Elements	Navigation Subsystem

Personnel	Jinkai Qiu; Tanmay Agarwal
Procedure	
1. Executes navigation-only behavior tree 2. Fetch navigates to the points given by the user using rviz	
Verification Criteria	
1. Robot is able to navigate autonomously in the workspace without intervention 80% of the times 2. Robot is able to avoid static and slow dynamic obstacles while executing navigation 80% of the times	

Test 9: Restocking - Starting from remote start point

Objective	
Validating the capability of the robot to autonomously restock items with a remote start point	
Requirements	Robot autonomously restock items with a remote start
Equipment	Fetch, Suction Gripper, Opened Box, Shelf, Computer
Elements	Manipulation Subsystem; Perception Subsystem; Navigation Subsystem
Personnel	Gaurav Sethia; Siddharth Ghodasara;
Procedure	

1. Fetch traverses to the shelf
2. Fetch identifies the box and gets its 3D pose
3. For all objects inside the box
    a. Fetch segments of the objects inside the box
    b. Fetch finds a grasping pose using depth information and segmentation mask
    c. Fetch uses the suction gripper to grasp the object
    d. Fetch plans and executes the motion to place the object
    e. Fetch places the object on the shelf	

Verification Criteria	
1. The system is able to navigate to the restocking location within 2 minutes 2. The system identifies the box and its 3D location within the bounds of the box	

3. The system segments 90% of the objects in the box that are visible 4. The system is able to generate a grasp location within 30 degrees of surface normal 5. The system is able to grasp the object using a suction gripper within 5 tries 6. The robot is able to drop plan motion to drop location on the shelf within 3 minutes.

Test 10: Task Prioritization

Objective	
Validating the robot can prioritize retrieval commands over restocking	
Requirements	The robot aborts restocking and switches to retrieval during execution
Equipment	Fetch, Computer
Elements	Integration
Personnel	Jinkai Qiu
Procedure	
1. Execute the restocking behavior on the robot 2. When the robot is restocking, click button at GUI to retrieve 3. Let the robot finish the retrieval process (dummy task complete flag after 30 seconds) 4. Observe the robot going back to the restocking procedure	
Verification Criteria	
1. Robot should shift to retrieval mode within 1 minute after finishing the immediate task	

Test 11: Retrieval - Static

Objective	
To validate the system is able to remove items from the shelf	
Requirements	Removing one item per request

Equipment	Fetch, Stocked Shelf, Computer
Elements	Manipulation Subsystem
Personnel	Tanmay Agrawal
Procedure	
1. Teleop Fetch close to the shelf 2. From the UI, instruct the robot to retrieve a desired item 3. Fetch segments and identify the location of the object 4. Fetch generates a suction pose to graph the object 5. Fetch plans motion to grasp the object 6. Fetch grasp the object	
Verification Criteria	
1. The robot retrieves an item without collision 80% of the times	

Test 12: Retrieval - Delivery

Objective	
To validate the system is able to remove items from the shelf and deliver to desired location	
Requirements	Remove one item from the shelf and deliver to a desired location
Equipment	Fetch, Suction Gripper, Stocked Shelf, Computer
Elements	Manipulation Subsystem; Perception Subsystem; Navigation Subsystem
Personnel	Robert Kim, Jinkai Qiu
Procedure	
1. From the UI, instruct the robot to retrieve a desired item 2. Fetch navigates to close to the shelf 3. Fetch segments and identify the location of the object 4. Fetch generates a suction pose to graph the object 5. Fetch plans motion to grasp the object 6. Fetch grasp the object	
Verification Criteria	

1. The robot navigates to the retrieval location without intervention 80% of the times 2. The robot grasps the item within 5 retries 3. The robot retrieves an item without collision 80% of the times 4. The robot brings the item to the user without intervention 80% of the times

Test 13: FVD

Objective	
System Integration and Validation Test for FVD	
Requirements	Completing the verification criteria and system requirements
Equipment	Fetch, Shelf, Open Box, Suction Gripper, Computer
Elements	Manipulation, Navigation, Perception, and UI
Personnel	Entire Team
Procedure	
1. Connect external PC to Jetson for visualization 2. Demonstrate Retrieval Capabilities, where: a. User sends retrieval command through UI b. Robot will navigate autonomously to the shelf c. Robot will grasp one item d. Robot will navigate back to the user to deliver the item 3. Demonstrate Restocking Capabilities, where: a. Users sends a restocking command through UI b. Robot will navigate autonomously to the restocking location, where items are close-by to the shelf within an open box c. Robot will pick one item from the open box and restocks it to the shelf 4. Demonstrate Task Priority, by giving a retrieval command while the robot is restocking, such that the robot retrieves the item	
Verification Criteria	
1. The system delivers a medical item per user request within 5 minutes while traveling a distance of 15m 2. The system restocks one medical item one the shelf within 5 minutes 3. The system finishes current object restocking and prioritizing retrieval tasks	

Appendix: Requirements

Table 1: Mandatory Functional and Performance Requirements

Functional Requirement	Performance Requirement
M.F.1 The system shall receive inputs from the users	M.P.1 The system will receive inputs from the user in less than 5 seconds
M.F.2 The system shall localize in the pre-mapped environment	M.P.2 The system will localize in the environment within an error of 5cm
M.F.3 The system shall retrieve medical supplies	M.P.3 The system will retrieve objects with success rate of more than 80% accuracy
M.F.4 The system shall plan and navigate to its destination	M.P.4 The system will plan a global path in 5 seconds and navigate to its destination within maximum speed of 0.8m/s
M.F.5 The system shall restock items	M.P.5 The system will restock each item within 5 minutes with 80% success rate
M.F.6 The system shall know how to grasp	M.P.6 system shall produce valid grasp 80% of the times

Table 2: Mandatory Non-Functional Requirements

Non-Functional Requirements
M.N.1 The system will perform rapid retrieval of desired objects
M.N.2 The system will adhere to all relevant standards pertaining to medical robotic systems
M.N.3 The system will have a modular design: for hardware, software, and all things in between
M.N.4 The system will be aesthetic
M.N.5 The system will detect malfunctions and errors so as to notify user
M.N.6 The system will remain available in times of need