

APEX Labs

Automated Precision EXperimentation Laboratories

Task 4.1: Fall Project Test Plan



Team H:

Arnav Kharbanda
Farnaz Alam Ahmed
Juan Muerto
Karthik Srinivasan

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Introduction

The purpose of this document is to provide a high-level framework to test the APEX Labs system throughout the fall semester. The aim of this framework is to validate that all previously identified system requirements are appropriately addressed in a timely manner. This framework is structured such that the APEX Labs system can be built in a parallel bottom-up approach - from subsystem creation to high-level integration. This plan also provides an overall timeline that the team can use to deduce whether work is getting done at an appropriate pace - or whether effort must be increased in order to meet expected milestones. Ultimately, by using this plan, our team will be able to showcase a minimal viable product version of APEX Labs by the fall validation demo (FVD).

Logistics

Personnel

The team does not require external support in conducting any of the tests. For subsystem-level tests, the owners of the particular subsystem will be involved. However, for a system-level test that involves interactions among multiple subsystems, the entire team will be present.

Equipment

We would be using Our Custom Mobile Base, which includes swerve modules, a robot arm, and 2x ZEDx Cameras (one on top of the mobile base and another on the wrist of the Robot arm), the PC, one webcam, and wellplates for all our tests.

Location

Most of these tests will occur at the Newell Simon Hall(NSH Caged Area).

Schedule

Event	Date	Capability Milestones	Tests	Requirements
PR7	09/09	- Set up the workflow and test videos - Hardware and software setup complete - Simulation environment configured - All team members onboarded to the fall stack	T.PE.1	
PR8	09/23	- Able to collect videos from the lab space with the webcam - Base Mobility software is complete.	T.PE.2, T.MO.1	M.F.9, D.F.11, D.F.12 M.P.7, D.P.11, D.P.12
PR9	10/07	- The improved planning subsystem is complete. - The robot must be able to plan a path for grasping, placing, and moving wellplates.	T.MO.2 , T.PL.1 , T.PL.2 , T.PL.3	M.F.9, D.F.11, D.F.12 M.P.7, D.P.11, D.P.12
PR10	10/28	- Reduce the processing time of the anomaly detection pipeline - Mobility sensor fusion/SLAM complete.	T.PE.3, T.MO.3	M.F.9, D.F.11, D.F.12 M.P.7, D.P.11, D.P.12
PR11	11/11	- Perception subsystem detects anomalies and localizes all equipment. - Parallely running the anomaly detection workflow with the main systems - Manipulation subsystem picks and places well plates	T.PE.4 , T.MA.1 , T.MA.2	M.F.9
FVD	11/16	- The system places the well plate into the lab machine - Commands the lab machine - Picks up the well plate - Transfers it across the lab into a different machine - Then commands that other machine.		all
FVD Encore	11/23	Fine-tune performance.		all

Tests

T.MO.1 - Motor Integration	
Objective	Verify that the autonomy stack can command motors.
Elements	Mobility
Location	NSH Caged Area
Equipment	Computer, Mobile Base
Personnel	Juan
Procedure	☐ Turn on the mobile base and Thor Jetson. ☐ For each motor: ☐ Command the motor's velocity via ROS2 messages. ☐ Command a 90-degree position for the motor via ROS2 messages.
Verification Criteria	☐ For each motor: ☐ Confirm that the motor is “spinning” at the commanded velocity. ☐ Confirm that the motor is in the correct position.

T.MO.2 - Mobility X/Y Positioning	
Objective	Verify that the base moves the commanded distance in X/Y direction
Elements	Mobility
Location	NSH Caged Area
Equipment	Computer, Mobile Base
Personnel	Juan
Procedure	☐ Turn on the mobile base and Thor Jetson. ☐ Command base to move 1 meter in the X direction. ☐ Command base to move 1 meter in the Y direction. ☐ Command base to move -1 meter in the X direction. ☐ Command base to move -1 meter in the Y direction.
Verification Criteria	☐ Base moves requested direction and distance.

T.MO.3 - Mobility/Navigation Integration	
Objective	Verify that the base moves to a desired X/Y position in the map
Elements	Mobility
Location	NSH Caged Area
Equipment	Computer, Mobile Base
Personnel	Juan/Arnav
Procedure	☐ Turn on the mobile base and Thor Jetson. ☐ Command base to move to a specific X, Y position.
Verification Criteria	☐ Base moves to the requested X, Y position in the map.

T.PL.1 - Path Planning	
Objective	Verify if the system generates a collision free path for all use cases.
Elements	Planning
Location	NSH Caged Area
Equipment	Computer
Personnel	Karthik
Procedure	☐ Load the environment and the robot into the path-planning framework. ☐ Input the following use cases: ☐ Base position to the location of the plate. ☐ Move the plate to the liquid handler. ☐ Move from the liquid handler to the shaker. ☐ Move from the shaker to the output bin. ☐ Observe the path generated by the environment.
Verification Criteria	☐ Generated paths should be feasible and collision-free. ☐ Paths should be planned within 1s (validate change to RRTConnect). ☐ Each plan should be reliable - it should be generated 10 times continuously.

T.PL.2 - Anti-spillage	
Objective	Verify whether the system can generate a path to transport the well plate without spillage.
Elements	Planning
Location	NSH Caged Area
Equipment	Computer
Personnel	Karthik
Procedure	☐ Load the environment and the robot into the path-planning framework. ☐ Input the following use cases: ☐ Move the plate to the liquid handler. ☐ Move from the liquid handler to the shaker. ☐ Move from the shaker to the output bin. ☐ Placing in the liquid handler ☐ Placing in the shaker module ☐ Placing in the output bin ☐ Observe the path generated by the environment.
Verification Criteria	In all cases, the system generates a path where the z-orientation of the end effector does not change, and no liquid is spilled

T.PL.3 - Trajectory Smoothness	
Objective	Verify whether the system can generate a smooth trajectory.
Elements	Planning
Location	NSH Caged Area
Equipment	Computer
Personnel	Karthik
Procedure	☐ Cases to test - all cases from T.PI.1 - T.PI.4
Verification Criteria	☐ The generated trajectory is smooth enough for the robot to execute in real life (differentiable, with no sharp edges).

T.PE.1 - Set-up the basic anomaly detection	
Objective	To set up the basic anomaly detection pipeline in our workstation
Elements	Perception
Location	NSH Caged Area
Equipment	Computer
Personnel	Farnaz
Procedure	☐ Set up the environment in the workstation ☐ Run the anomaly detection policy with available videos ☐ Verify the flagging of the policy in JSON format
Verification Criteria	☐ The flagging output in the JSON file

T.PE.2- Set up camera	
Objective	Set up a webcam in our workspace and process videos
Elements	Perception
Location	NSH Caged Area
Equipment	Computer, camera
Personnel	Farnaz
Procedure	☐ Stream a webcam to collect video of pipetting liquid ☐ Process the video with our workflow ☐ Improve the policy architecture with OpenAI VLM.
Verification Criteria	☐ Verify the camera is streaming. ☐ Verify the policy is processing the video output.

T.PE.3 - Test Improved Policy	
Objective	Improve the policy architecture to reduce the processing time
Elements	Perception
Location	NSH Caged Area
Equipment	Computer, camera
Personnel	Farnaz
Procedure	☐ Execute the updated policy pipeline using the optimized architecture. ☐ Benchmark processing latency across sample video runs.
Verification Criteria	☐ The processing time should be reduced from 30 mins now

T.PE.4 - Integrate with the main system	
Objective	Integrate the anomaly detection pipeline with the main perception and monitoring stack
Elements	Perception
Location	NSH Caged Area
Equipment	Computer, camera
Personnel	Farnaz
Procedure	☐ Connect the anomaly detection policy module with the main system workflow. ☐ Run end-to-end integration tests using live camera feeds and system inputs.
Verification Criteria	☐ Verify real-time event reporting and logging across the system.

T.MA.1 - Wellplate Placement in Opentrons OT-2	
Objective	Verify that the robot can accurately place a wellplate into the designated Opentrons OT-2 deck location.
Elements	Manipulation
Location	NSH Caged Area
Equipment	Computer, XArm-6, Gripper, Opentrons OT-2, Wellplate
Personnel	Karthik/Arnav
Procedure	☐ Pick and place a wellplate into the target OT-2 deck location. ☐ Repeat for 10 trials and record successful placements.
Verification Criteria	☐ At least 9/10 placements succeed without manual correction.

T.MA.2 - Wellplate Placement in Shaker Module	
Objective	Verify that the robot can accurately place a wellplate into the designated position on the shaker.
Elements	Manipulation
Location	NSH Caged Area
Equipment	Computer, XArm-6, Gripper, Shaker Module, Wellplate
Personnel	Karthik/Arnav
Procedure	☐ Pick and place a wellplate into the shaker fixture. ☐ Repeat for 10 trials and record successful placements.
Verification Criteria	☐ At least 9/10 placements succeed without manual intervention.

T.FVD - Fall Validation Demonstration Test	
Objective	Perform an experiment semi-autonomously.
Elements	User Interface subsystem, perception subsystem, planning subsystem, manipulation subsystem, lab machine integration subsystem, monitoring subsystem, navigation subsystem.
Location	NSH Caged Area
Equipment	Computer, XArm 6, APEX Labs platform, cameras, OpenTron OT-2, custom shaker module, and well plates.
Personnel	Arnav, Farnaz, Karthik, Juan
Procedure	☐ A user enters an experiment description. ☐ The XArm 6 scans the environment to detect necessary equipment. ☐ The perception subsystem detects, segments, and localizes the desired equipment. It passes this information to the planning subsystem. It also detects whether a particular type of anomaly is present and then reports it. ☐ The planning subsystem generates a plan to grasp, move, and place the desired equipment in the OT-2. The manipulation subsystem executes this plan. ☐ The OT-2 is commanded to dispense liquid from a test tube rack that has already been filled and placed inside the OT-2. ☐ The wellplate is moved to the slot in the base, and the base then navigates to the shaker module. ☐ The planning subsystem generates a plan to grasp, move, and place the desired equipment in the shaker module. The manipulation subsystem executes this plan. ☐ The shaker module is commanded to shake for 30 seconds. ☐ The planning subsystem generates a plan to grasp, move, and place the desired equipment in the output bin. The manipulation subsystem executes this plan.
Verification Criteria	☐ System completes the experiment end-to-end without manual intervention beyond the OT-2 slot press. ☐ Placement of equipment is performed within a ± 5 mm error bound. ☐ Grasping is performed with 75% accuracy

Appendices

Mandatory Requirements

FR No.	Functional Requirement	PR No.	Performance Requirement
M.F.3	Recognize Lab Equipment	M.P.1	90% accuracy. False-positive of 5%.
M.F.4	Localize Lab Equipment	M.P.2	3cm of ground-truth. Orientation with 5 degrees.
M.F.5	Plan to Reach Lab Equipment	M.P.3	Collision-free path 95% of the time.
M.F.6	Grasp Lab Equipment	M.P.4	70% grasp success rate.
M.F.7	Place Lab Equipment	M.P.5	90% placement success rate.
M.F.8	Command Lab Machines	M.P.6	100% correct control commands.
M.F.9	Detect Anomalies	M.P.7	80% detection success rate

Desirable Requirements

FR No.	Functional Requirement	PR No.	Performance Requirement
D.F.3	Accept Experiment Description from User	D.P.1	Convert natural language to executable commands with 85% accuracy.
D.F.10	Communicate Status	N/A	N/A
D.F.11	Map and Localize within the Lab	D.P.11	Estimate the mobile base's global position within the lab map with a translational error of ≤ 5 cm and an orientation error of $\leq 10^\circ$.
D.F.12	Navigate Between Lab Stations	D.P.12	Plan and execute a global path to the designated target workstation >95% of the time.