Master of Science
Robotic Systems Development

DarkBot
Quadruped Robot for Assistive Search in Narrow and Cluttered Environment

Team NightWalkers

16-681: Spring Test Plan
Group B

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1. Introduction

The purpose of this document is to detail the testing plan of Team B - Project DarkBot for the spring 2023 semester. The objective of these tests is to ensure that our subsystems are aligned with the target performance requirements listed in Appendix A. The progress of the tests will be regularly updated in progress reviews and the results will be shown in the Spring Validation Demonstration.

Additionally, this document provides a comprehensive overview of the key milestones for our project. The tests are designed such that small tests are carried out before complex ones. The team will carry out them sequentially to meet all requirements for the spring semester.

2. Logistics

In the spring semester, the team will carry out all tests at the MRSD Lab. All four team members will jointly carry out the tests and no additional personnel is needed for our project. The following equipment will be necessary for the majority of our tests:

– The Team B desktop

– Unitree Go1 robot

– NVIDIA Jetson AGX Xavier

– AirLab payload

– Fisheye camera and IR camera for testing

3. Schedule

PR	Date	Test Title
1	Feb 15	Control Interface Test
2	Mar 1	Simulation Verification Test, Payload Software Verification Test, Payload Hardware Integration Test, Payload Software Integration Test
3	Mar 22	Sim2Real Test, Localization in Known Map Test
4	Apr 5	Peak Performance Test, SLAM Test
5	Apr 19	Human Detection Test with Pre-scripted Navigation
6	Apr 26	Planning Test

4. Tests

4.1. Test 1: Control Interface Test

Objective	– Demonstrate communication with robot via ROS – Assess the integrity of the Unitree Robot hardware and control interfaces – To verify that, given commands sent to the robot, its internal network and control boards function properly to send and receive necessary communication messages
Elements	– ROS – Robot Network: WiFi Module, Central Switch, Ethernet Connections – Control Boards: Raspberry (Sport), MCU (Actuation), Nvidia Nano x2 & NX (Perception)
Equipment	– Robot – Laptop – Ethernet Cable – Joystick Controller – Robot Protection Hanger
Personnel	– person
Procedure	– item a – item b
Verification	– The system will show user real time visualization of camera stream, human position, & 3D map

4.2. Test 2: Simulation Verification Test

Objective	– To verify that the physical robot possesses qualitatively equivalent low-level behaviors as the high-fidelity simulation model
Elements	– Gazebo Simulation – Unitree Go 1 Edu Robot
Equipment	– Desktop (Simulation) – Laptop (Remotely Sending Terminal Command to the Robot) – Joystick Controller – Robot Protection Hanger
Personnel	– Saha
Procedure	– Turn ON the robot and open simulation software on the computer – Make sure both the simulated robot and physical robot have the same setup – Send commands for simple leg motion to both the simulated robot and – physical robot to move each of their legs, respectively – Record their actuation behavior
Verification	– The leg actuation behaviors from both ends must be qualitatively equivalent

4.3. Test 3: Payload Software Verification Test

Objective	– If using NX as the main computer, verify data streaming from payload sensors to NX functions properly while both Lidar and IMU are connected to the Unitree robot – If using Orin as the main computer, verify that data streaming, from payload sensors and Unitree sensors to Orin, functions properly and that the network bandwidth suffices the communication between external Orin and Unitree NX & two Nanos.
Elements	– Sensor Payload: 3D Velodyne Puck + IMU + Nvidia Orin(=TBD) – Unitree Robot
Equipment	– Sensor Payload: 3D Velodyne Puck + – IMU + Nvidia Orin(=TBD) – Unitree Robot – Ethernet Cables – Laptop – Robot Protection Hanger
Personnel	– Saha, Zack
Procedure	– Connect a PC or laptop with the robot – SSH to the main computer – Check the continuity and steadiness of the data streams from all sensor components
Verification	– All data streams must be continuous and steady without interruption or losses.

4.4. Test 4: Payload Hardware Integration Test

Objective	– To verify the integrity of the robot platform and sensor payload in the following: – The fixture provides reliable physical attachment between the robot and the sensor payload in both robot walking and sport mode – The electrical wiring connections between the sensor payload and the robot remain firm and tight in both robots walking an sport mode
Elements	– AirLab's Sensor Payload – Fixture Plate – Unitree Go 1 Edu Robot
Equipment	– AirLab's Sensor Payload – Fixture Plate – Unitree Go 1 Edu Robot – Joystick Controller – Protective Cushion/Padding
Personnel	– Zack
Procedure	– Install fixture plate onto the robot – Install the sensor payload on the fixture plate – Manually lift up the sensor payload and check whether the robot-fixture-payload integrity of – Use the joystick to command the robot to walk forward, backward, and sideways to check the robot-fixture-payload integrity – Use the joystick to command the robot to run in sport mode forward, backward, and sideways to check the robot-fixture-payload integrity – Perform the above procedure again with all electrical connections plugged in to check whether all components are powered throughout the entire process
Verification	– Fixture plate and sensor payload do not become loose – No crack or damage occurs. – Electronic equipment stayed powered on and function properly throughout the entire testing process (i.e., as if the robot is standing still)

4.5. Test 5:Payload Software Integration Test

Objective	– To verify the communication between Orin and NX/Nanos on the robot have seamless communication to support basic subprocesses in the exploration stack
Elements	– Unitree robot – Autonomous exploration software stack – Sensor/compute payload
Equipment	– Unitree robot – Joystick controller – Sensor compute payload – Laptop – Ethernet cable – Robot protection hanger
Personnel	Andrew
Procedure	– Push a bug-free code onto Orin and run a sub-process in the exploration stack – Check if the messages sent from robot Nano/NX perception boards and Raspberry/MCU sport board are received and properly processed to produce desired output
Verification	– The sub-process should be able to run continuously for a while without any crashes and produce correct outputs

4.6. Test 6: Human detection test

Objective	– To test human detection neural network performance on the local computer, without slam
Elements	– the human detection system
Equipment	– TeamB computer – fisheye camera – IR camera – a TeamB member
Personnel	– Connie
Procedure	– The camera is placed at 7m distance facing a human under good lighting conditions. The human moves between various poses to demonstrate the failure and success modes of human detection at this distance.
Verification	– human shape is recognized and marked on Rivz within 5 seconds in each of the following positions at 7m sub-processes: standing, seated, side-lying, lying on his back, lying on his stomach.

4.7. Test 7: Sim2Real Test

Objective	– To verify the same high-level routine code will generate the same behavior from both the physical robot and the simulated robot
Elements	– Gazebo – Unitree Robot
Equipment	– Linux desktop or laptop – Unitree Robot – Joystick controller – Robot protection hanger
Personnel	– Andrew, Saha
Procedure	– Complete a bug-free high-level routine code – Push it to the simulated robot on Gazebo and record its high-level behaviors (e.g., translational/rotation motion of the entire robot) – Push it to the physical robot and records its actual high-level behaviors (e.g., translational/rotation motion of the entire robot) – Compare two sets of data and compute the percent difference error
Verification	– The simulation and physical system must possess the same qualitative high-level behavior – The changes in translation and rotation from the simulated robot and physical robot must be within 20%

4.8. Test 8: SLAM Verification Test

Objective	– Verify all the state-estimate-purpose related hardware is working and Orin can access the necessary data stream and messages seamlessly before SLAM stack integration
Elements	– Velodyne Puck 3D LiDAR, IMU, Orin – Unitree Robot sensors and internal network
Equipment	– Sensor compute payload – Unitree robot – Joystick controller – Laptop – Robot protection hanger
Personnel	– Andrew, Zack
Procedure	– Study what data streams and messages are needed for SuperOdometry-based SLAM to work properly – Push a script to Orin so that it can receive these messages all at once – Check whether data and messages received are expected
Verification	– All the data and messages should be accessed continuously without any issues while this process does not interfere with other running processes

4.9. Test 9: Peak Power and Endurance Test

Objective	– To verify the robot is able to function at an extended period of time when all the compute-related components are running at maximal allowable bandwidth
Elements	– Robot: Nano x2, NX, Main Control Unit, Raspberry – Payload: Orin
Equipment	– Unitree robot – Sensor compute payload – PC or laptop – Ethernet cable – Robot protection Hanger
Personnel	– Zack
Procedure	– Turn on the robot – Secure robot with protection hanger – Push exploration-related code onto Orin and boards in the robot – Have the necessary code run simultaneously – Watch the status of the robot and payload compute, including remaining battery life, temperature (if applicable), memory consumption, and remaining communication bandwidth
Verification	– The overall system should be able to run for at least 30 minutes continuously without any issues to support future development

4.10. Test 10: Simultaneous Localization and Mapping (SLAM) Test

Objective	– To verify that the robot is able to map an unknown area well while remaining a reasonably accurate pose throughout the mapping process
Elements	– Unitree robot hardware – AirLab's sensor payload – SLAM software stack
Equipment	– Unitree robot hardware – AirLab's sensor payload – Joystick controller – Laptop
Personnel	– Andrew, Zack
Procedure	– Turn on the robot and make sure all components function properly – Use the joystick controller to make sure the robot is controllable and able to move forward/backward/sideward – Use the laptop to send commands to the robot to start mapping mode – Use the joystick to move the robot a bit to make sure a map is initialized and growing – Control the robot to go around MRSD lab and/or NSH B level on pre-prescribed and measured "ground truth" routes for later comparisons – Come back to the area near map initialization location – Finish mapping and switch to pure localization mode
Verification	– The robot is able to run through the entire process without crashing – The robot pose trajectory should remain within 0.5m compared to the ground truth routes on standard floor maps – The map created should easily coincide with the standard floor map upon visual inspection – The map creation process does not interfere with other software processes in terms of communication bandwidth, memory, and computation consumption

4.11. Test 11: Human Detection Test with Pre-scripted Navigation Test

Objective	– To test human detection neural network performance on the robot (without slam, the information of human location is not added to the slam map)
Elements	– the human detection system
Equipment	– TeamB computer – a robot with cameras – and a team B member
Personnel	– Connie
Procedure	– Input the start point and destination point for the robot, having a human lying on the ground near its destination (within 7 meters) under good lighting conditions. The human moves his body and makes different poses.
Verification	– the human shape is recognized and marked on Rivz within 5 seconds in each of the following positions at a 7m distance: standing, seated, side-lying, lying on his back, and lying on his stomach.

4.12. Test 12: Planning Test

Objective	– Human Detection Test with SLAM capabilities and planning between waypoints
Elements	– Unitree robot hardware – AirLab's sensor payload – SLAM software stack
Equipment	– Unitree robot hardware – AirLab's sensor payload – Joystick controller – Laptop
Personnel	– Saha
Procedure	– Turn on the robot and make sure all components function properly – Use the joystick controller to make sure the robot is controllable and able to move forward/backward/sideward – Use the laptop to send commands to the robot to start mapping mode – Give the robot 5 waypoints so that the planner finds a trajectory through them
Verification	– The human shape is recognized and marked on Rivz within 5 seconds in each of the following positions at a 7m distance – The robot is able to plan between waypoints