**Team HARP (Team D)**

**MRSD Project - II**

**Spring Test Plan**

**2/3/2016**

**Abhishek Bhatia**

**Alex Brinkman**

**Feroze Naina**

**Lekha Mohan**

**Rick Shanor**

Table of Contents

**Introduction3**

**Setup3**

Test Locations3

Personnel3

System Equipment3

**Test Schedule Overview4**

**Tests5**

Run FVE using UR5 simulator 5

Demonstrate UR5 accessing the APC configuration space6

UR5 autonomy integration demo 7

Single item system integration demo 8

Fault handling and failure mode testing 9

Aggregate statistics for 12-bin run 11

Spring Validation Experiment 12

Spring Validation Experiment - Encore 13

**Introduction**

This document highlights biweekly milestones such that Team Harp can demonstrate a completely autonomous pick-and-place system for the Spring Validation Experiment (SVE). Each test procedure documents test objectives, procedure, equipment, personnel, location, and verification criteria.

**Setup**

**Test Locations**

All tests will be conducted in the caged area of NSH B-Level

**Personnel**

All tests will be conducted by some, or all, of the following personnel

* Abhishek Bhatia
* Alex Brinkman
* Lekha Mohan
* Feroze Naina
* Rick Shanor

Individual roles are defined and assigned on a test by test basis. All tests done on hardware are to be recorded.

**System Equipment**

The following list will be required for all tests unless otherwise noted in the equipment section.

* UR5 robot and support structure
* Kinect V2
* Custom UR5 end effector and Kinect mount
* Desktop computer configured appropriately
* UR5 interface including e-stop button
* Cardboard 9 bin stowage shelf and cardboard order bin

**Test Schedule Overview**

|  |  |
| --- | --- |
| **Test**  | **Progress Review** |
| Run FVE using UR5 simulator | PR07 (Week 3) |
| Demonstrate UR5 accessing the APC configuration space | PR08 (Week 5) |
| UR5 autonomy integration demo | PR09 (Week 7) |
| Single item system integration demo | PR10 (Week 10) |
| Fault handling and failure mode testing  | PR11 (Week 12) |
| Aggregate statistics for 12-bin run | PR12 (Week 14) |
| Pick at least 3 correct items from the shelf in 15 minutes | SVE (Week 15) |
| Pick at least 3 correct items from the shelf in 15 minutes | SVE Encore (Week 16) |

**PR07: Run FVE using UR5 simulator**

**Objective**

The objective of this test is to complete the transition from PR2 to UR5. The code base is modified to run the Fall Validation Experiment (hardware-in-loop simulation) using UR5. This test Integrates input handling, vision pipeline and collision model within the state controller.

**Elements**

* ROS integration
* Simulation Environment
* Input handling
* Nominal shelf localization
* Collision avoidance in simulation
* Vision pipeline in ROS
* Baseline grasp strategy

**Location** -- MRSD Lab (NSH Level-B)

**Test Equipment**

* System equipment from the ‘System Equipment’ section
* Nine bin images captured using 20 select amazon picking challenge items

**Personal**

* Simulation operator

**Procedure**

* Collect images of 9 shelf bins and label them appropriately ‘bin\_A.pcd’ to ‘bin\_I.pcl’
* Create work order representing shelf contents as a .json file
* Plug in the Kinect to the computer
* Setup the Kinect facing the shelf, approximately centered and 1 meter away
* Run the script run\_kinect\_shelf\_demo.launch and view simulation on screen

**Verification Criterion**

* Shelf localized, verified via RVIZ visualization
* Arm does not collide with shelf in simulation, verified via visualization
* Arm goes to item of interest on 6 of 9 shelves, verified via visualization

**PR08: Demonstrate UR5 accessing the APC configuration space**

**Objective**

The objective of this test is to demonstrate that the UR5 robot platform mounted on a base can access all 9 bins of the shelf.

**Elements**

* UR5 control
* UR5 configuration space
* Base mechanical design

**Location** -- MRSD Lab (NSH Level-B)

**Equipment**

* System equipment from the ‘System Equipment’ section

**Personal**

* Robot operator

**Procedure**

* Connect the UR5 and Kinect to the computer
* Use the UR5 teleop controller to move the robot to each of the shelf bins

**Verification Criterion**

* The end effector goes inside every bin of the shelf
* The robot does not tip over

**PR09: UR5 Autonomy Integration Demo**

**Objective**

The objective of this test is to show control of the UR5 by autonomously moving the end effector into each shelf bin. This requires localization of the shelf, collision avoidance, and arm planning and execution. This validates simulation on the robot.

**Elements**

* Hardware control
* Shelf localization
* Self-collision avoidance
* Shelf collision avoidance
* Arm Planning

**Location --** MRSD Lab (NSH Level-B)

**Equipment**

* System equipment from the ‘System Equipment’ section
* Measuring tape
* Video camera

**Personal**

* Robot operator
* Safety specialist and e-stop operator
* Cameraman

**Procedure**

* Remove all contents from shelf
* Setup the arm approximately .75 meters from the shelf
* Set arm in initial configuration
* Ensure safety specialist and estop operator are prepared
* Run the launch file PR09.launch
* Wait while robot executes localization and trajectories
* Safely shut down robot after test is complete

**Verification Criterion**

* Robot moves end effector into all 9 shelf bins, verified via visualization
* Robot does not collide with the shelf, verified via visualization
* Robot localizes within 5 cm accuracy, confirmed via measurement between the base of the arm and the top left corner of the shelf

**PR10: Single Item System Integration Test**

**Objective**

The objective of this test is to demonstrate system integration. During this test, the shelf will be populated with one item per bin. The robot will visualize the shelf, determine a grasp plan, and acquire the item from the shelf. The robot will repeat this action for all 9 bins.

**Elements**

* Pose estimation for simplified vision problem
* Successful grasp identification and item acquisition
* Accurate suction feedback

**Location --** MRSD Lab (NSH Level-B)

**Equipment**

* System equipment from the ‘System Equipment’ section
* Nine pre-selected amazon picking challenge items plus accompanying JSON file
* Video Camera

**Personal**

* Computer operator
* Shelf stocker
* Safety specialist and e-stop operator
* Cameraman

**Procedure**

* Stock the shelf per the work order
* Move the arm to correct preposition
* Execute pre run checklist
* Robot prepositioned relative to shelf
* Suction system power is switched on
* Ensure kinect feed is configured
* Load JSON
* Execute PR10.launch with safety specialist operating estop
* Shut off robot after run is complete

**Verification Criterion**

The robot acquires 6 of 9 items successfully from the shelf and places them in the order bin.

**PR11: Fault handling and failure mode testing**

**Objective**

The objective of this test is to verify that the robot can gracefully handle likely failure modes. Fault configurations will be generated and the robot will be shown to behave as expected.

**Elements**

* Localization error handling
* Perception failure handling
* Grasping failure handling
* Peripheral Failure Handling

**Location -- M**RSD Lab (NSH Level-B)

**Equipment**

* System equipment from the ‘System Equipment’ section
* Video camera
* 20 select amazon picking challenge items dictionary

**Personal**

* Robot operator
* Safety specialist and e-stop operator
* Fault generator

**Procedure**

* **Subtest:** Fully occlude the shelf such that the robot cannot localize
* **Expected Outcome:** Robot recognizes shelf is unfound and tries to localize again. Three localization failures results in end of run.
* **Subtest:** Shelf is very cluttered such that items cannot be recognized
* **Expected Outcome:** Robot does not attempt to pick an item. Robot readjusts kinect and tries perception again. Two perception failures causes robot to move to next target item.
* **Subtest:** After item is identified, item is removed from shelf such pickup cannot be achieved.
* **Expected Outcome:** Pressure sensor identifies item is not picked up. Perception and grasping pipeline is again performed on shelf. Two failures cause robot to move to next target item.
* **Subtest:** Kinect power or USB cable is unplugged and replugged in
* **Expected Outcome:** Robot pauses while system restarts Kinect node automatically. If connection is reestablished, the run continues.
* **Subtest:** Arduino power or USB cable is unplugged and replugged in
* **Expected Outcome:** Robot pauses while system restarts suction node automatically. If connection is reestablished, the run continues.

**Verification Criterion**

Verification is confirmed when the robot can handle all failure modes listed above

**PR12: Aggregate Statistics for 12 Bin Runs**

**Objective**

The objective of this test is to determine configurations in which the robot fails to complete the picking task. For this test, 20 full system tests will be run. For each test, the shelf will be randomly set up with target items. Planning, perception, and grasping failures will be carefully documented. The majority of this test will be run outside of the progress review.

**Elements**

* System integration
* Aggregate stat collection and failure mode identification

**Location --** MRSD Lab (NSH Level-B)

**Equipment**

* System equipment from section ‘System Equipment’ section

**Personal**

* Robot Operator
* Shelf stocker
* Safety specialist and e-stop operator

**Procedure**

* Stocker randomly generates a work order via the workOrderGenerator.py script and then places the items on the shelf
* Execute pre run checklist
* Robot prepositioned relative to shelf
* Suction system power is switched on
* Ensure kinect feed is configured
* Load JSON
* Execute runAPC.launch with safety specialist operating estop
* Document run
* After run, shut down the robot safely
* Repeat procedure 20 times

**Verification Criterion**

* Robot never occurs catastrophic (run ending) failure
* Robot attempts to acquire items from all 9 shelf bins
* Robot outputs a JSON file of the final shelf configuration
* Results are carefully documented in PR12.xls

**Spring Validation Experiment**

**Objective**

The objective is to demonstrate the working of our integrated system. Shelf will be setup with 25 items distributed over different shelf bins (1-3 items per shelf). Once an input is received, the robot should autonomously pick objects specified in the input list off the kiva shelf and place them into the order bin.

**Elements**

* Complete system demonstration
* Shelf localization
* Collision avoidance
* Item identification
* Item Post estimation
* Path planning
* Grasp planning
* Suction based grasping
* Grasp feedback
* Error handling

**Location --** MRSD Lab (NSH Level-B)

**Equipment**

* System equipment from section ‘System Equipment’ section
* Items with different geometries (shortlisted from APC 2016 item dictionary)
* Order bin
* Gripper subsystem – ShopVac, suction cup based end-effecter, arduino Nano based suction PCB, pressure sensor

**Personal**

* Robot Operator
* Shelf stocker
* Safety specialist and e-stop operator
* Cameraman and recorder

**Procedure**

* Populate shelf with all 25 items from the 2015 APC item dictionary
* Input text file indicating the 10 randomly selected items as well as bin locations
* The system will repeat the delivery process for 20 minutes and attempt to deliver as many items into the order bin as possible

**Verification Criterion**

This test will verify all system level requirements, including:

* Automatically recognize items in the bin and report results to a GUI on the computer
* Automatically detect object and recognize its pose to find a valid suction surface
* Automatically move the arm to the desired grasping location
* Grasp the item without damaging or dropping it
* Withdraw the item from the shelf bin and place it into the order bin

**Spring Validation Experiment Encore**

The encore experiment will be the same as the spring validation experiment. If the first spring validation experiment is successful, we may make some minor modifications to our experiment.