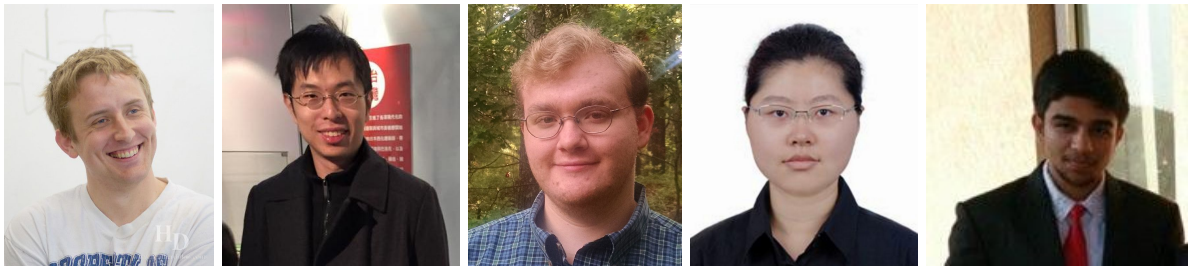
TEAM

PLAID

Autonomous Picking System



TEST PLAN
Sponsor: Dr. Maxim Likhachev

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TEAM E
Michael Beck
Akshay Bhagat
Matt Lauer
Che-yen Lu
Jin Zhu

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1. Introduction

This Test Plan includes the Spring 2017 schedule and verifiable milestones for Team E. The outlined tests and verification procedures have been chosen in line with the project goals of creating an autonomous picking system. The system should be capable of identifying, localizing, grasping, and transporting items from a shelf unit to one of three desired storage totes. This system design is based off of work from the Fall 2016 semester, and incorporates an actuated framing and shelf system, as well as multiple vision sensors, in conjunction with a robotic arm which utilizes an end effector and grasper. Due to the project's reliance on the continual rollout of information for this year's Amazon Picking Challenge, the schedule for tasks have been chosen such that as much of the system can be completed in separate identifiable stages as possible with present information in mind. The final goal is to establish and implement the full working system with all hardware installed and controlled by April 26th 2017, in conjunction with the Spring Validation Experiment.

2. Logistics

2.1 Test Location

All tests will be performed in the "Cage" storage area, within the B-Level of Newell-Simon Hall at Carnegie Mellon University.

2.2 Personnel

All tests will be performed by the members of Team E. All members will be present for every test, barring unforeseen circumstances. These members include:

- Michael Beck
- Akshay Bhagat
- Matt Lauer
- Che-yen Lu
- Jin Zhu

2.3 Equipment

The following equipment will be in use for all tests (any equipment specified within test procedures will be in addition to these components):

- Server rack system, containing multiple CPUs and GPUs
- UR10
- Festo linear actuator
- Microsoft Kinect and/or Intel RealSense vision sensors
- 2016 and/or 2017 Amazon Picking Challenge items
- 1-3 Storage totes

2.4 Functional Requirements

The project's functional requirements can be found in Appendix A. This document will reference the requirements by their correlating number rather than their title (e.g., MF 1).

3. Test Schedule

Progress Review #8 (2/15)

MVP (non-actuated) Test: System slider actuated, multiple kinects, utilization of E-graphs, RGB CNN providing identification and location of items, picking from wooden shelf mockup
M.F. 1, 3, 4

Progress Review #9 (3/1)

Deformable Grasping Test: Deformable grasping code implemented (system determines grasping surfaces based on point clouds)

Shelf Localization Test: shelf bins are localized by april tags
M.F. 1, 3, 4

Progress Review #10 (3/22)

Systems Control Test: Demonstrated control over all system actuators through the state machine
Non-deformable Grasping Test: grasping strategies implemented for 50% or more of non-deformables
M.F. 1, 3, 4

Progress Review #11 (4/5)

Gripper Test: new gripper installed into system and controlled
JSON Test: system is able to interpret JSON orders and deliver picks to all 3 totes as specified
M.F. 2, 4, 5

Progress Review #12 (4/17)

System Hardware Test: System frame and shelf fully assembled, with all actuators mounted appropriately.
MVP (actuated) Test: Demonstrated ability to do a full picking run based off of SVE requirements, including beginning and ending the run with the unfolding and closing of the system drawers.
M.F. 1, 2, 3, 4, 5, 6

Spring Validation Experiment (4/26)

4. Tests

4.1 Progress Review #8 (2/15)

4.1.1 MVP (non-actuated) Test

Objective:
Demonstrate system design viability

Elements:
System test

Additional Equipment:
Wooden Shelving, HARP or FVE end effector

Procedure:

1. Populate the wooden shelving with items from the 2016 APC.
2. Dictate pre-determined items to pick within the state machine.
3. The system will identify the chosen items and pass their position along two axes to the grasping subsystem.
4. The arm will move the end effector over one of the chosen items.
5. Suction will engage and grasp the item.
6. The arm will move the item over a tote and the system will disengage suction.
7. Steps 3-6 will repeat until all chosen items have been picked.

Verification Criteria:
System uses more than one vision sensor in order to identify and localize items, through the use of an RGB CNN. The arm utilizes experience graphs and the linear actuator slide when executing plans. The system is able to pick a small subset of items (4+) from the wooden shelving and place them in a tote.

4.2 Progress Review #9 (3/1)

4.2.1 Deformable Grasping Test

Objective:
Implement software strategies for determining grasping surfaces for deformable items.

Elements:
Subsystem test

Additional Equipment:
Wooden Shelving, HARP or FVE end effector

Procedure:

1. Populate 2 bins with deformable items.
2. Have the vision system localize the items and record their point clouds.
3. Use PCL functions in order to find valid grasping surfaces on the point clouds.
4. Pick the items using the determined grasping surfaces.
5. Continue until all of the populated items have been picked.

Verification Criteria:
The determined grasping surfaces can be displayed within the software system. The arm moves the end effector to the chosen grasping surfaces when picking the deformable items.

4.2.2 Localization Test
Objective:
Implement system self-localization through a combination of stationary and eye-in-hand sensors.

Elements:
Subsystem test

Additional Equipment:
Wooden shelving

Procedure:

1. Have the vision system find the relative frame of bin april tags in correspondence to the sensors.
2. Use ROS packages and frame transforms to determine the positioning of all system frames relative to the world frame.
3. Display the projected point clouds of the system bins over the planning scene within Rviz.
4. Move the stationary vision sensors +/- 1 cm in any direction while still displaying the planning scene within Rviz.

Verification Criteria:
Demonstrate that the projected point clouds within Rviz are a match to the planning scene within a known tolerance, with both the vision sensors in their original position and after perturbing them.

4.3 Progress Review #10 (3/22)

4.3.1 Systems Control Test
Objective:

Implement all necessary hardware and software components in order to control all of the actuators which will be used for the final system.

Elements:
Subsystem test

Additional Equipment:
2-3 DC or Stepper motors.

Procedure:

1. Rotate the motors in a specified direction upon booting up the MVP demonstration from PR #8.
2. Perform the MVP demonstration from PR #8.
3. Rotate the motors in the opposite direction upon completing the demonstration

Verification Criteria:
Verify that the motors move a fixed controllable distance when they rotate in either direction at the beginning and end of the demonstration.

4.3.2 Non-deformable Grasping Test
Objective:
Implement software strategies for determining grasping surfaces for non-deformable items.

Elements:
Subsystem test

Additional Equipment:
Wooden shelving

Procedure:

1. Populate bins with non-deformable items from the APC 2017 list.
2. Have the vision system localize the items and record their point clouds.
3. Determine the 6-DOF pose for the items.
4. Use CAD models in conjunction with the 6-DOF pose to find appropriate grasping surfaces.
5. Pick the items using the determined grasping surfaces.
6. Continue until all of the populated items have been picked.

Verification Criteria:

The determined grasping surfaces can be displayed within the software system. The arm moves the end effector to the chosen grasping surfaces when picking the deformable items.

4.4 Progress Review #11 (4/5)

4.4.1 Gripper Test

Objective:
Implement the final design gripper for the system.

Elements:
Subsystem test

Additional Equipment:
Wooden shelving, final design gripper

Procedure:

1. Populate bins with a combination of items from the 2016 and 2017 APC which demonstrate a range of grasping challenges.
2. Attempt to pick each item.

Verification Criteria:
Demonstrate that the implemented gripper is controlled by the system. Show that the gripper is capable of grasping all non-blacklisted competition items.

4.4.2 JSON Test

Objective:
Implement item order and reporting within the software system.

Elements:
Interface test

Additional Equipment:
Wooden shelving

Procedure:

1. Populate the shelving with items.
2. Create a JSON file that reports the item bin locations, as well as an item order.
3. Run the MVP demonstration from PR #8
4. Output a JSON at the end of the run with the current item locations.

Verification Criteria:

Demonstrate that the system picks the items which are listed on the item order, and that it outputs the correct item locations at the end of the picking run.

4.5 Progress Review #12 (4/17)

4.5.1 System Hardware Test

Objective:
Install all system hardware, including framing and actuators.

Elements:
System test

Additional Equipment:
Actuated aluminum shelving

Procedure:

1. Populate the shelving with items from the APC 2017 list.
2. Use the actuators to roll out the shelf drawers to 1-2 discrete locations.
3. Have the drawers remain stationary at those discrete locations for 30 seconds.
4. Use the actuators to roll the shelf drawers back into their starting positions.

Verification Criteria:
Demonstrate that the aluminum shelving can hold the challenge items, in both their starting position and their out-folded positions. Show control over the drawer positioning within known tolerances. Verify that the drawers are sturdy and suitable to meet the weight requirements and any cantilever loading.

4.5.2 MVP (actuated) Test

Objective:
Integrate all system components for the Spring Validation Experiment.

Elements:
System test

Additional Equipment:
Actuated aluminum shelving, final design gripper

Procedure:

1. Perform the steps for the Spring Validation Experiment (reference 4.6 of this document).

Verification Criteria:

Demonstrate that the system can perform all aspects of the Spring Validation Experiment within a picking run. The system does not need to meet quantifiable goals for the Spring Validation Experiment such as number of items picked within a given time frame.

4.6 Spring Validation Experiment (4/26)

Objective:
Meet all system requirements.

Additional Equipment:
Actuated aluminum shelving, final design gripper

Procedure:

1. The shelf will be populated with 32 items from the APC 2017 dictionary.
2. The system will be given a JSON file reflecting the correct item bin locations, as well as the desired tote for each item.
3. The perception system will recognize items in each bin and report the results to the workstation.
4. The perception system will localize itself and the shelf to the robot arm platform.
5. The perception system will detect the item of interest determined by the workstation and recognize its pose to find a valid suction/gripping surface.
6. The path planner will move the UR10 outside the desired bin or over the desired item surface.
7. The grasping system will implement a strategy based on the item to attempt to grasp the item on a predefined surface, communicating with path planning to move the arm.
8. The suction system will adhere to the item surface.
9. The path planner will move the item over the desired tote.
10. The grasping system will disengage suction and drop the item into the tote.
11. Repeat steps 5-10 till time is up or all tasks are completed.

Verification Criteria:

1. Pick up at least 12 items and drop them inside their target totes within 15 minutes, dropping no more than 2 items to the floor

2. Drop items into the totes from no more than .3m from the bottom of the totes

3. Generate an item report in the form of a JSON for the items remaining on the shelf, with 100% accuracy for item bin locations (excluding any dropped items)

Appendix A - Functional Requirements

MF 1: Hold all challenge items on a fabricated shelf
MF 2: Accept/Interpret user input
MF 3: Identify and localize items
MF 4: Pick items from shelf
MF 5: Place items into target tote
MF 6: Generate item report