Critical Design Review

TEAM HARP
HUMAN ASSISTIVE ROBOTIC PICKER
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Outline

1. Project Description
2. System Requirements
3. System Architecture
4. Current System Status
5. Project Management
6. Semester Conclusions

Project Description

Project Description

Amazon sells 306 items per second and has 96 fulfillment centers across the United States

HARP aims to deliver an autonomous robot to pick specified item off an Amazon warehouse shelf and place them in a box.

Use Case


Kindle 2 Has Arrived
Sleeker design. More storage. Longer battery life. Choose from over 245,000 books all available in under 60 seconds. And now Kindle can read to you. Our revolutionary wireless reading device just got better.
Learn more
amazonkindle
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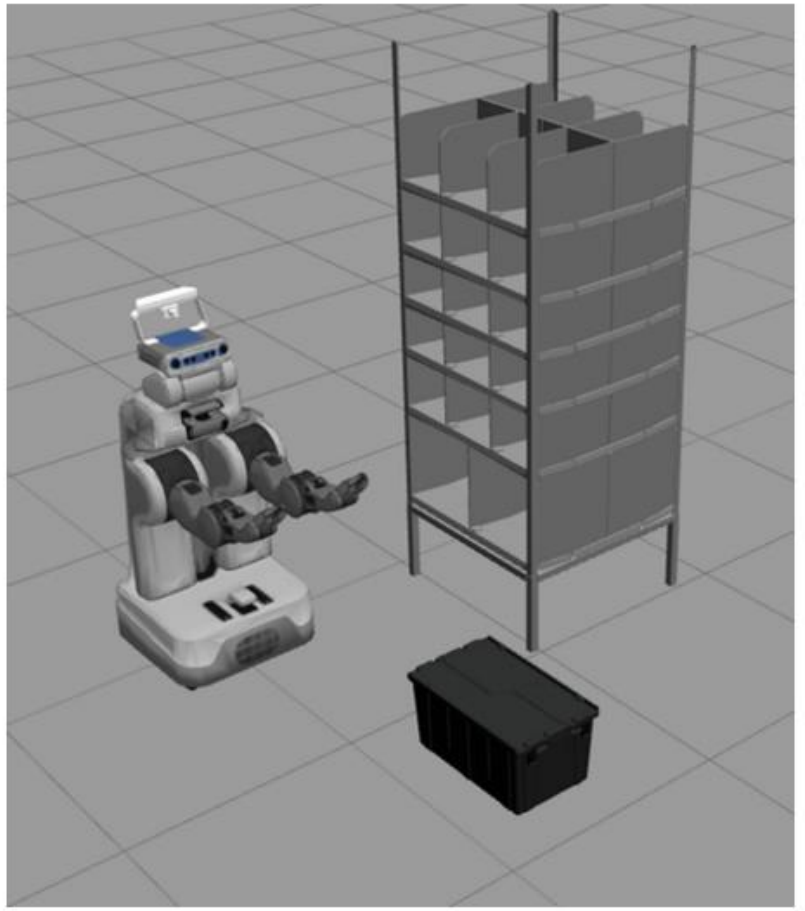
amazon
PrimePantry



System Requirement

Functional Requirements

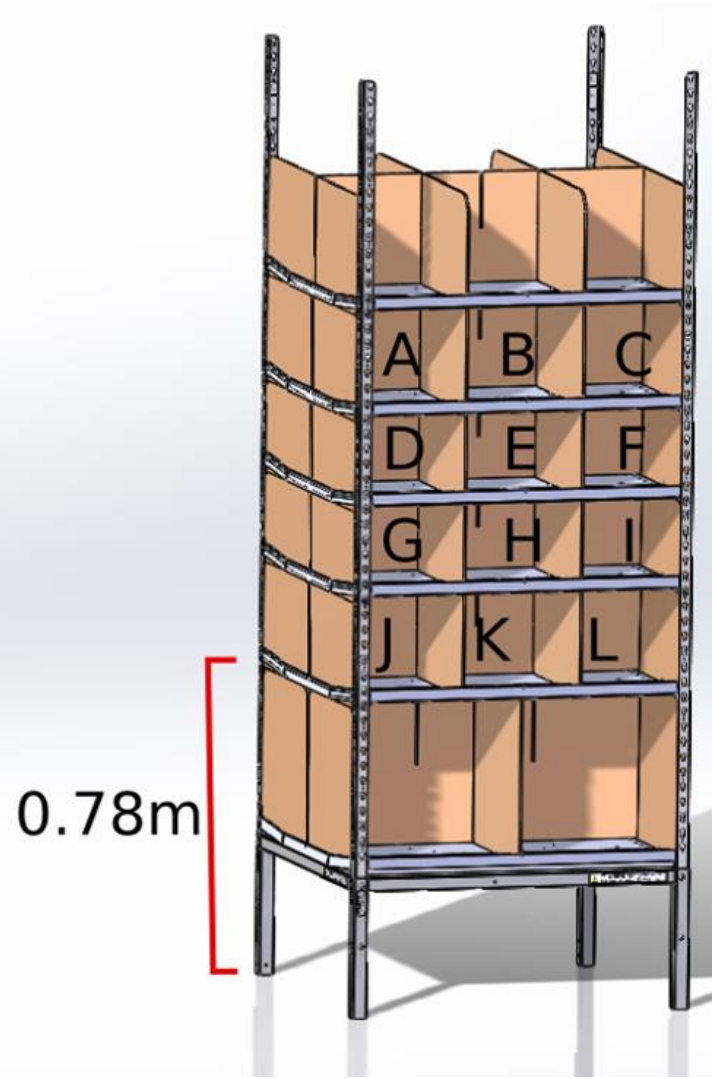
The robot shall…

1. Accept order list from user
2. Autonomously parse items in the order list to generate item plan
3. Autonomously determine positions and orientations of target items
4. Autonomously picks item from shelf bin
5. Autonomously places item in order bin

Performance Requirements

The robot must…

1. Interpret work order with 100% accuracy
2. Autonomously identify object with 90% accuracy
3. Autonomously determine suction grasping surface on 50% of attempts
4. Autonomously pick item of known pose from shelf bin on 75% of attempts
5. Autonomously place 90% of picked item in order bin from a height of no more than .3 meters
6. Acquire at least 3 items in under 20 minutes
7. Be able to lift items up to .5kg mass
8. Acquire items from bins located at a max height of 1.86m and minimum height of .78m
9. Acquire items from a .27m x .27m shelf bin



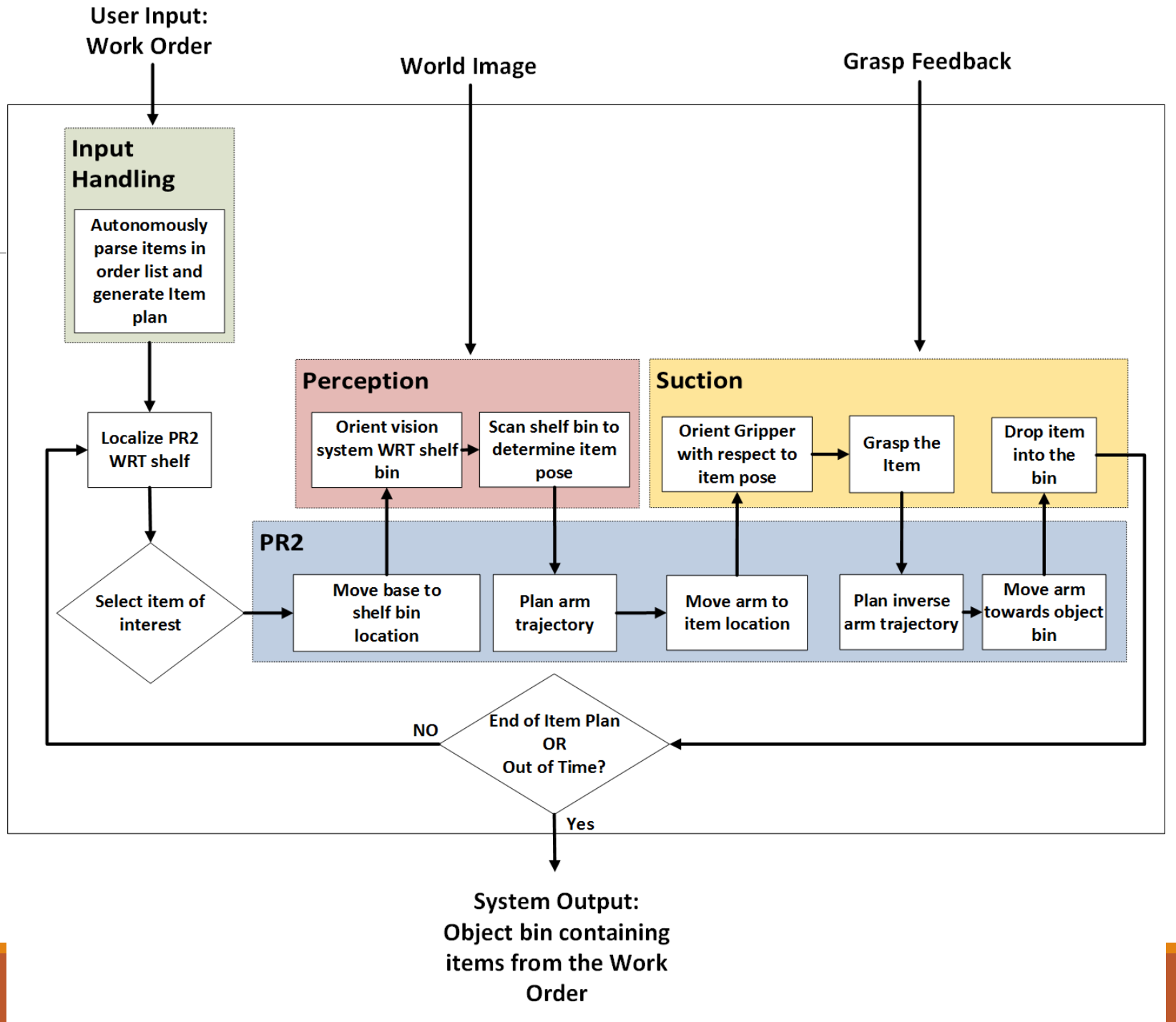
Nonfunctional Requirements

The robot must…

1. Cost no more than $4000
2. Be completed by May 1st, 2016
3. Be transportable or available at ICRA 2016
4. Be robust to lighting between 320-500 lux
5. Be available for testing at least 1 day per week
6. Start and stay within a 2m by 2m boundary (except the end effector)
7. Have an emergency stop

System Architecture

Functional Architecture



Physical Architecture

Global Planner

Two Quad-Core i7 Xeon Processors
24 GB Memory and 500 GB HDD
Ubuntu 12.04
ROS Groovy
SMACH State Controller

ROS Services

Gripper

- Grasp Planner
- Arduino
  - Relay
    - Impeller
      - Suction Cup
  - Pressure Sensor

PR2

- Arm Planner
  - Left Arm
  - Right Arm
- Motion Planner
  - Mobile Base
  - Spine

Perception

- Item Recognizer
  - Pan and Tilt Mechanism
  - Computer ROS Indigo USB 3.0
    - Kinect 2.0

Hardware

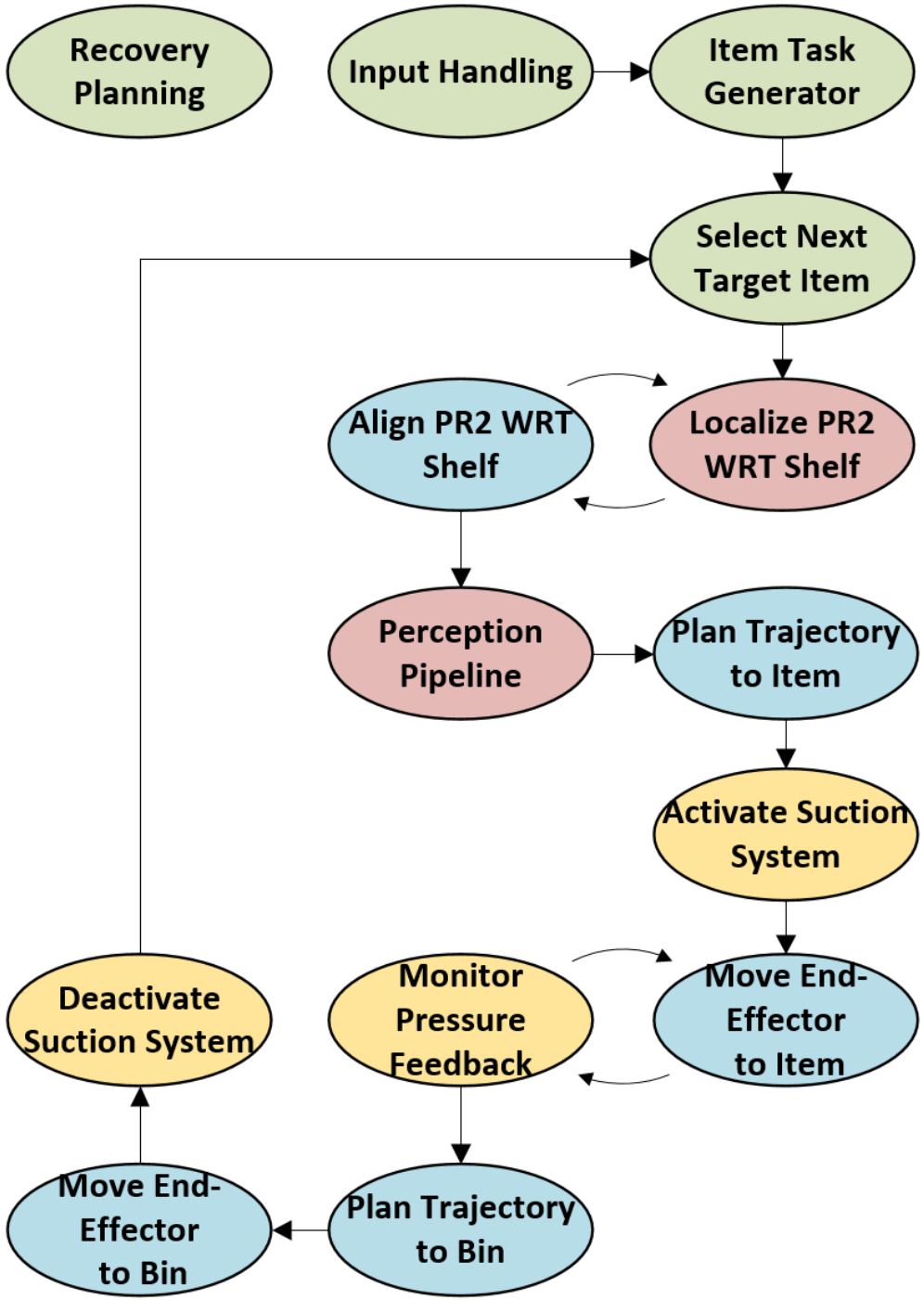
Software Architecture

State Controller
- SMACH Viewer
- Shelf and Item TF Publisher

Perception
- Point Cloud Library
- Kinect2 Node and TF Publisher

Platform
- Robot State Publisher
- RVIZ Simulation
- PR2 Navigation
- PR2 Moveit! Group

Suction
- ROS Serial



Current System Status

Fall Targeted Requirements

Perception
Autonomously determine positions and orientations of target items with 50% accuracy
Be robust to lighting between 320-500 lux

Grasping
Be able to lift items up to .5kg mass
Acquire items from a .27m x .27m shelf bin

Platform
Autonomously pick item of known pose from shelf bin on 75% of attempts
Autonomously place 90% of picked item in order bin from a height of no more than .3 meters

Perception System Description

Capture Kinect 2.0 RGBD data

↓

Filter shelf from depth cloud

↓

Euclidian segmentation

↓

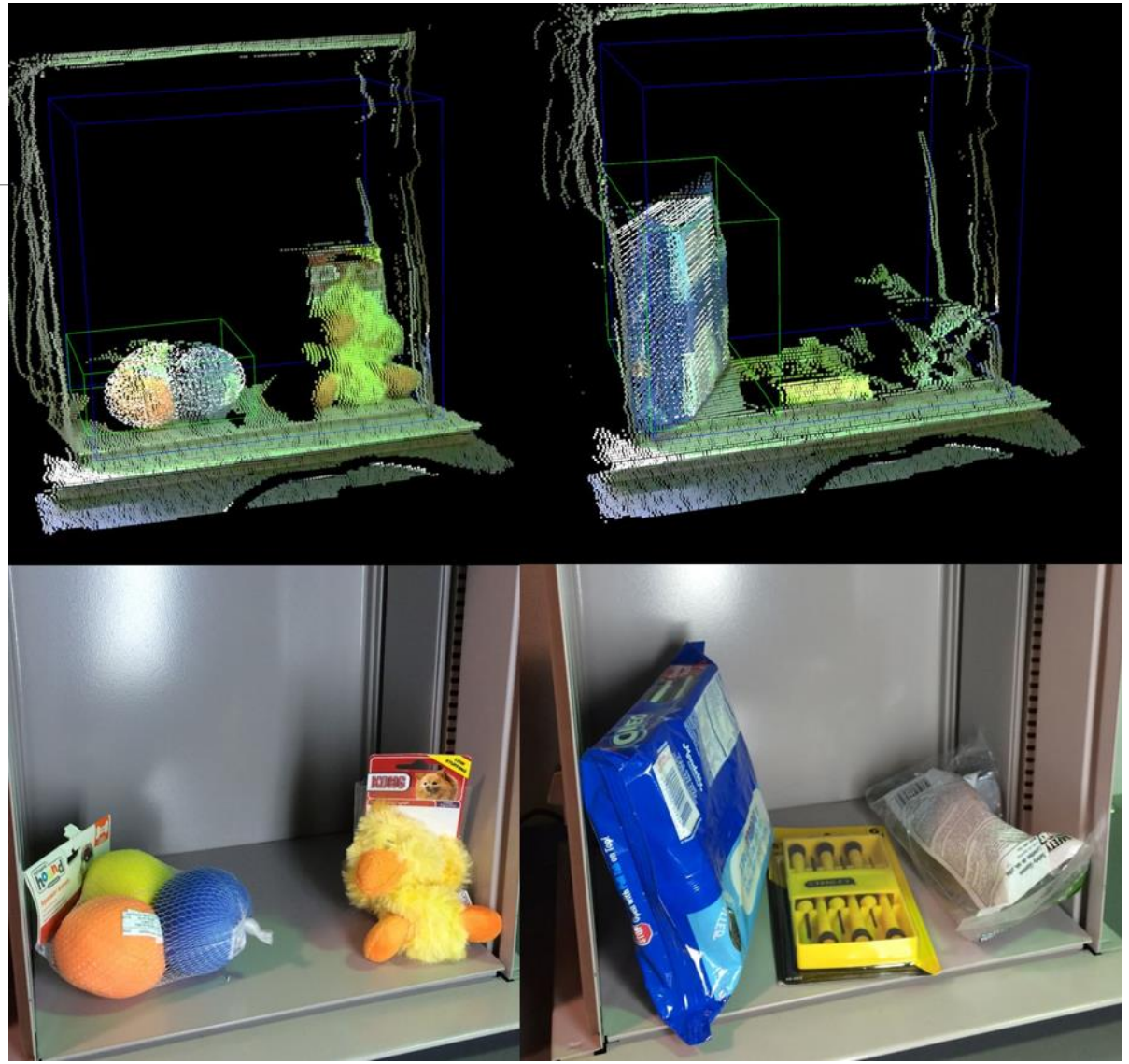
Cluster segments to find item

↓

Item identification and pose estimation

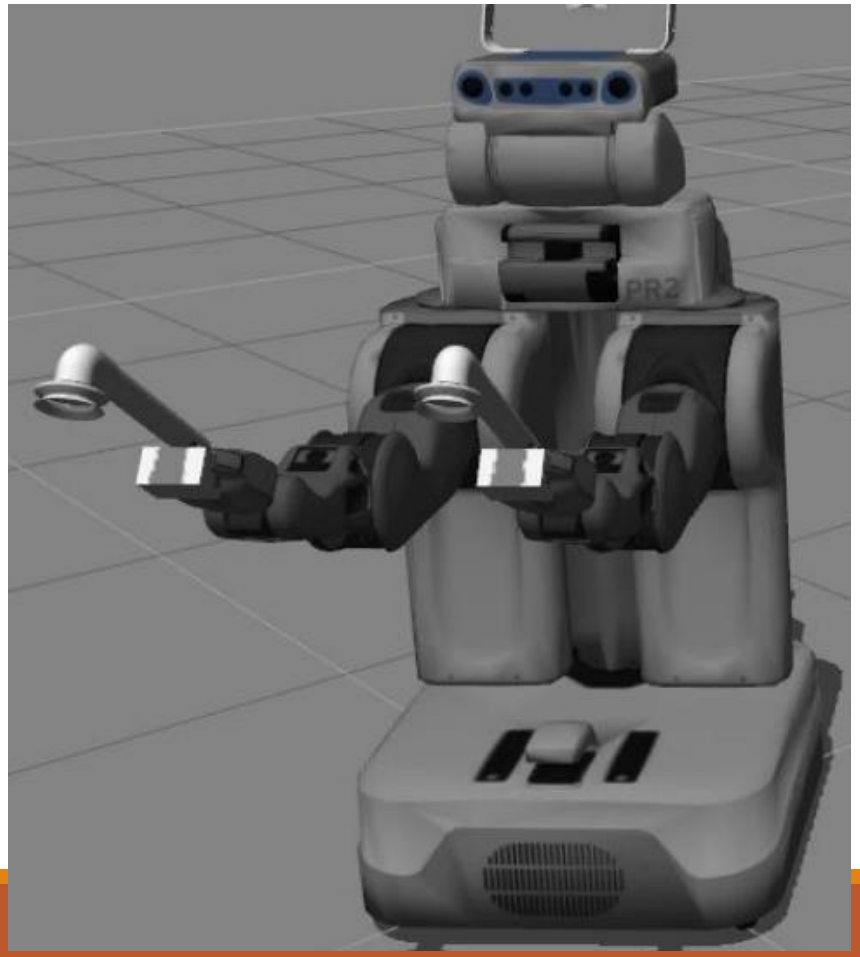
Perception FVE

	Two Items	Three Items
Correct Tests	22	13
Incorrect Tests	3	12
Accuracy	88%	52%
90% CI	72%-97%	34%-69%
Clustering Failure	1	3
ID Failure	0	6
Pose Failure	2	3
Average Run Time	15.66	19.93



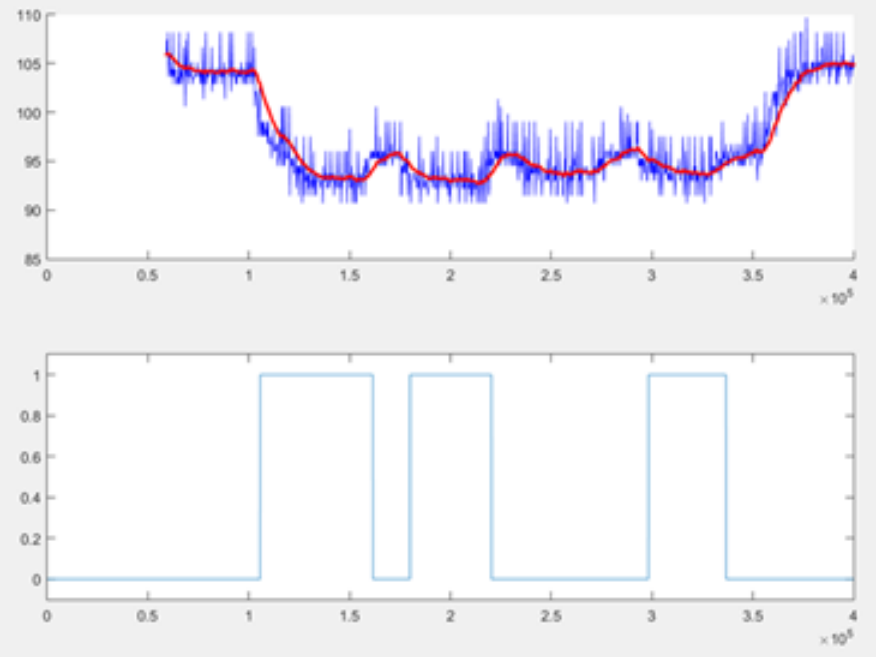
Suction Mechanical Design

- High flow low pressure vacuum system
  - Shop-Vac impeller provides 200 CFM and 40 kPA
- Custom suction cup held by the PR2's two finger gripper
- Capable of acquiring all objects from the 2015 APC item list



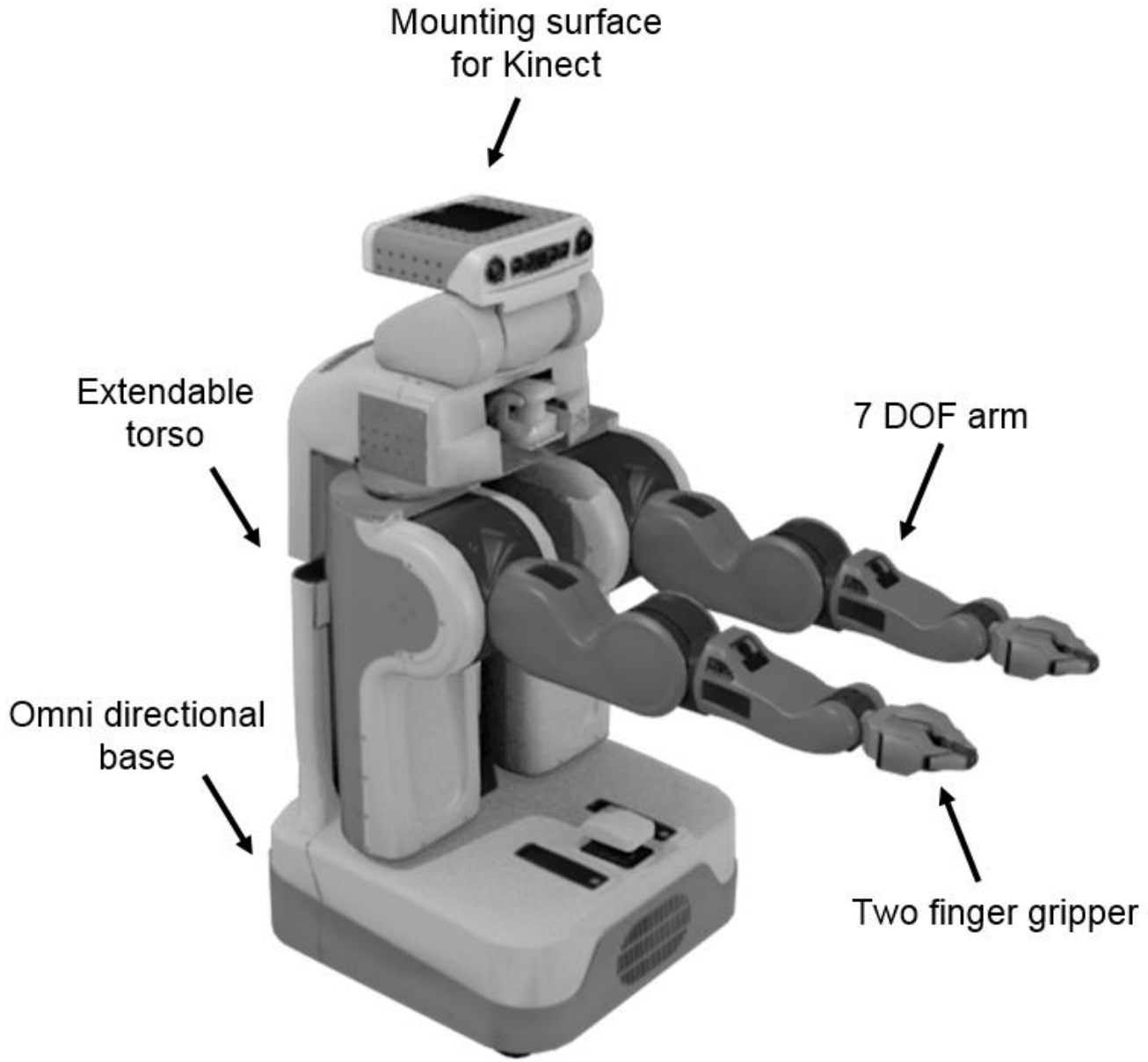
Suction Electrical Design

- Custom PCB controls up to two vacuums and reads four analog sensors
- ROS Serial used to communicate with main computer
- Pressure sensors predicts when item has been acquired
- All electronics neatly packaged in custom enclosure



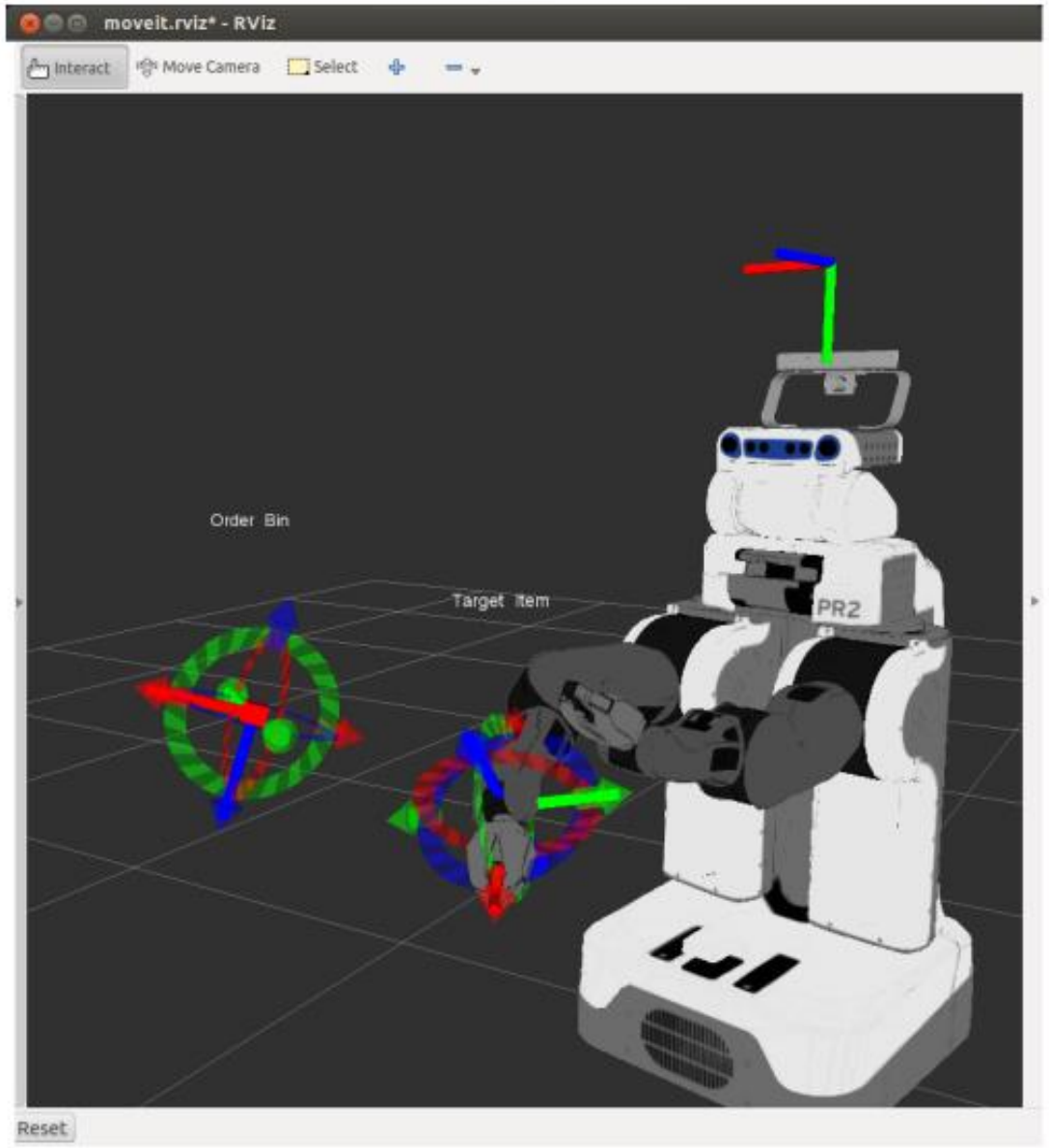
Platform System Description

- Full ROS support
- Integrated computer with two i7 processors and 24gb ram
- Two 7 degree of freedom arms with two finger grippers
- Omni directional base
- Extendable torso



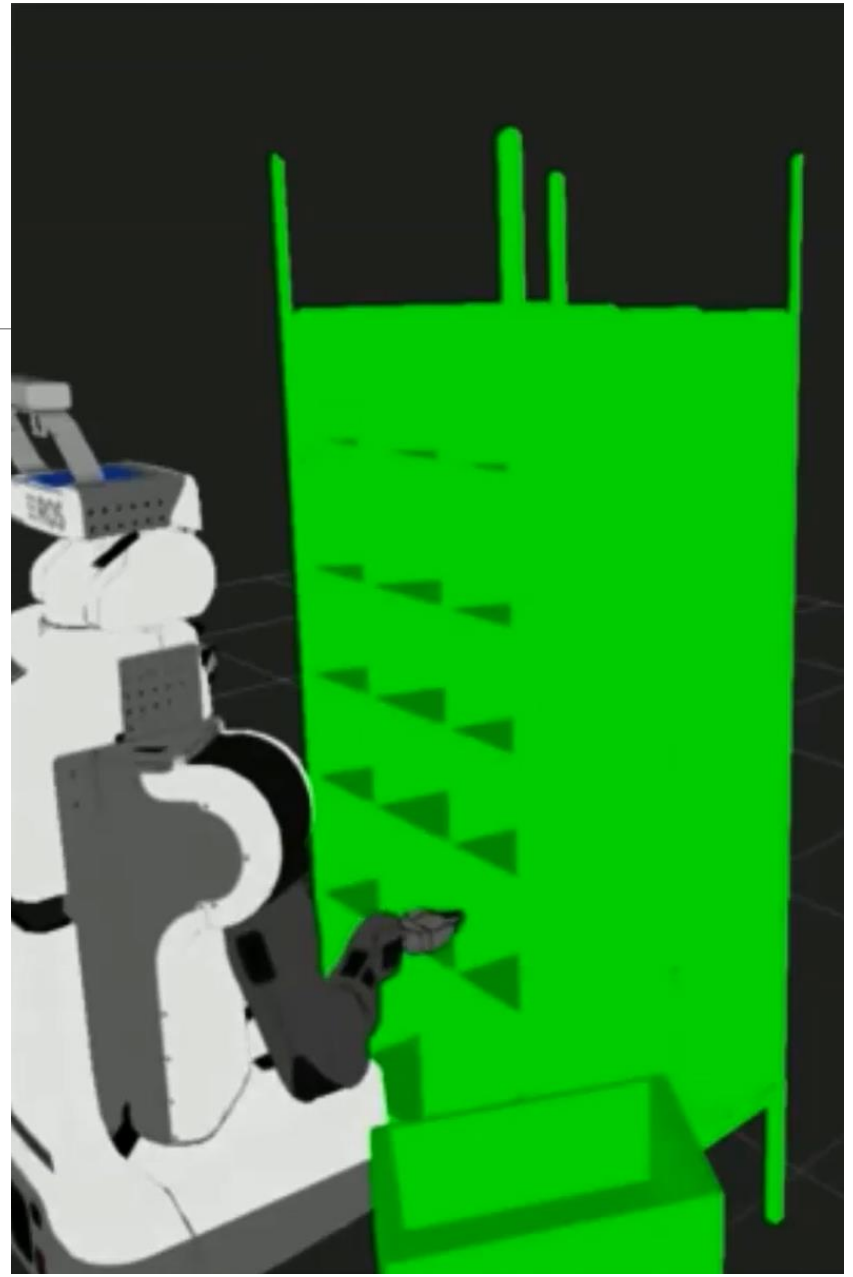
Arm Manipulation and Base Control

- MoveIt and OMPL packages used to plan and execute arm trajectories
- Custom PD controller moves robot base along shelf
- TF tree manages robot frames over time

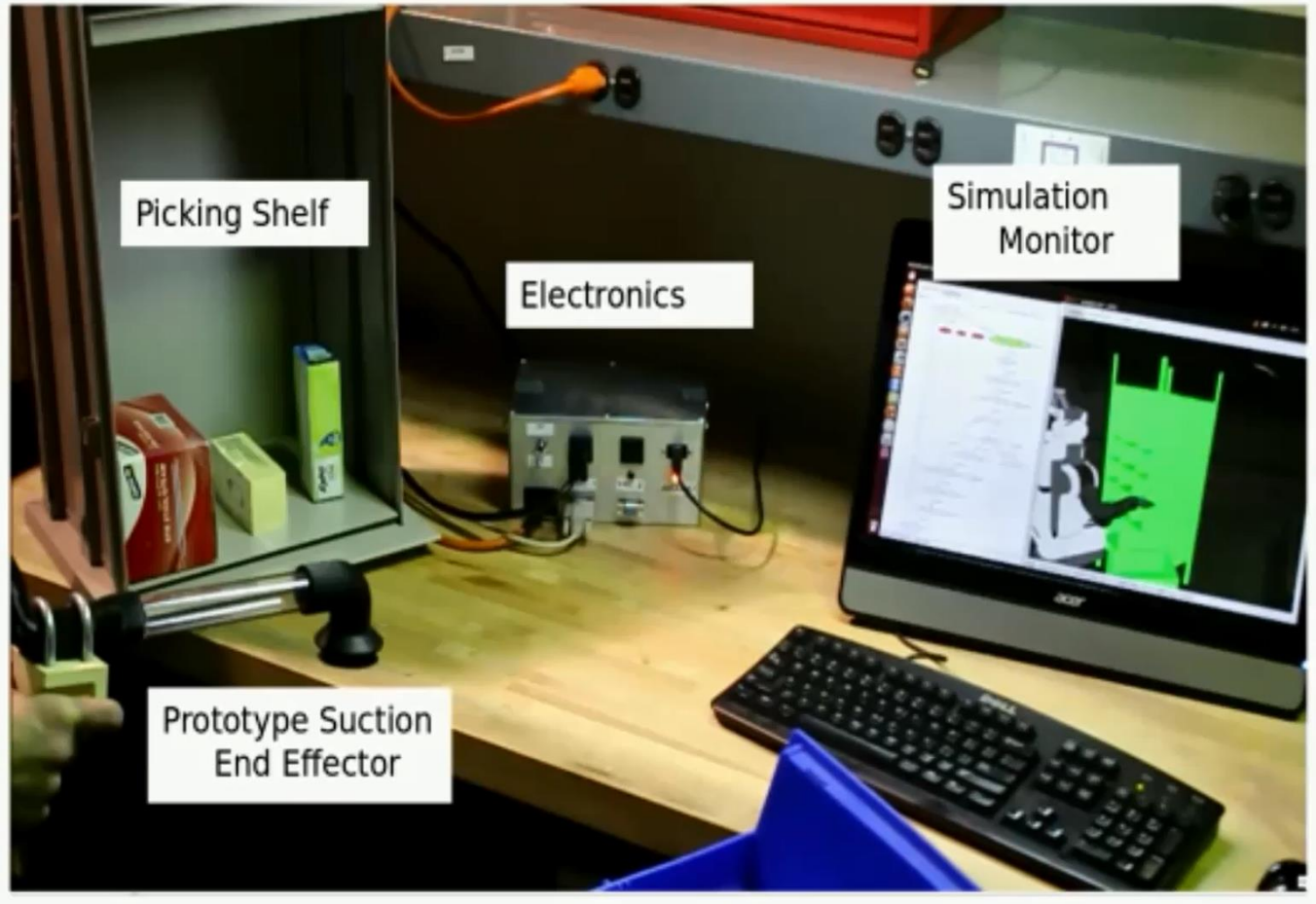


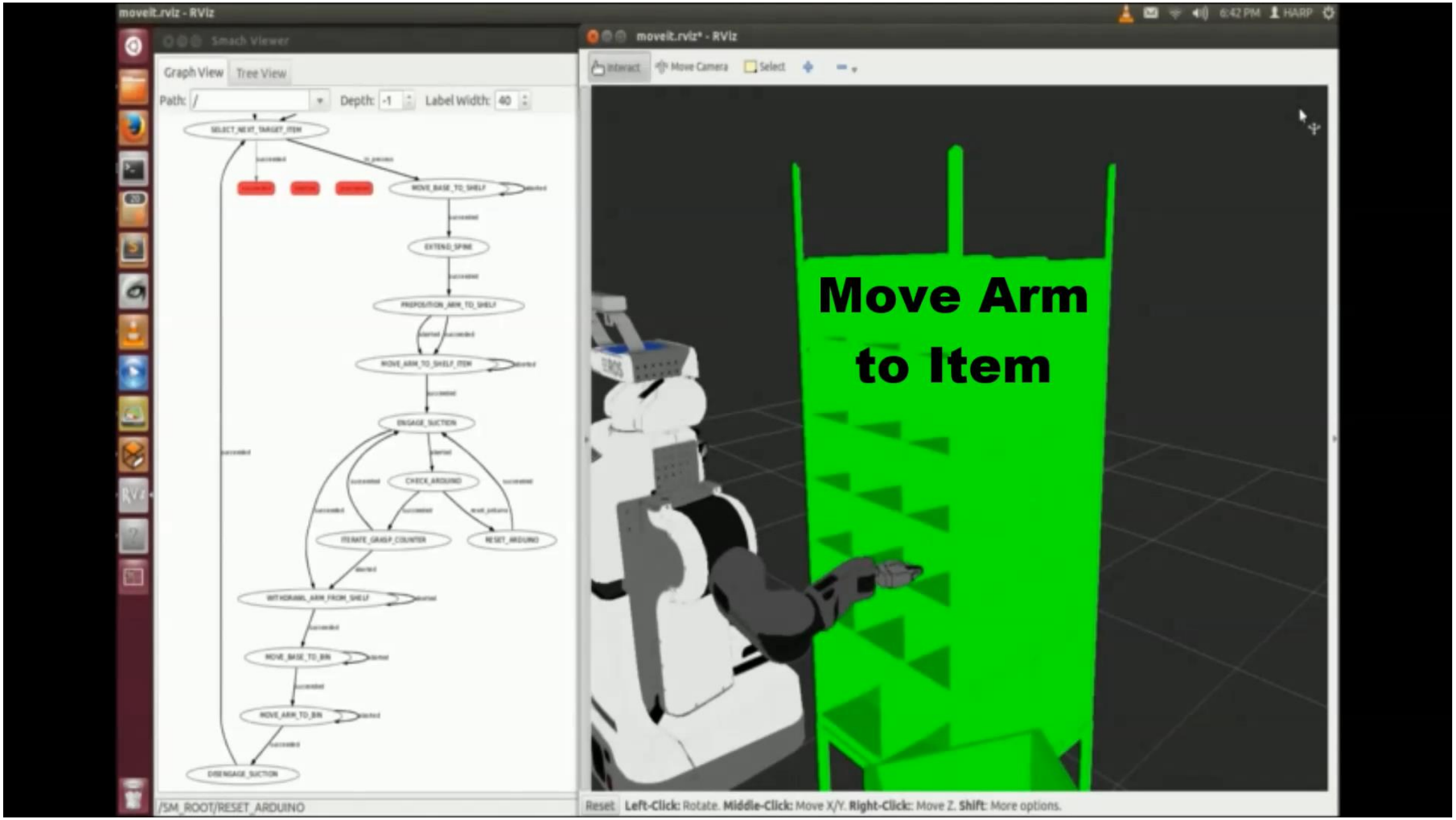
PR2 Simulation and State Controller

TODO



Platform Fall Validation Experiment





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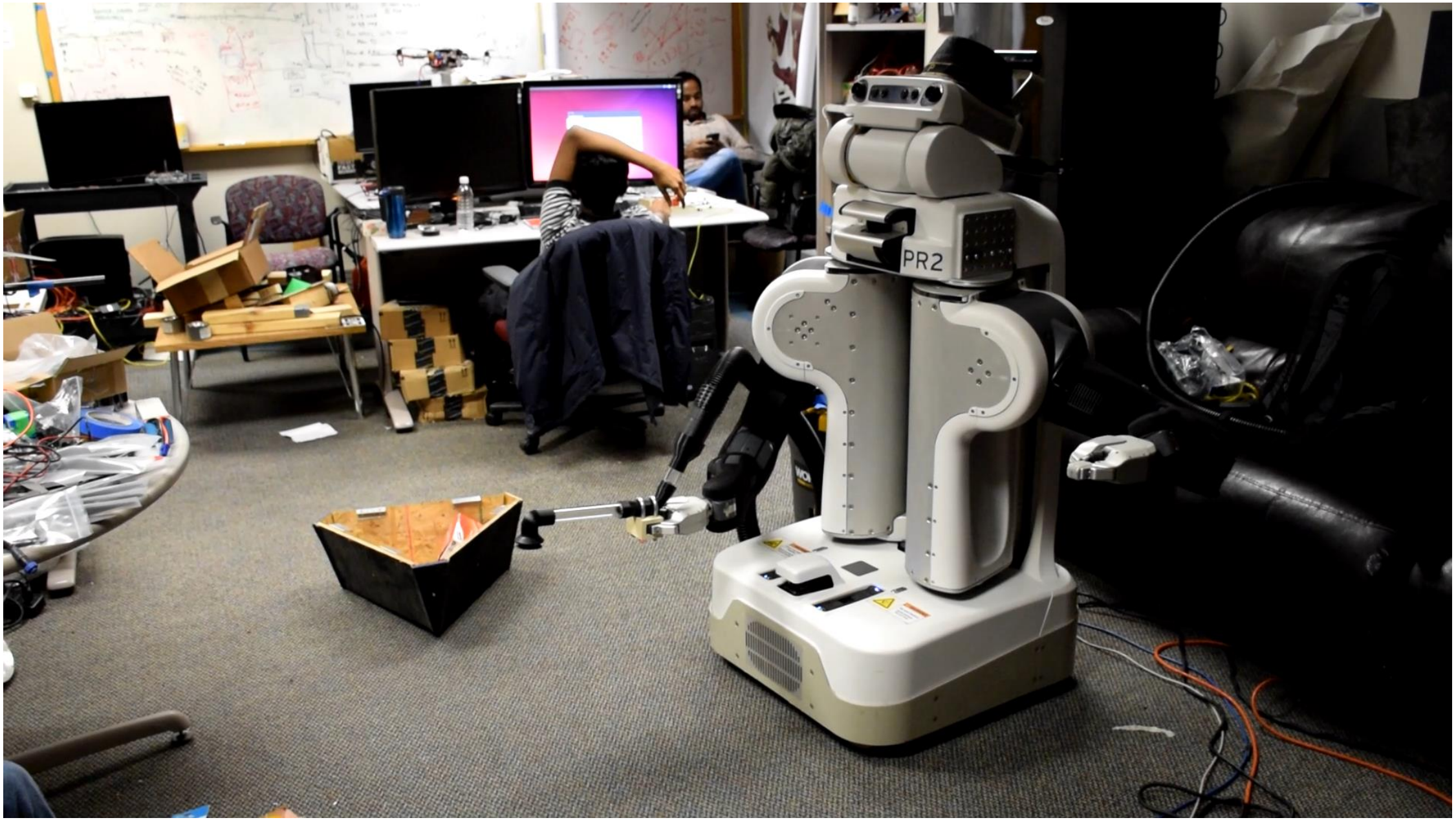

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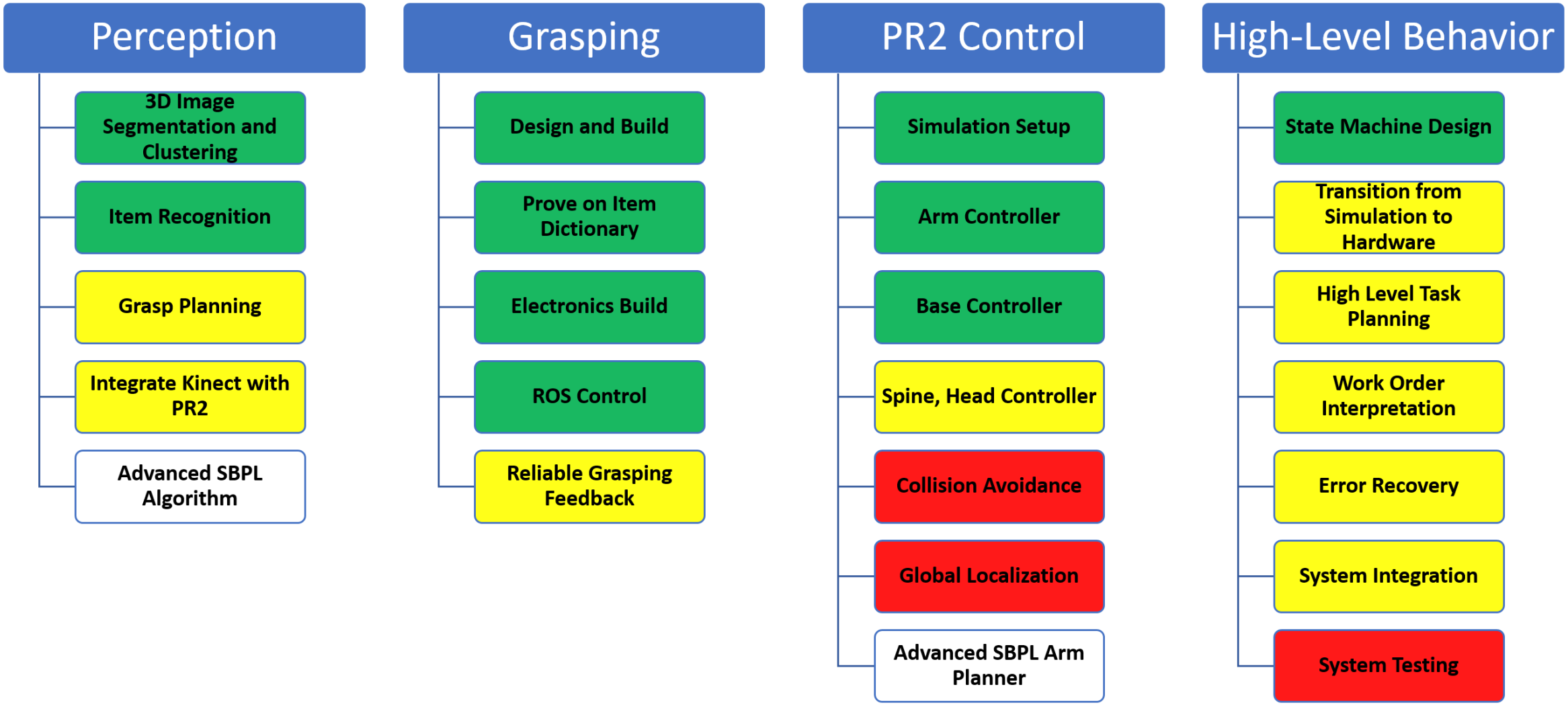
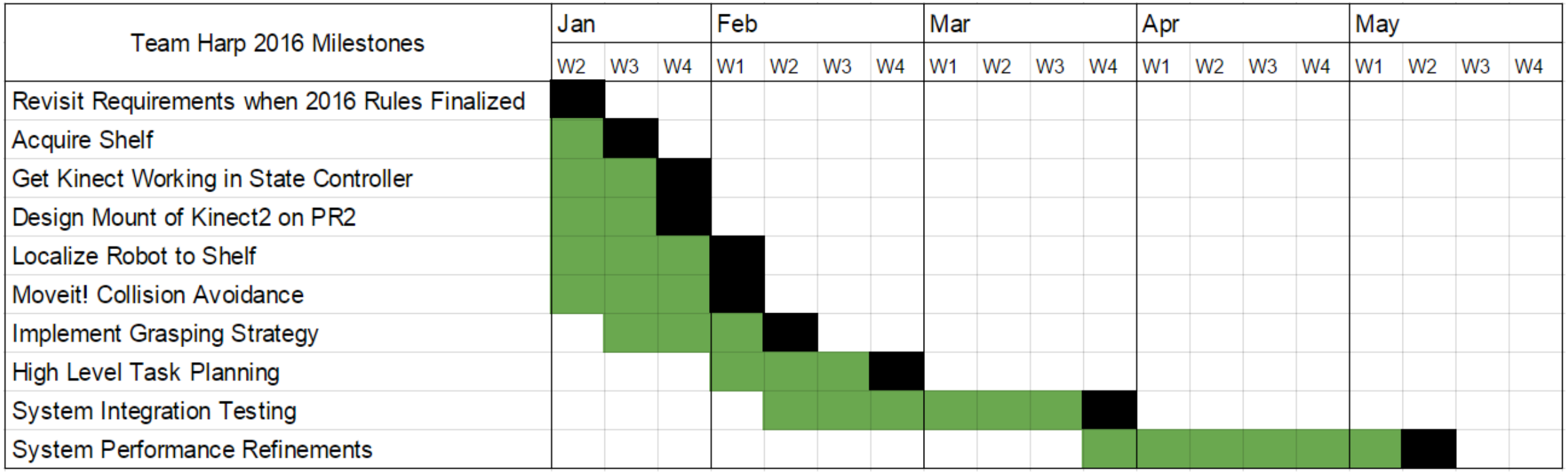
Project Management

Work Breakdown Structure



2016 Milestone Schedule



Spring Validation Experiment

Goal: Acquire at least 3 items in under 20 minutes.

Procedure:

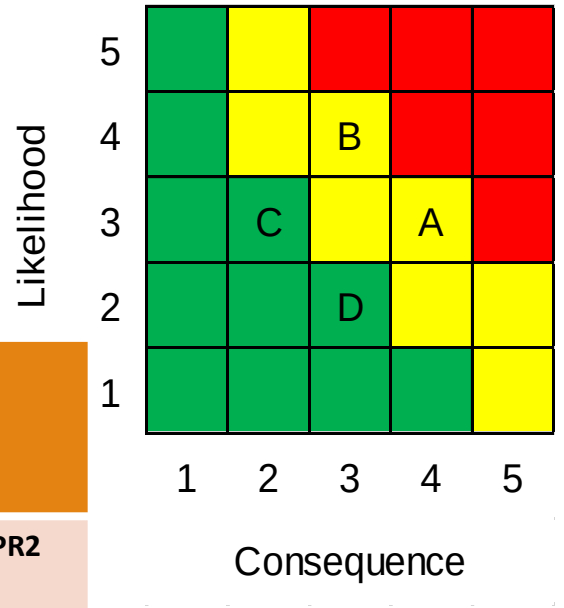
1. Populate shelf with all 25 items from the 2015 APC item dictionary
2. Input text file indicating the 10 randomly selected items as well as bin locations
3. The system will…
   - Automatically recognize items in the bin and report results to a GUI on the computer
   - Automatically detect object and recognize its pose to find a valid suction surface
   - Automatically move the arm to the desired grasping location
   - Attempt to grasp the item without damaging or dropping it
4. Withdraw the end effector / item from the shelf bin and place it into the order bin
5. The system will repeat the delivery process for 20 minutes and attempt to deliver as many items into the order bin as possible

Budget

Item Description	Cost
Suction Prototype	$ (109.42)
Shop Vac (Qty 2)	$ (245.58)
Electronics	$ (224.52)
Kinect 2	$ (140.00)
Item Dictionary	$ (50.00)
Total Cost	$ (769.52)
Remaining Funds	**$ 3230.48**

Risk Management

	Risk	Description	Type	Cause	Consequence	Mitigation
A	Perception system viewing angle	View from PR2 may be insufficient to generate grasp vector	Technical	Mounting Limitations on PR2 Algorithm sensitive to perspective angle	System cannot pick certain items	Detailed analysis of PR2 Mounting design Leave time for algorithm refinements
B	Depth sensor cannot detect specular items	Irregular items may not match well to Ground Truth Models	Technical	Ground Truth model Sparse Item in odd configuration	System cannot pick certain items	View shelf from multiple angles Add color features to algorithm
C	Gripper design may be insufficient for new 2016 rules	A stowage task may make current design ineffective	Technical	Requirements change	Suction end effector redesign	Have several designs in mind anticipating rule change
D	Perception algorithm does not scale on crowded shelf bins	Perception algorithm runs in $O(n^3)$ for n items	Technical	ICP algorithm requires large amount of computation	May not be competitive	Parallelize algorithm Use SBPL algorithm



Semester Conclusions

Key Lessons Learned

- Know when to take personal growth roles vs productivity roles
- Be wary of working with new or unsupported hardware
- Know when to cut your losses
- Use your fellow MRSD students for help and advice

Key Spring Semester Activities

- Revisit requirements when 2016 rules are finalized
- Develop and refine localization Approach
- Integrate perception subsystem with PR2
- Refine perception and grasping strategy
- Improving system level performance