Preliminary Design Review

Team HARP
Human Assistive Robotic Picker
(Abhishek, Alex, Feroze, Lekha, Rick)
Carnegie Mellon University

Project Description

Project Description

Project HARP aims to deliver an autonomous robotic picker to Interpret work orders, find target items, and retrieve target items.

Our system will utilize Intelligent perception, robust autonomous decision-making, a capable manipulation platform, and an innovative suction system.

The PR2 research platform will be used courtesy of the Search-based Planning lab at CMU

PR2 Research Platform

Prof. Maxim Likhachev

Andrew Dornbush

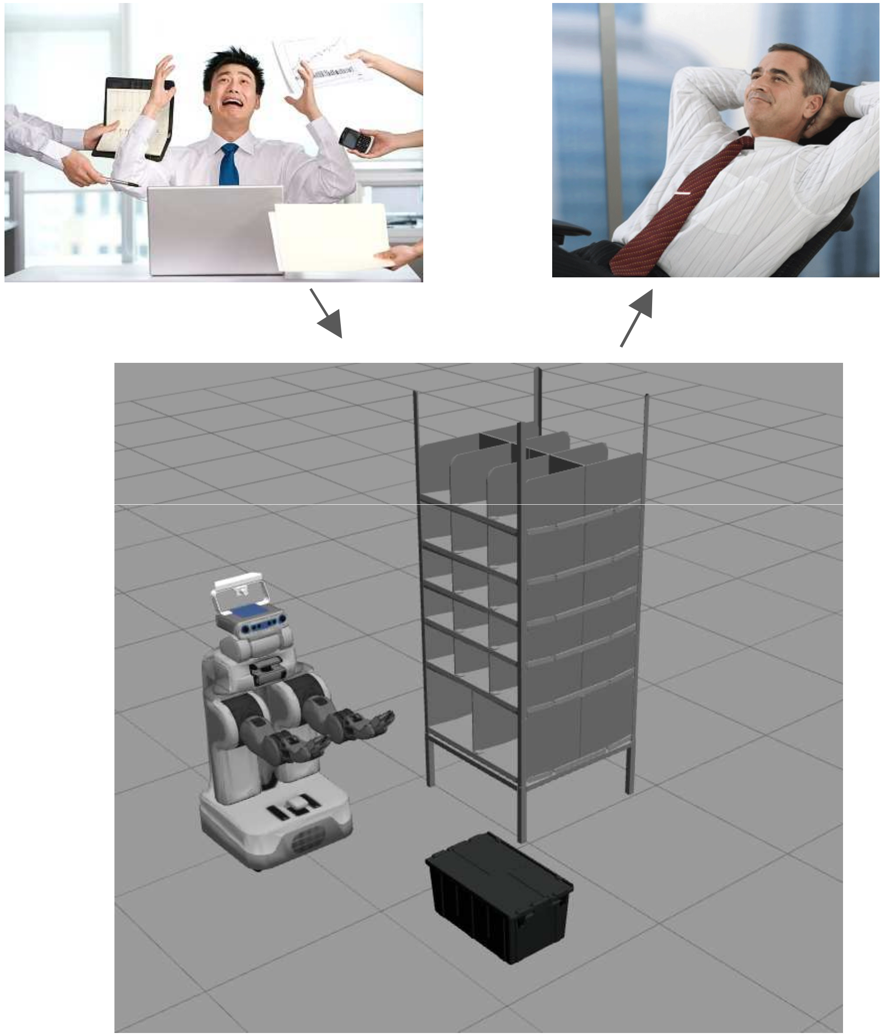
Venkat Narayanan

Use Case

Imagine you are an overworked MRSD student it’s the night before your project demo, you’re tight on budget, low on sleep when the unthinkable happens… your main drive motor burns out.

Lucky for your, Amazon just implemented the HARP in its order fulfillment warehouse, driving down rush delivery fees and decreasing fulfillment times. You find a replacement on Amazon and to your amazement it can arrive in 12 hours. As soon as you click the ‘order now’ button, HARP comes to life. Moments later your drive motor arrives to HARP on a Kiva robotic shelf. HARP interprets your order, visually confirms the location of the motor on the shelf, and retrieves the item. Once HARP is finished, your motor is packaged and loaded into a delivery truck destined for NSH.

The next morning you get your motor and impress the MRSD professors with your awesome demo, thanks to HARP.



Requirements


oreo_mega_stuf
champion_copper_plus_spark_plug
expo_dry_erase_board_eraser
genuine_joe_plastic_stir_sticks
+1
munchkin_white_hot_duck_bath_toy
crayola_64_ct
mommys_helper_outlet_plugs
sharpie_accent_tank_style_highlighters
+3
stanley_66_052
+1
safety_works_safety_glasses
cheezit_big_original
paper_mate_12_count_mirado_black_warrior
feline_greenies_dental_treats
elmers_washable_no_run_school_glue
mead_index_cards
+2
rolodex_jumbo_pencil_cup
+2
first_years_take_and_toss_straw_cup
highland_6539_self_stick_notes
+3
mark_twain_huckleberry_finn
+1
kyjen_squeakin_eggs_plush_puppies
+1
kong_sitting_frog_dog_toy
+1
kong_air_dog_squeakair_tennis_ball
+2
dr_browns_bottle_brush
+1
kong_duck_dog_toy
+3
laugh_out_loud_joke_book

System Level Requirements

There have been no changes in system level requirements

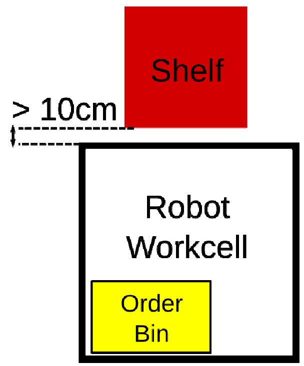
Functional Requirements
The robot shall…

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
6. Does not drop items
7. Does not damage items

Nonfunctional Requirements

The robot must...

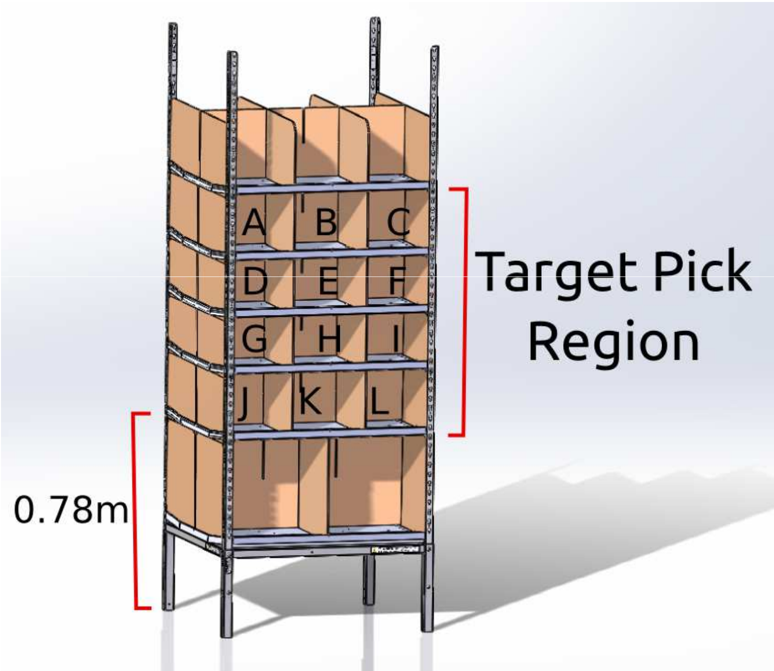
1. Cost no more than $4000
2. Be completed by May 1st, 2016
3. Transportable or available at ICRA 2016
4. Robust to environmental variations including lighting and physical geometry
5. Robust to lighting between 320-500 lux
6. Be available for testing at least 1 day per week
7. Start and stay within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



Performance Requirements

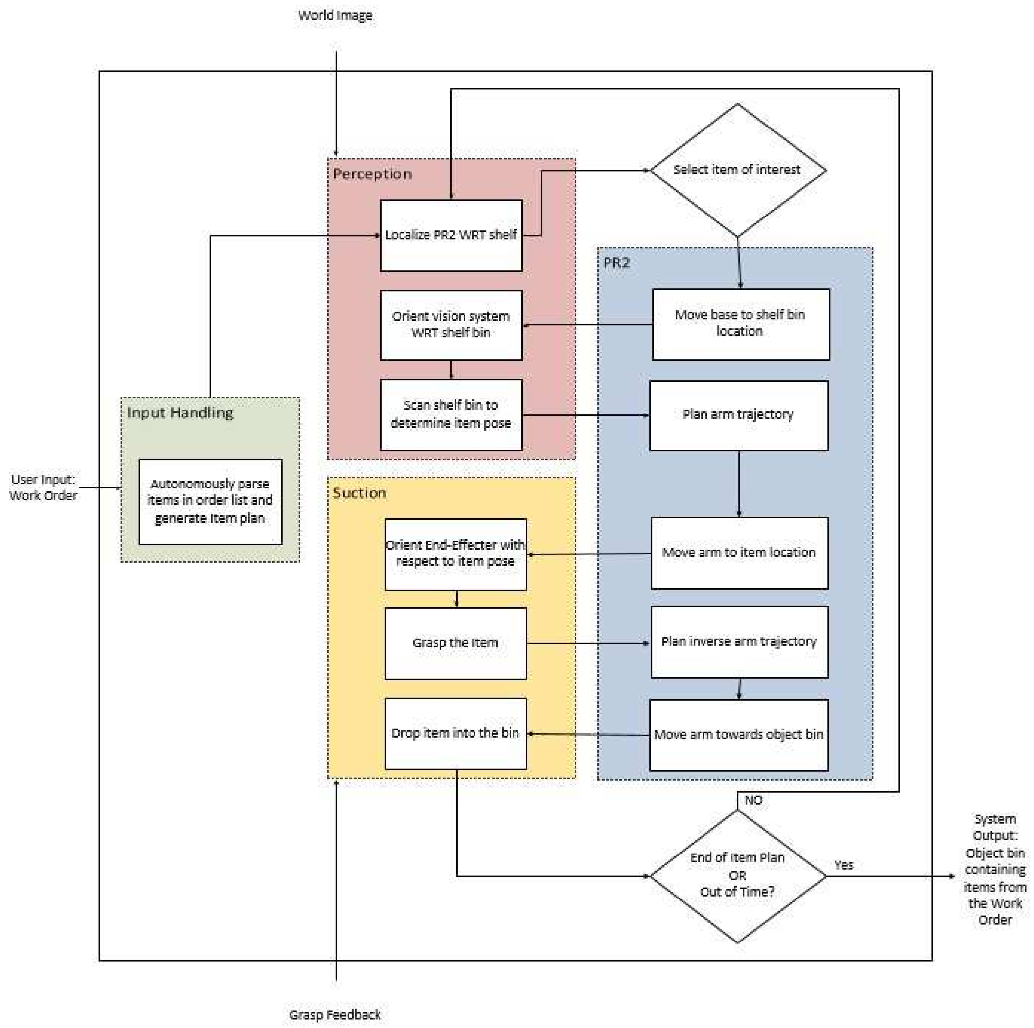
The robot must…

1. Interpret work order with 100% accuracy
2. Autonomously identify object with 90% accuracy
3. Autonomously determine suction grasping surface on 75% of attempts
4. Autonomously picks item of known pose from shelf bin on 50% of attempts
5. Autonomously places 90% of picked item in order bin from a height of no more than .3 meters
6. Acquire at least 3 items of 10 total attempts 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

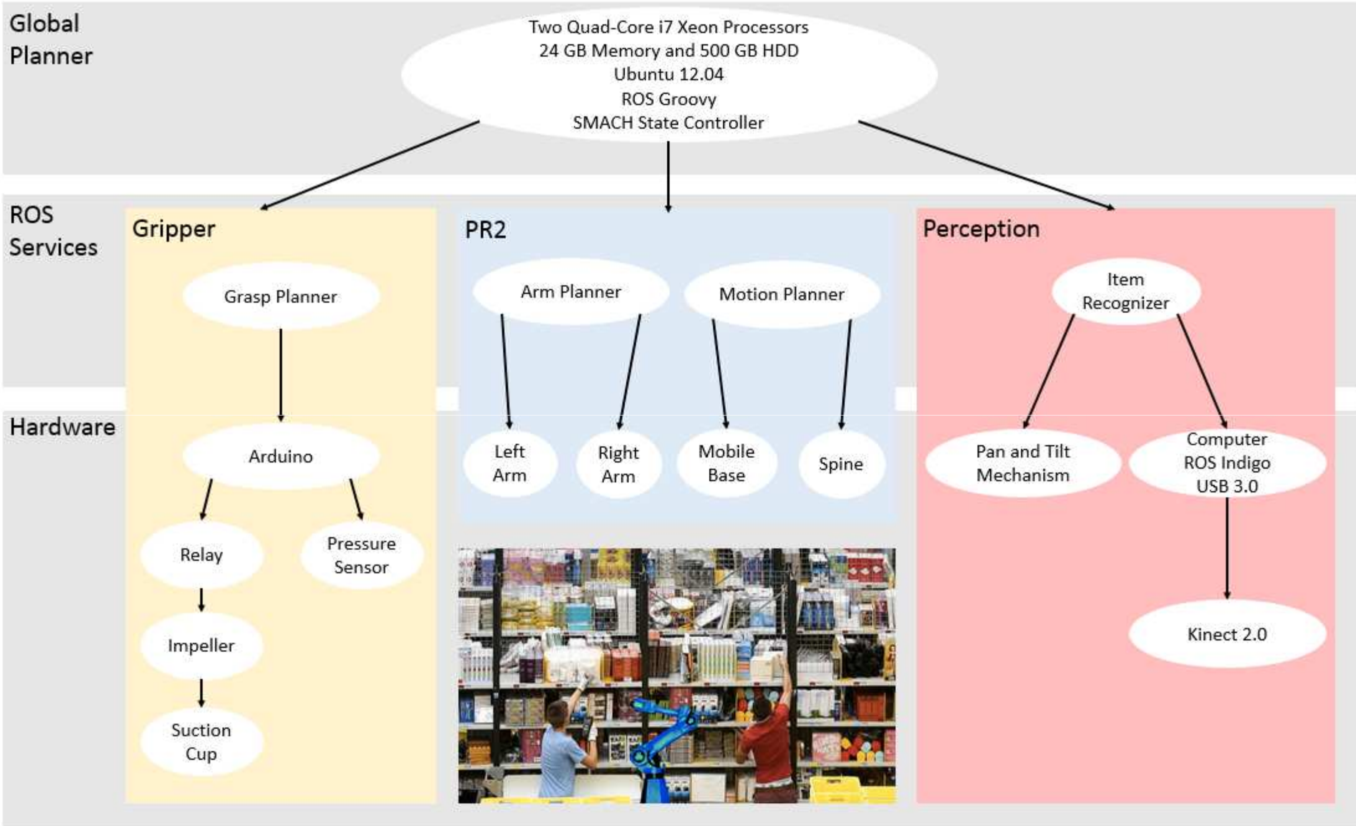


Architecture

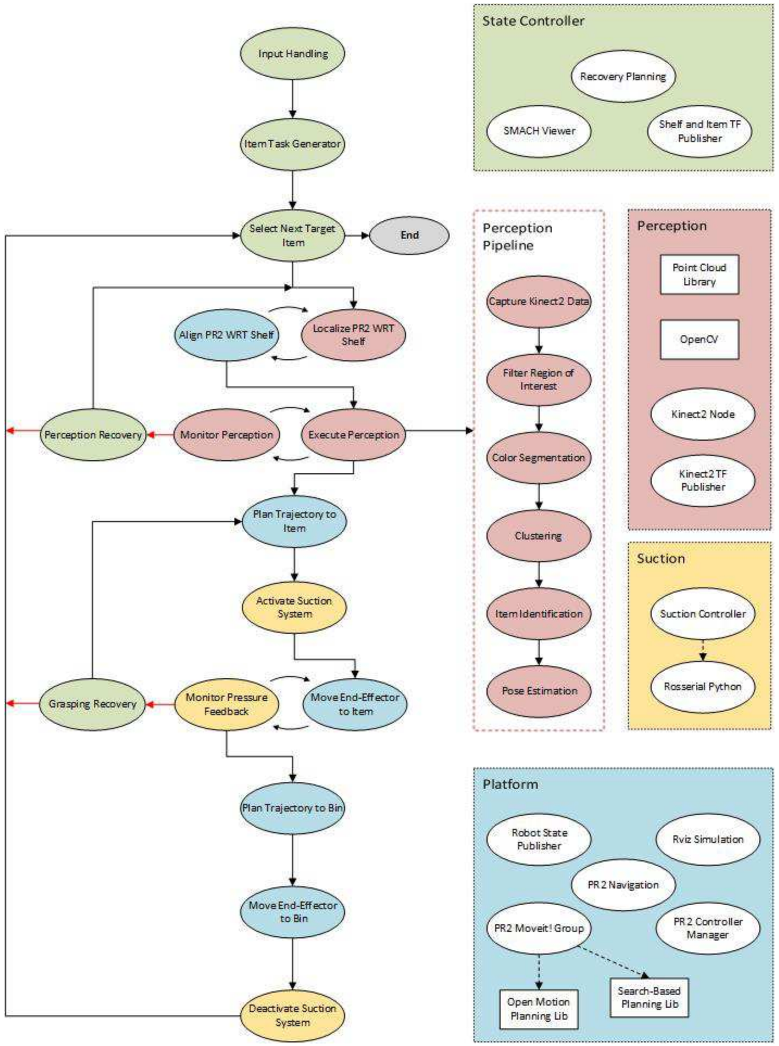
Functional Architecture



Physical Architecture



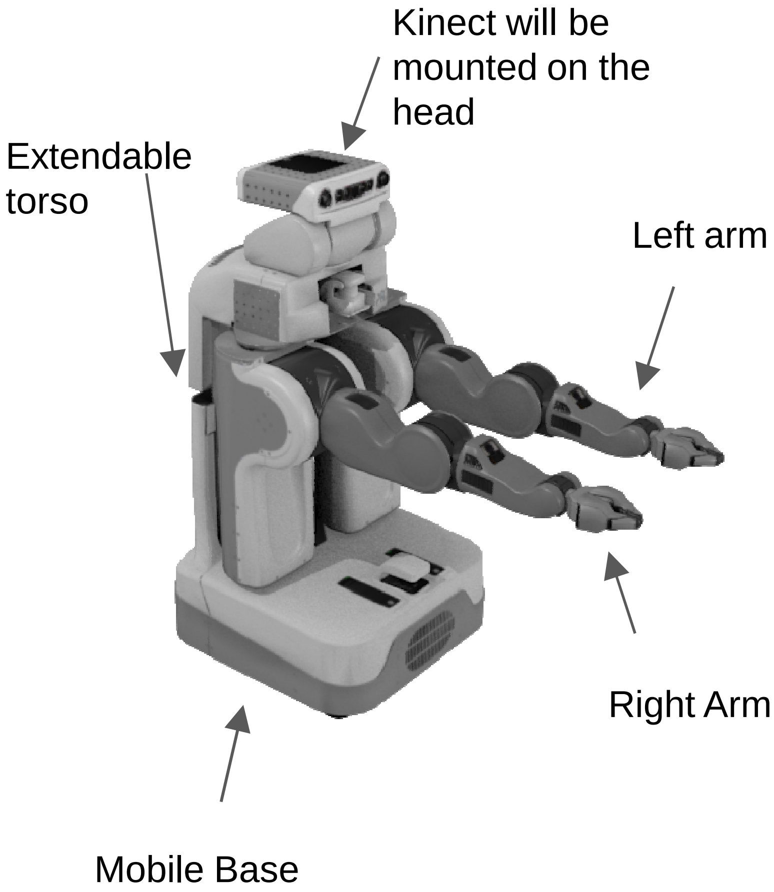
Software Architecture



Platform Subsystem

PR2 Robot Platform

- Willow Garage PR2 robot at SBPL
- 7 DOF
- Arm payload - 1.8kg
- Full ROS support
- Can be simulated in rviz
- Requires a platform for reaching top bin of shelf (~1.86m)



Planning Subsystem

Arm Kinematics:

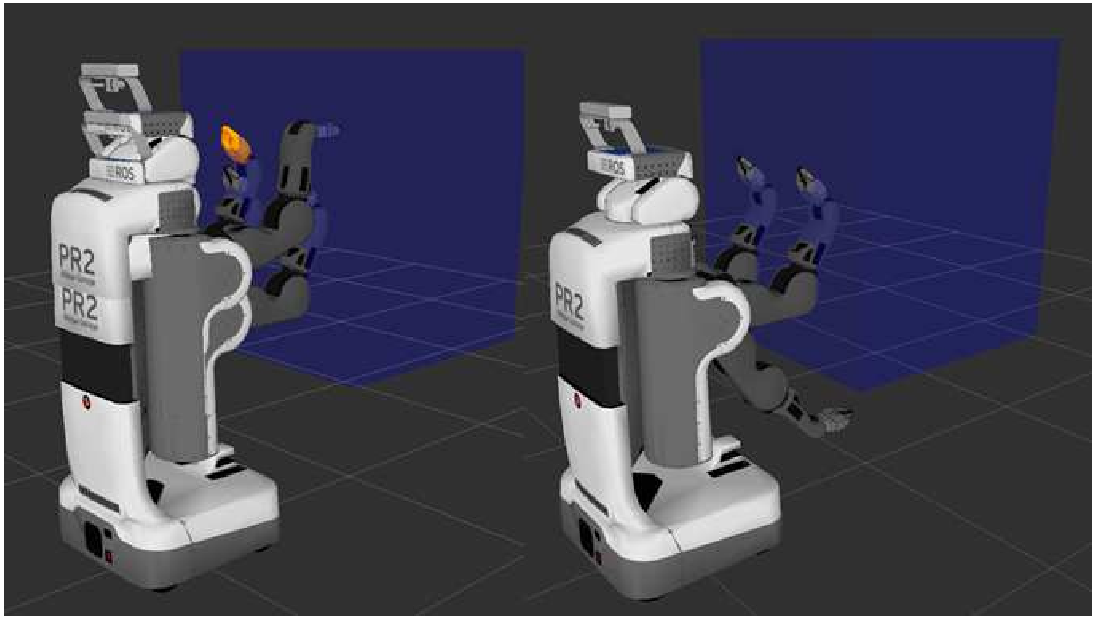
- Controlled using pr2_controller ROS package
- MoveIt planner using OMPL library
- Later switch out OMPL for SBPL’s library

Mobile Base Navigation:

- Controlled with standard ROS move_base package

PR2 System Status

- Used MoveIt! to explore PR2 workspace in RVIZ
- Teleop control of PR2 robot using PS2 joystick
- IK control of PR2 in simulation
- Working towards IK control of PR2 platform
- Work in progress for PR2 base navigation in



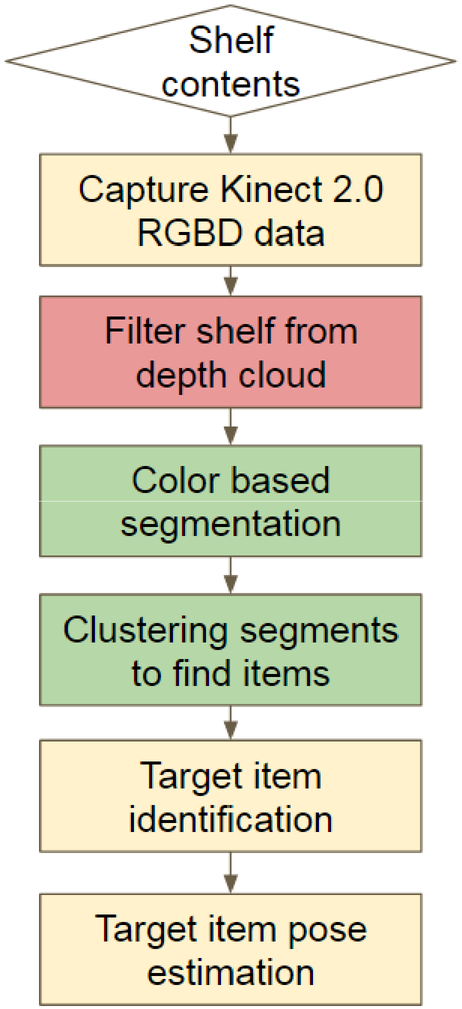
PR2 System Status

https://www.youtube.com/watch?v=2ZCQBrxa7nQ

Perception Subsystem

Perception Subsystem Description

- Capture kinect 2 image and pipe RGBD data to main computer
- Filter out shelf from image based on known world model
- Find items on shelf using segmentation and clustering
- Histogram feature matching to identify item and orientation



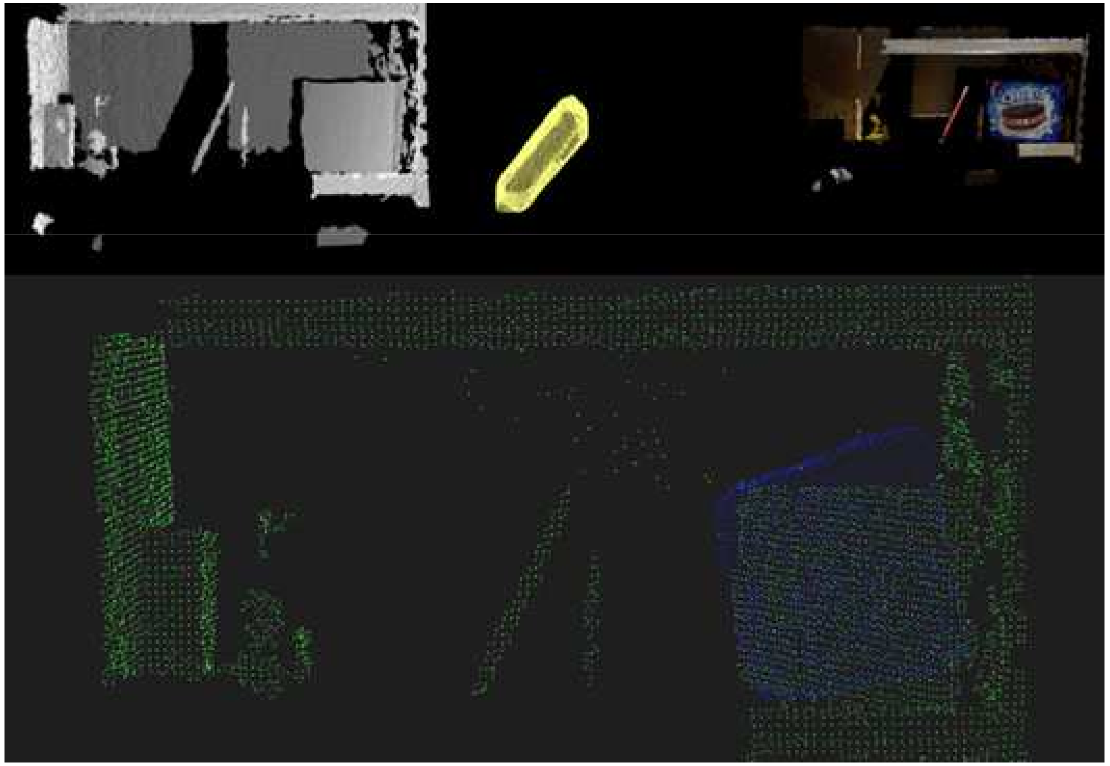
Perception System Status

Segmentation and Clustering

- Segmentation using RGB color and depth data
- Segments combined to identify item location assuming horizontal workspace
- Intensity of neighborhood points determine the segments of the same objects

Perception System Status

3D Feature Matching



- Calculate normal vectors of ground truth model
- Match SHOT features between ground truth and shelf scene
- Calculate transformation to fit model into scene

Gripping Subsystem

Suction System Description

Electronics

1. Relays power Vacuum pump
2. Allows for ROS control of System
3. Enables pressure feedback

Vacuum Pump

1. High-flow Low-pressure system to provide suction

Custom End-effector

1. Grasping block for PR2 gripper
2. Modified suction cup for improved performance
3. Pressure sensor mounting

Electronics

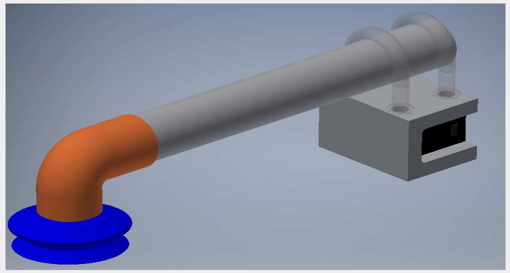
Pressure Sensor
MPX5700ASX-ND

ROS-connected Arduino
Micro

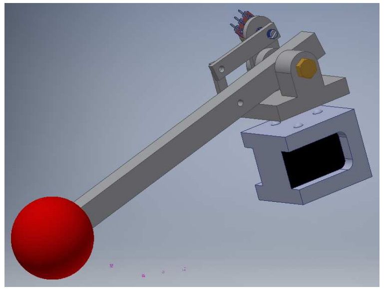
AC Power Relay
Crydom Series 1 D1240

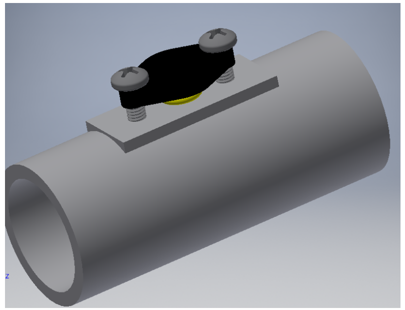
Vacuum Pump

Custom End-Effector



Suction System Status





Electronics

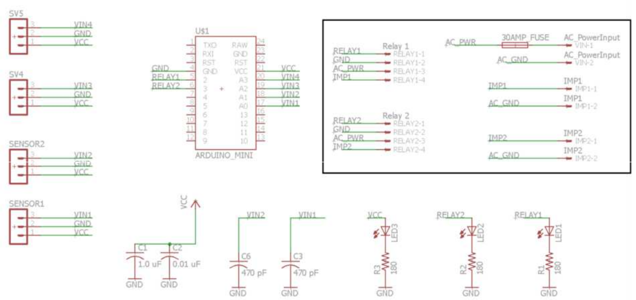
- Initial Circuit built and tested with pressure sensor and Arduino Uno
- Completed ROS node to take commands from computer and broadcasting pressure readings
- Designed control electronics circuit. Estimated completion 11/15/2015

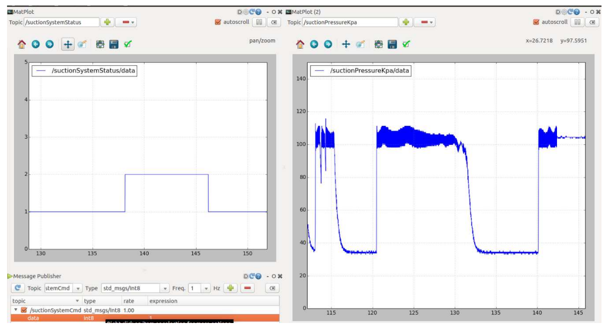
Vacuum Pump

- Prototyped systems using ShopVac, DC vacuum pump, and Bernoulli vacuum
- Sourcing impeller for 200 CFM and 400 kPa

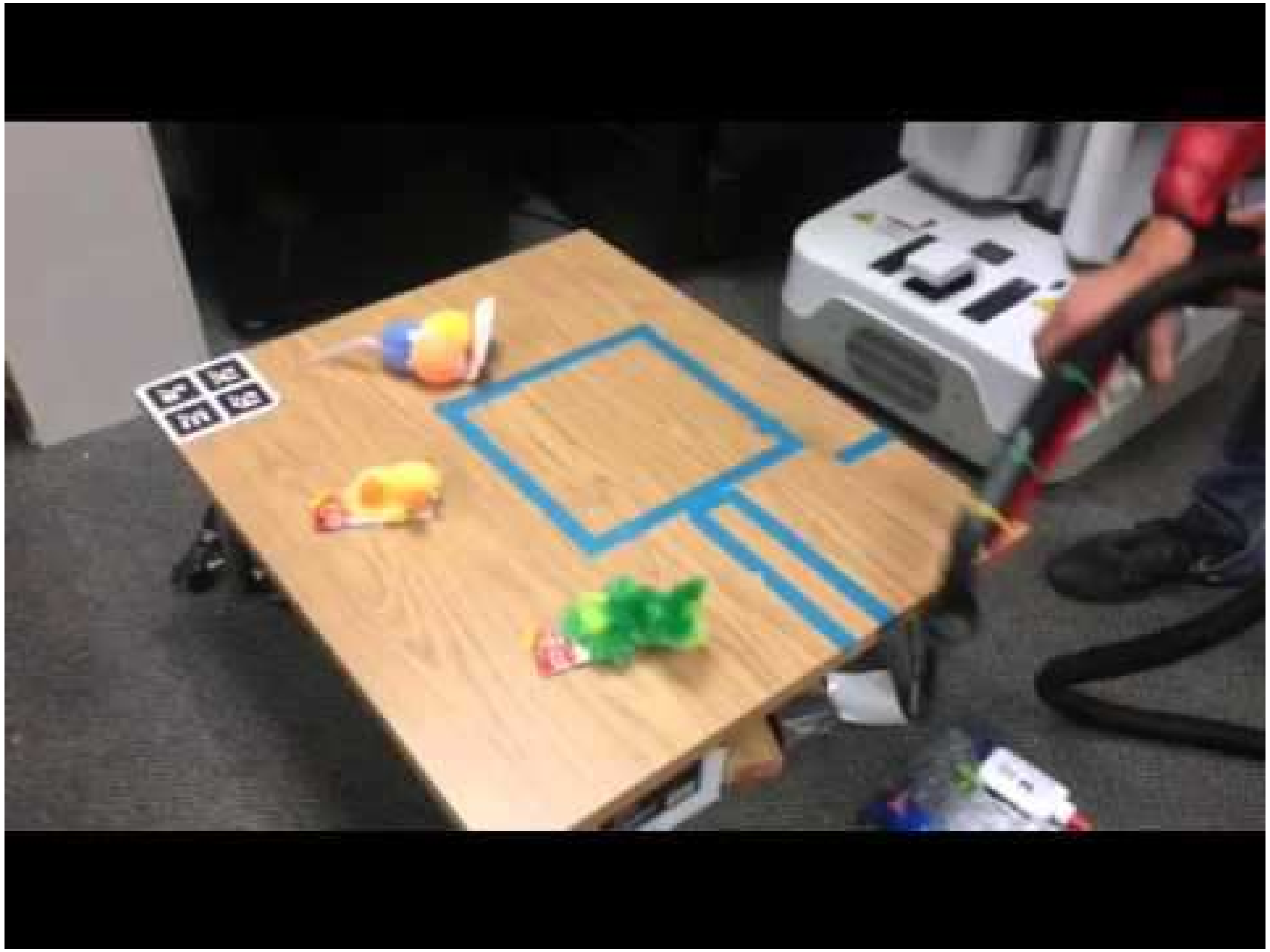
End Effector

- Designed several instances of final-intent end effector
- Designed durable end effector for testing





Suction System Status



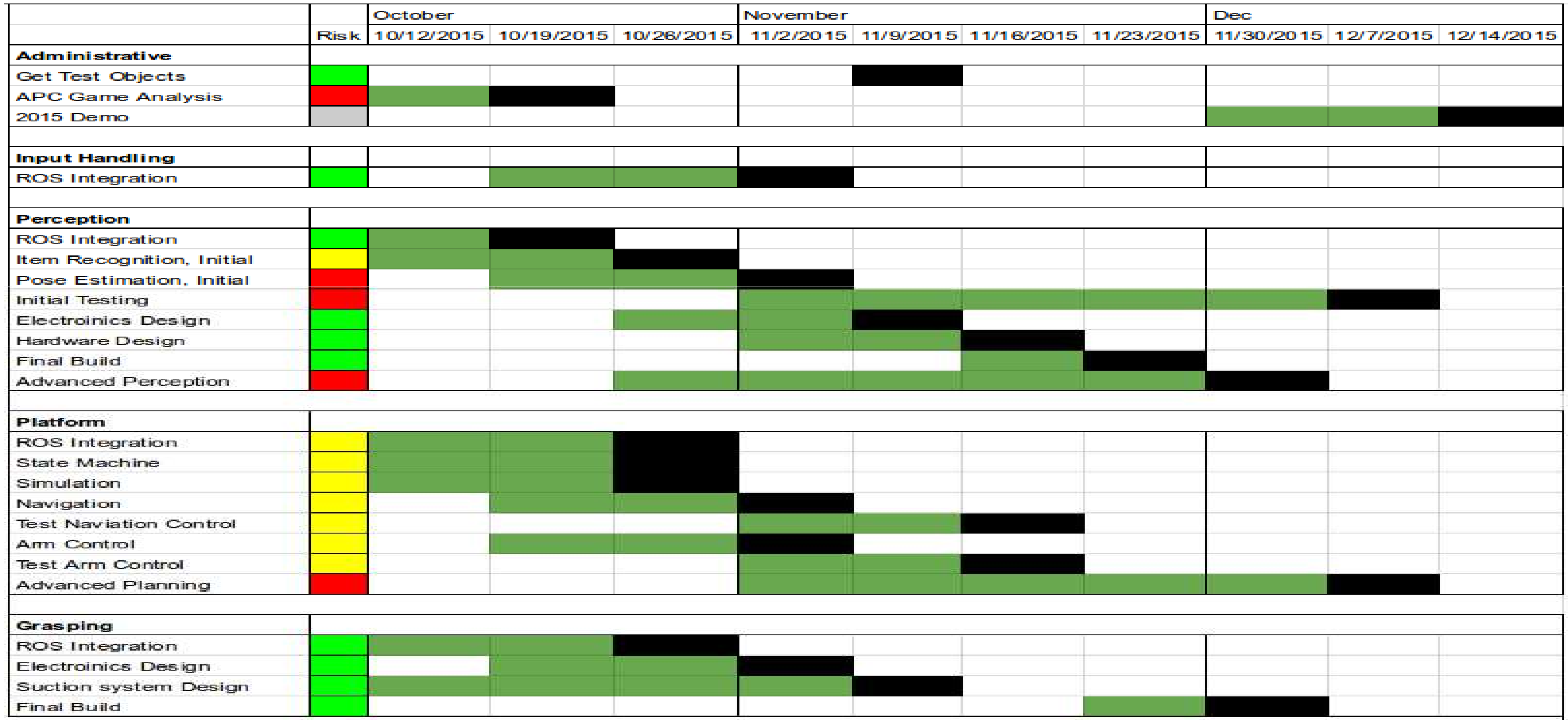
https://www.youtube.com/watch?v=acOdkD7zp_4

Project Management

Project management - WBS - 1

Prog	1st	2nd	Perception	Prog	1st	2nd	Platform	Prog	1st	2nd	Grasping	Legend
	Feroze	Alex	ROS Integration		Alex	Feroze	ROS Integration		Alex	Feroze	ROS Integration	In Progress
	Lekha	Rick	Item Recognition, Initial		Alex	Bhatia	State Machine		Feroze	Bhatia	Electroinics Design	Not Started
	Rick	Lekha	Pose Estimation, Initial		Feroze	Bhatia	Simulation		Rick	Alex	Suction system Design	Complete
	Lekha	Rick	Initial Testing		Bhatia	Feroze	Navigation		Rick	Feroze	Final Build	
	Rick	Lekha	Electroinics Design		Bhatia	Feroze	Test Naviation Control					
	Rick	Lekha	Hardware Design		Feroze	Bhatia	Arm Control					
	Rick	Lekha	Final Build		Feroze	Bhatia	Test Arm Control					
	Venkat	Lekha	Advanced Perception		Andrew	Bhatia	Advanced Planning					

Schedule



October
November
Dec
Risk
10/12/2015
10/19/2015
10/26/2015
11/2/2015
11/9/2015
11/16/2015
11/23/2015
11/30/2015
12/7/2015
12/14/2015
Administrative
Get Test Objects
APC Game Analysis
2015 Demo
Input Handling
ROS Integration
Perception
ROS Integration
Item Recognition, Initial
Pose Estimation, Initial
Initial Testing
Electroinics Design
Hardware Design
Final Build
Advanced Perception
Platform
ROS Integration
State Machine
Simulation
Navigation
Test Naviation Control
Arm Control
Test Arm Control
Advanced Planning
Grasping
ROS Integration
Electroinics Design
Suction system Design
Final Build

Fall Validation Experiments Test Plan

Experiment 1: Perception Experiment

1. Station kinect .5 meters from shelf
2. Place 1-3 items on the shelf, non occluding
3. Run perception through command line
4. Output 3D scene w/ bounding box around item of interest
5. Repeat 10 times, showing 70% success

Experiment 2: Gripper Experiment

1. Distribute all 25 items across a shelf
2. Randomly order items for pickup
3. Manually turn on vacuum
4. External operator holds PR2 gripping block and acquires item
5. Verify external LED changes color when seal is formed
6. Move gripper from shelf to bin
7. Manually turn off vacuum
8. Verify external LED changes color when seal is

Budget

Part	Supplier	Unit Price	Quantity	Total Cost
Perception Subsystem				
Kinect 2.0	Microsoft	$140	1	$140
Computer	Newegg	$800	1	$800
Platform Subsystem				
PR2	Sponsor	$0		$0
Grasping Subsystem				
Suction Cups	Piab	$75	1	$75
Tubing	McMaster	$50	1	$50
Arduino Mini	Amazon	$20	2	$40
Pressure Sensor	DigiKey	$25	2	$50
40 Amp AC Relay	DigiKey	$30	2	$60
3D Printing	MechE Shop	$200	1	$200
Potentiometer	DigiKey	$5	1	$5
Vacuum Impeller	TBD	$80	2	$160
Misc				
Testing Items	Amazon	$100	1	$100
Kiva Shelf	APC	$0	1	$0
		Total Build Cost		$1,680

Risk Management

Risk ID	Risk	Description	Type	Cause	Consequence	Mitigation Plans
1	System Integration	Integrating each sub-system in ROS framework	Technical	Technical difficulty and beyond personnel skill	Failing to meet validation experiment /Project objectives	•Continuous validation of subsystems •Implementing a modular software architecture
2	Amendment in rules	Change in APC rules that might deviate from project goals/description	Programmatic	Unavailability of rules	Project scope becomes infeasible given time constraint.	•Working on subsystems that are unlikely to change •Buffer time to add features
3	Not competitive enough	Not being challenging enough to represent CMU at APC	Programmatic	Failing to meet deliverables	Unable to participate in APC	Working towards weekly deliverables under the guidance of sponsor Maxim and Technical advisor
4	Procuring	Supply of hardware at	Programmatic	Failure to provide	Unable to participate in APC	In constant touch with

RISK CONSEQUENCE CHART