Collaborative Cyborg Backpack Platform (CoBorg)

System Development Review

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THE ROBOTICS INSTITUTE

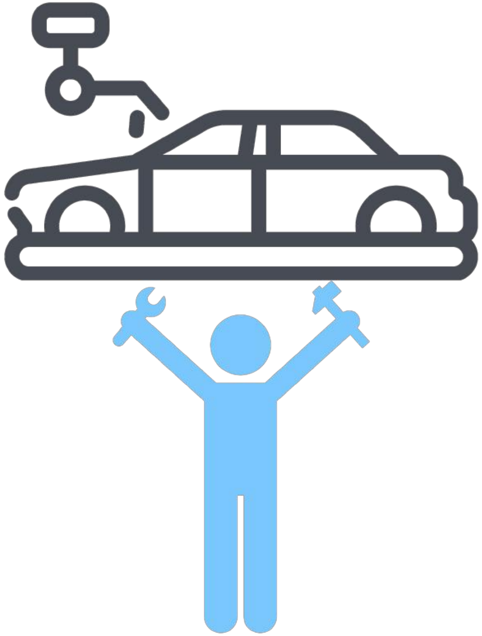
Carnegie Mellon University

Project Description

Project Description

Productivity
Safety

Injuries
Low Impact Roles



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Project Description - Use Case

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Project Description - Fall 2021

Requirements Modifications

Requirements Modifications - Task Space

NEW

- FM7 - Shall successfully reach points within a good working range
  - PM7.1 - Radius: 1.5 to 3 feet
  - PM7.2 - Horizontal Angle: -10 to 10 degrees
  - PM7.3 - Vertical Angle: Parallel to ground, up to 10 degrees before vertical

- FM8 - Shall account for user's hands, error, and movement when achieving "good working range" (Stability)
  - PM8.1 - Mechanical capability even if user moves 6" in any direction and/or rotates 90 degrees to the left or 20 degrees to the right

- FM8 - Shall account for user's hands, error, and movement when achieving "good working range" (Vision)
  - PM8.2 - Detect user's hands, even if they are 17 degrees outside the task space horizontally, and 10 degrees outside vertically
  - PM8.3 - Will detect user's hands only if the backs are facing the cameras (no under-handed grips)

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Requirements Modifications - Obstacle Avoidance

NEW

- Object Detection:
  - F.M.9 - Shall detect obstacles within task space.
    - *P.M.9.1 - Will detect obstacles within 1m of depth camera mount.*
    - *P.M.9.2 - Will generate voxels on obstacle surfaces with <1.25" between the voxels.*

- Arm Avoidance:
  - F.M.10 - Shall avoid the user's arm during actuation.
    - *P.M.10.1 - Will not collide with the stationary user's arm during actuation 90% of the time.*

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Current System Status

Overall System

Input:

Sensing data

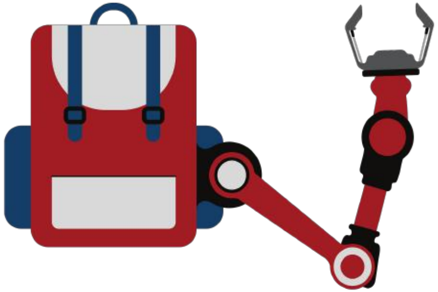
(voice, depth camera, tracking camera)

Coborg System

Sensing, Vision, Voice, Motion Planning, Actuated Manipulation

Output:

Stabilizing part / Compact mode



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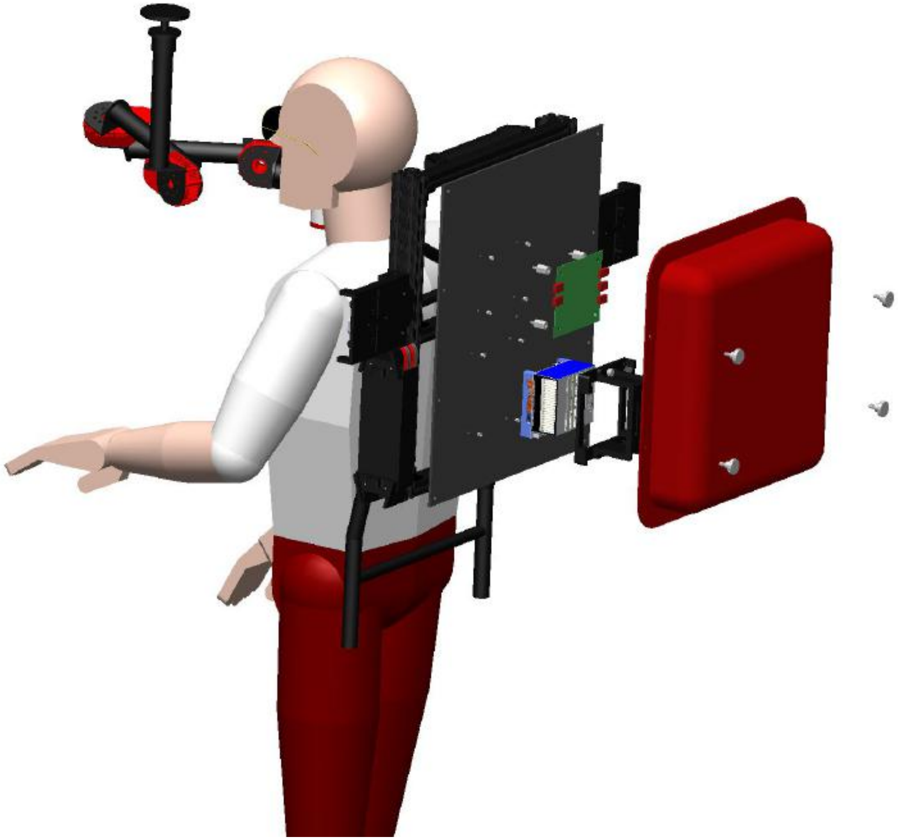
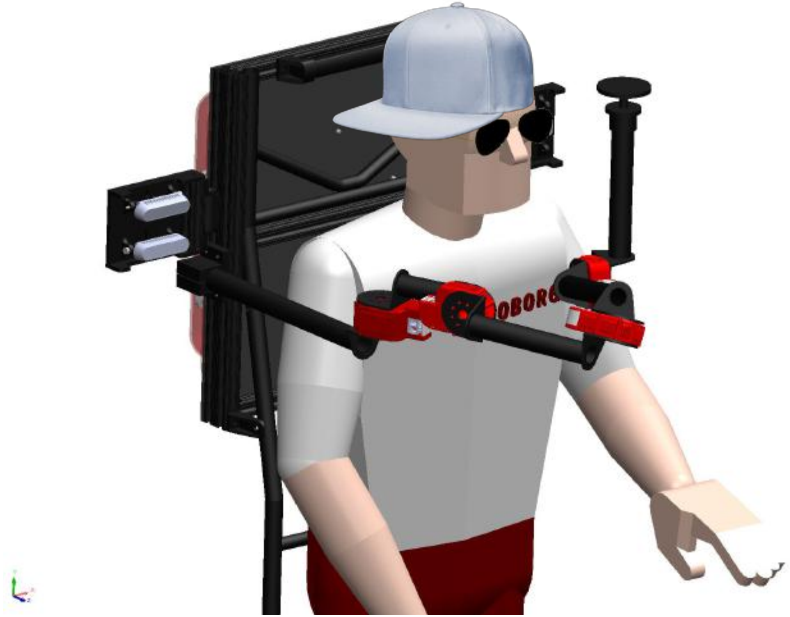
Current System Status - Hardware (Aesthetic)

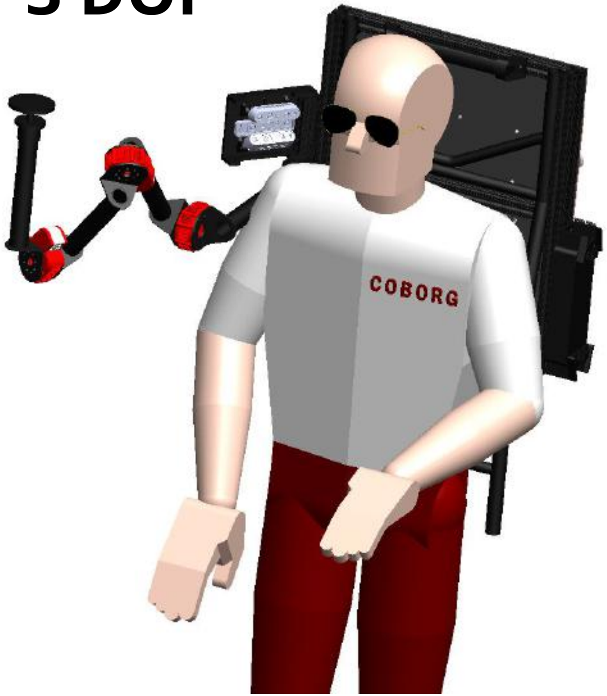




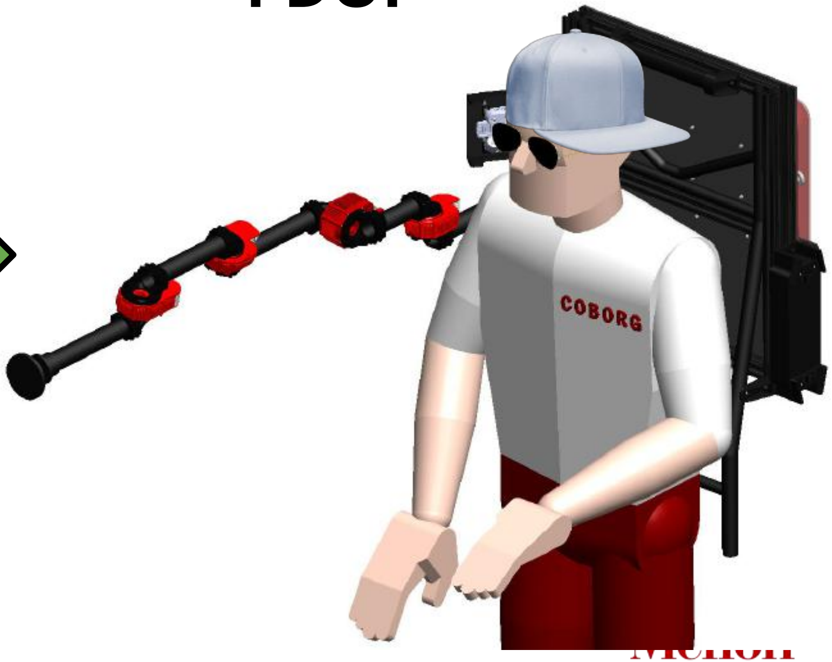
Black Anodize Orders	In Addition to the Processing Days Shown Above			
• Parts only • Cut to length profiles less than or equal to 60" • Mill-finish shapes less than or equal to 60"	10-12			

Current System Status - Hardware (Functional)

3 DOF

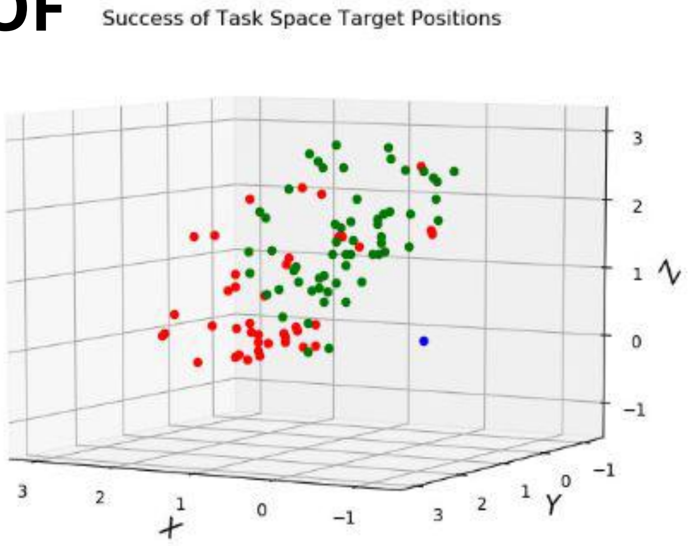


4 DOF

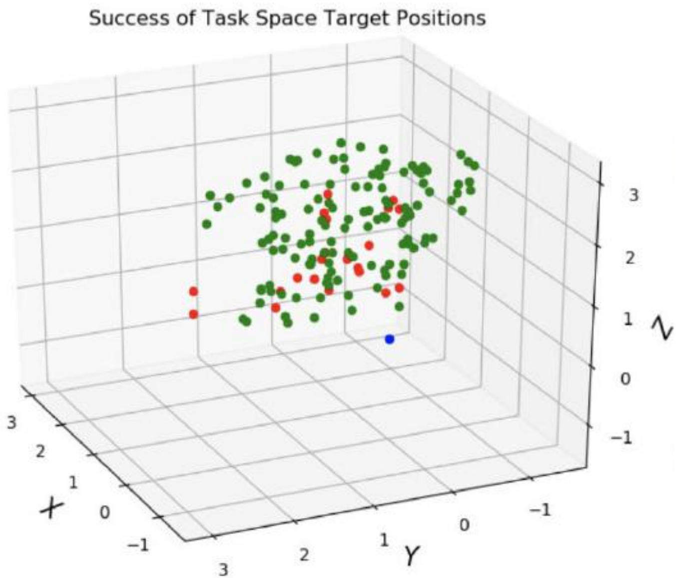


Current System Status - Hardware (Functional)

3 DOF



4 DOF




```
('Task space success ratio: ', 0.59)
('Extended Task space success ratio: ', 0.37)
('Buffer space success ratio: ', 0.44)
('Stability task space success ratio: ', 0.4)
('Stability buffer space success ratio: ', 0.47619047619
```

```
('Task space success ratio: ', 0.86)
('Extended Task space success ratio: ', 0.76666666666
('Buffer space success ratio: ', 0.7882882882882883)
('Stability task space success ratio: ', 0.74920634920
('Stability buffer space success ratio: ', 0.98550724
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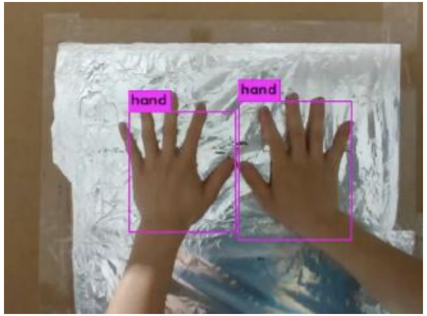
Subsystem - Perception (Vision)

Hand Detection

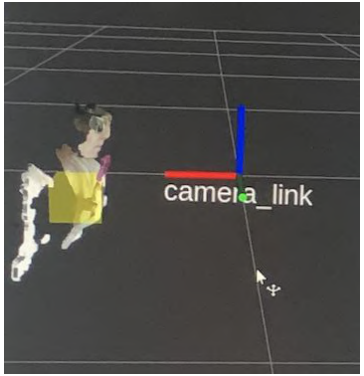


Input: **Raw RGB image + point cloud**

Output: **3D target part position + surface normal**

Process:

- 2D YOLO v3 hand detection to extract 2D bounding box
- 3D hand bounding boxes using point cloud data
- Post-process to get averaged 3D position of hands (Deprecated)
- Post-process to get surface normal of averaged target position
- Post-process 3D position and surface vectors from two cameras (In progress)



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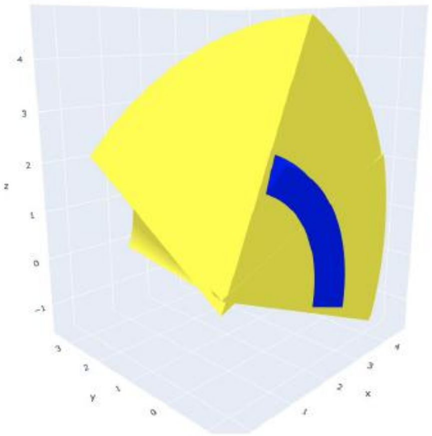
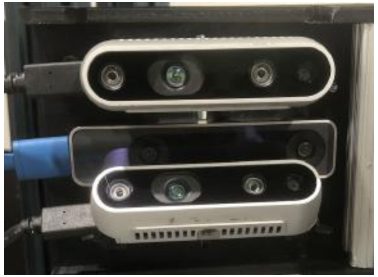
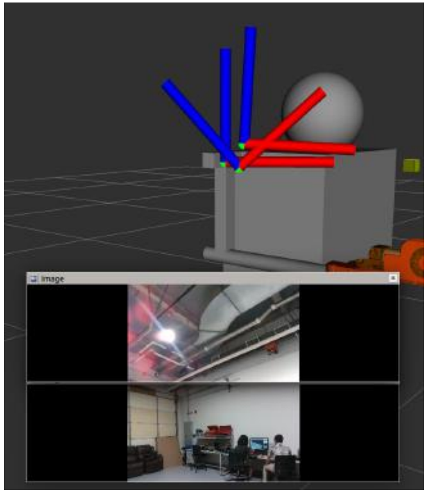
Current System Status - Vision

- Current stage:
  - Current level of functionality
    - *Performance validated (SVD): YOLO v3*
    - *Upgraded sensor system : 2 cameras*
    - *Integrating into main state machine*
  - Modeling
    - *Simulation of task space*
    - *Frame stitching*
    - *Frame transform*
  - Challenges
    - *Processing power, edge cases*







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Subsystem - Perception (Obstacle Avoidance)

Input: Point cloud

- D435i cameras will output the point clouds

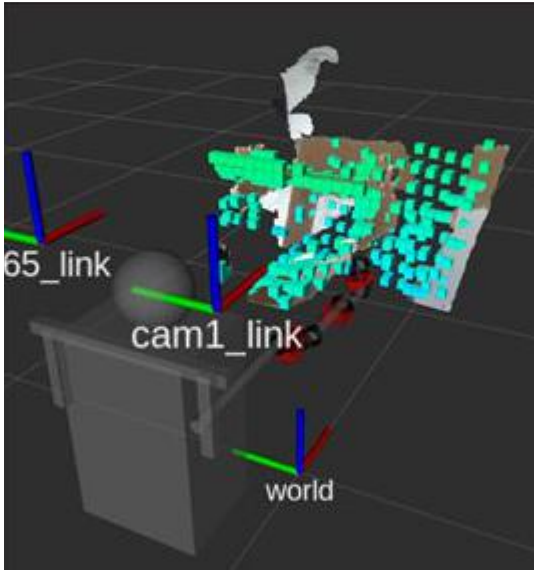
Output: 3D Obstacle Voxels

- Using Octomap integrated with Move-it

Process:

- Scan point cloud for obstacles within range
- Generate voxels over obstacles (user's arm)
- Plan path around detected obstacle

Obstacle Detection



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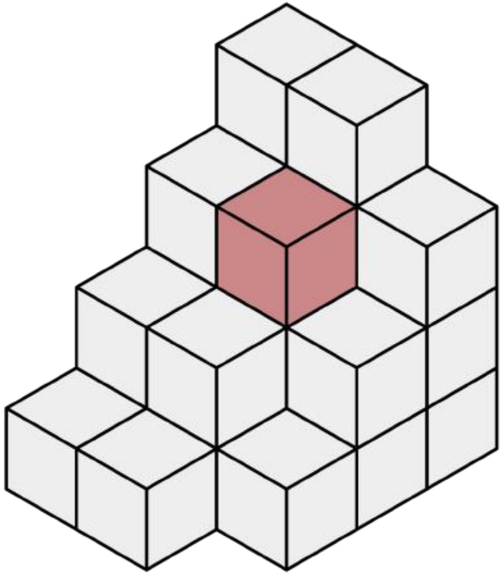
Current System Status - Obstacle Avoidance

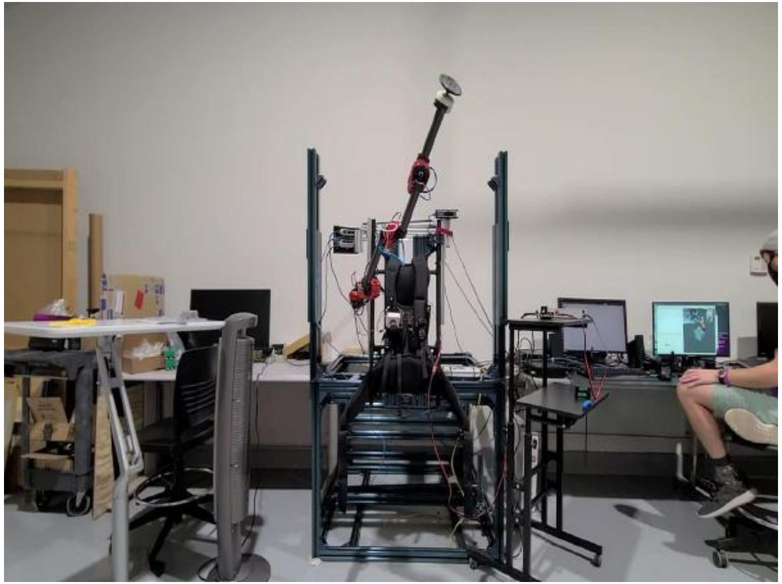
- Current stage of development
  - Current level of functionality
    - *Generates voxels around obstacles within 1m*
    - *Avoids user's arm based on detected obstacles*
  - Modeling & results of completed tests
    - *Voxels generate in RViz*
    - *Demo shown in next slide*
  - Challenges faced
    - *Trade off between detection & efficiency (FPS)*

- Major remaining challenges
  - Obstacle projection outside of vision space (desired)
  - Validation of system



Voxels

Current System Status - Obstacle Avoidance



Subsystem - Actuated Manipulation

Input: 3D goal points + obstacle mapping + frame transforms

- Vision subsystem outputs 3D position of hands
- D435i outputs depth point cloud converted to obstacles
- TF frame transforms between cameras and robot model frames

Output: Robot actuates to goal states

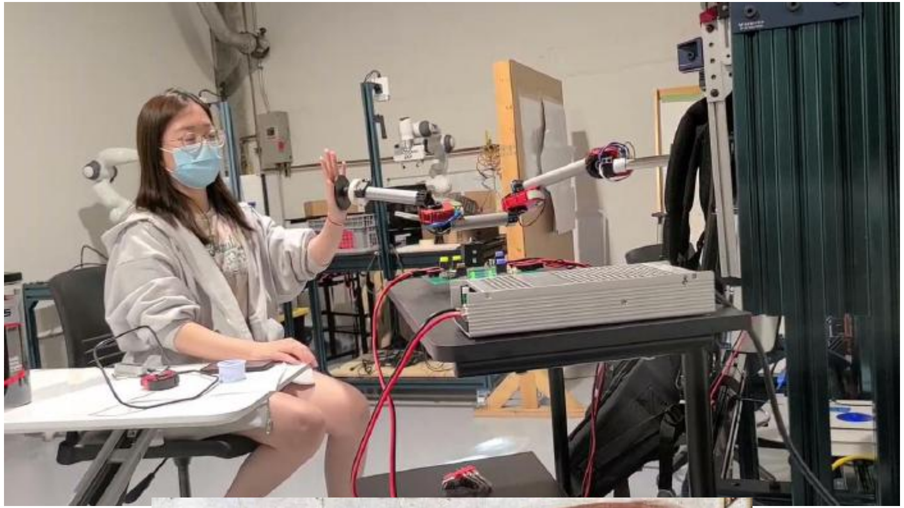
Process:

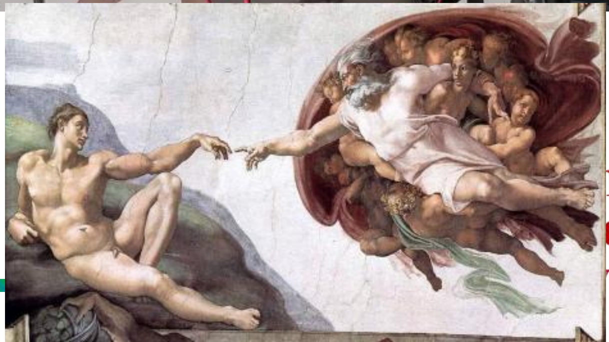
1. Process 3D goal position relative to cameras
2. Plan path from current state to goal state
3. Execute path
4. Execute motion compensation
5. Calculate temporal transform in t265_odom_frame
6. Stabilize relative to updated 3D goal
7. Release control & “go home”

Current Status, Challenges

Current System Status - Actuated Manipulation

- Resolved Rate
  - Motion compensation + stabilization control
  - Position based cartesian controller
  - Advantages: smooth trajectory control and transition





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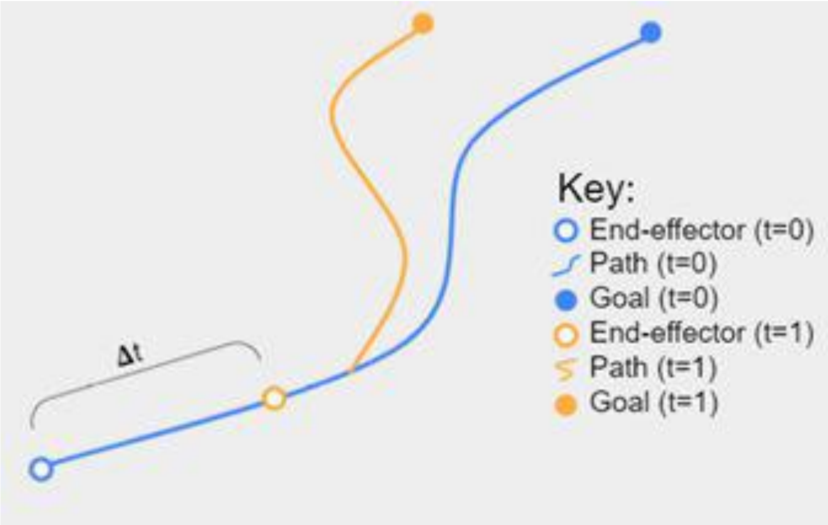
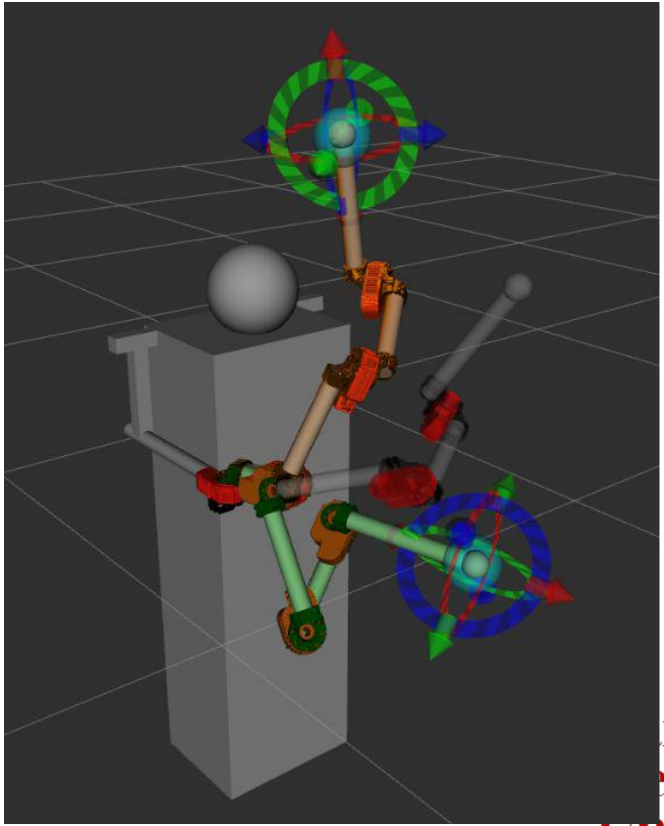
Current System Status - Actuated Manipulation





Project Management

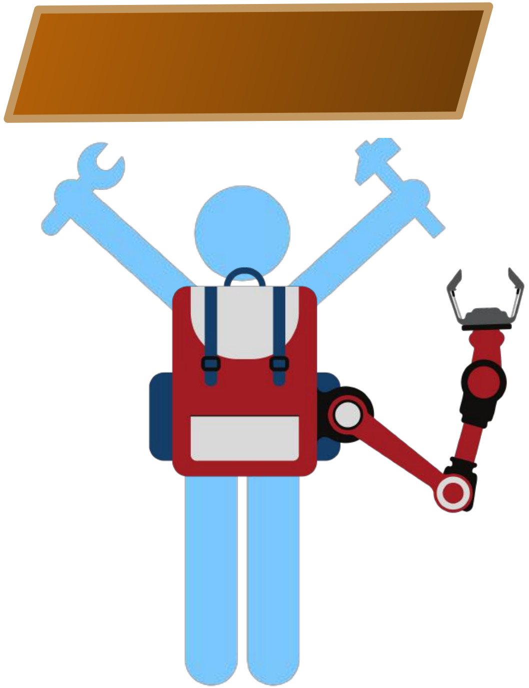
PM - Progress Reviews

Milestone	**Description**
PR 10: October 27	• Integrate hardware 2.0 • Initial use case demo • Arm stabilization demonstrated
PR 11: November 10	• FVD dry run

PM - FVD Test Plan

Location: NSH B512

Goal	Plan
Demonstrate system capability, simplicity, reliability, and time capability	Use the Coborg to attach a panel to the testing structure (by screws) and remove it.
Demonstrate that system can compare to human operator(s)	Demonstrate one and two humans attaching the same panel. Time for comparison to Coborg.
Demonstrate stability and task space capability	Use the Coborg in a handful of repeated use cases while forcing it to stabilize in different areas of the task space
Demonstrate battery life	Check remaining power after total usage, extrapolate to time limits
Demonstrate comfort	Assess user comfort after prolonged, continuous usage



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PM - Projected Fall Expenditures

No.	Part Name	Cost
1	Fiberglass Shell Assembly	$400.00
2	Laser Cut Acrylic Base	$200.00
3	Carbon Fiber Tubing	$125.00
4	Electrical Components	$300.00
5	T-Slotted Aluminium Assembly	$500.00
Total Costs		**-$1525.00**
Budget Remaining		**+$1766.21**

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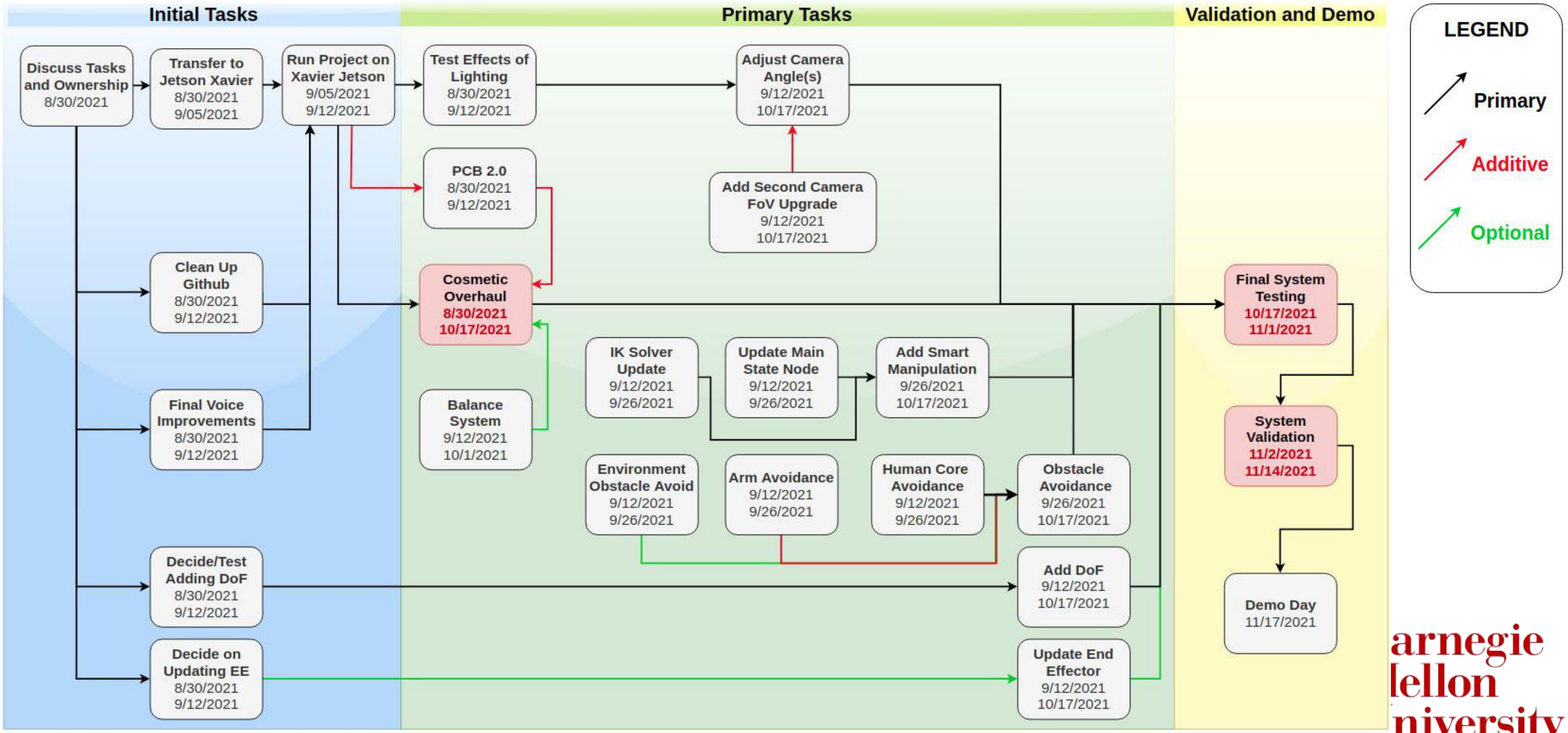
PM - Current Budget

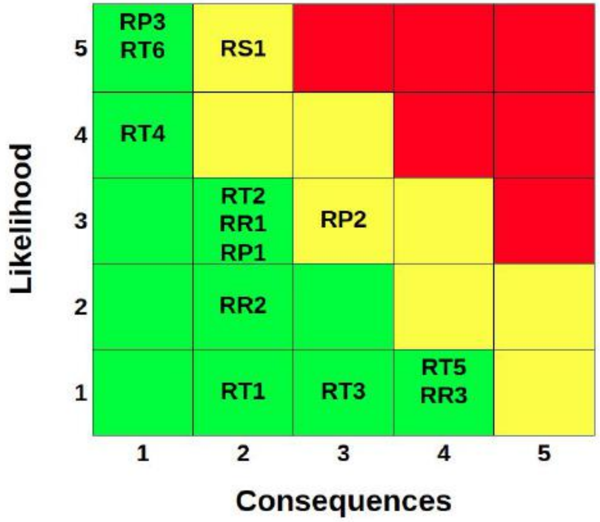
No.	Part Name	Cost
1	Voice Subsystem Parts	$34.98
2	Robot Hardware	$119.71
3	Supplementary Items	$501.61
4	Intel Realsense T265	$199.99
5	Computer Parts	$152.46
6	Nvidia Jetson Xavier AGX	$699.99
7	Hardware V2.0 Upgrade	$1967.13
Total Costs		**-$3675.87**
Budget Remaining		**+$1324.13**

Fall Schedule V3



PM - Risk

Risks	Title
'T' = Technical, 'R' = Resource, 'P' = Programmatic, 'S' = Schedule	
RT1	Hebi motor module dies
RT2	Main computer dies or does not perform per our requirements
RT3	Estop devices malfunction
RT4	TCP/IP connectivity is lost
RT5	Salus Robot disinfects CoBorg with a generous coat of liquid
~~RR1~~	~~Team lacks ROS fundamentals by start of spring semester~~
RR2	Unable to work 10hrs/week/member on MRSD project
RR3	Hazard occurs on user while wearing robot
~~RP1~~	~~Member contracts COVID-19~~
~~RP2~~	~~MRSD program gets disrupted due to COVID-19 pandemic~~
~~RP3~~	~~Our sponsor graduates in the spring of 2020~~
RP4	End Effector Breaks
RS1	**Hardware components do not arrive on time (2+ week delay)**



Level	Likelihood	Consequences
5	100%	1 Month/$2,000/Injury
4	80%	2 Weeks/$1,000
3	60%	1 Week/$500/Loss of function
2	40%	3 Days/$200
1	20%	1 Day/$50

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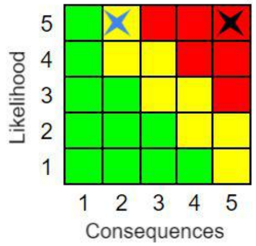
SCHEDULE RISK

Risk Title:	Risk Owner:	Date Submitted:	Date Updated:
Hardware components do not arrive on time (2+ week delay)	Husam Wadi	9/13/2021	10/14/2021

Description of Risk:	Risk Type?		Consequence	Likelihood
Critical components do not arrive when expected. This causes massive bottlenecks in integration and testing in the weeks leading to FVD.	☐	Technical	5	5
	☑	Schedule	**Mitigated Consequence**	**Mitigated Likelihood**
	☑	Cost		
Consequence if Risk is Realized:	☐	Programmatic	2	5
We will have to demo the Coborg as is, or with parts scavanged from MRSD inventory.				

Risk Reduction Plan Summary:

Action/Milestone	Date	Success Criteria	Consequence Reduction	Likelihood Reduction	
Reach out to parts manufacturer and request accelerated production	10/2/2021	Manufacturer agrees to remove long lead time component	3		☑
Order duplicate components from McMasterCarr	10/18/2021	Parts arrive overnight and are used instead	1		☐
					☐
					☐
					☐



Questions?