engineering laboratory

NIST National Institute of Standards and Technology • U.S. Department of Commerce

Inter-System Communication for Multi-Robot Control

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SALISBURY UNIVERSITY
FOUNDED 1925
Maryland

NIST National Institute of Standards and Technology • U.S. Department of Commerce

NIST SURF Program

National Institute of Standards and Technology

- A non-regulatory federal agency within the Department of Commerce
- Founded in 1901

Summer Undergraduate Research Fellowship

- Engineering Laboratory
- Intelligent Systems Division

Context

- *Laboratory Goal: Develop simple, accurate, and cost effective test methods for Mobile Manipulators*

- AGVs and robots arms from different manufacturers currently lack mechanisms for collaboration.

- Performance tests consist of multiple cases regarding AGV and robot arm coordination. [1]

- Mobile Manipulators currently lack standardized test methods.

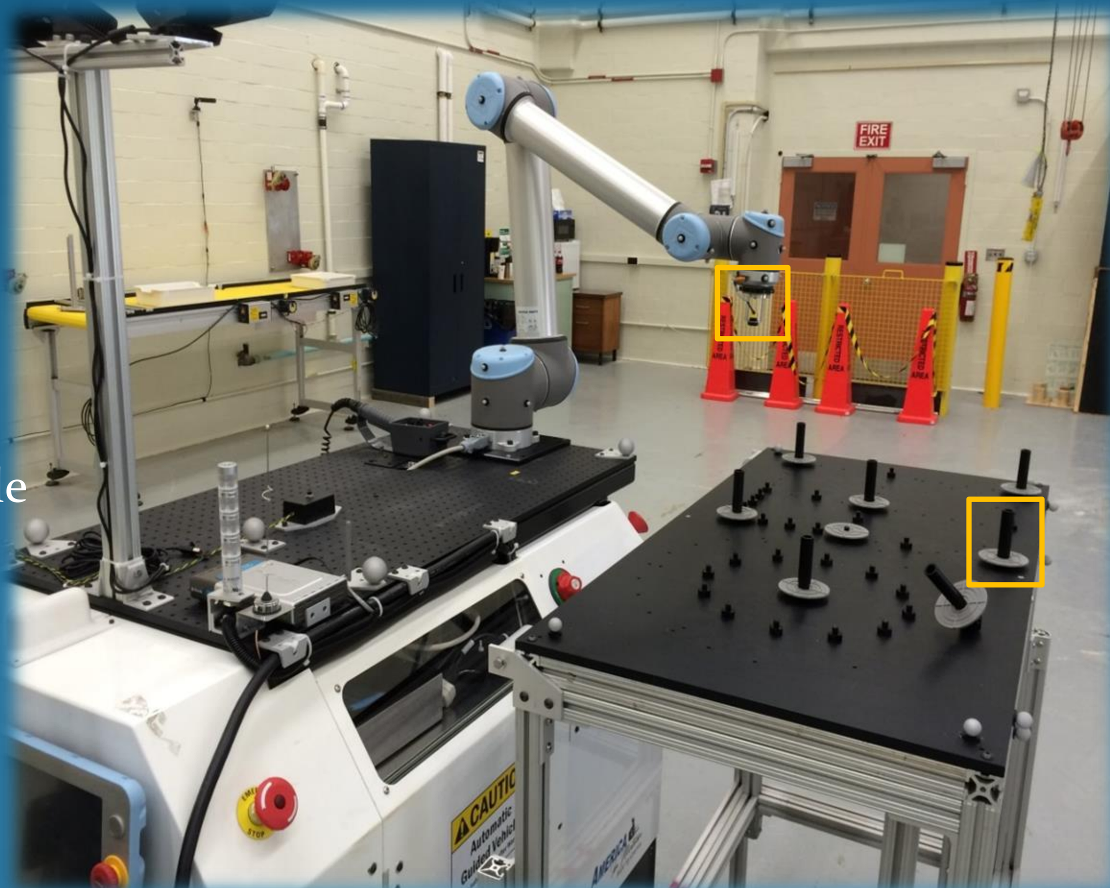
  - Development of test methods would typically use costly and complex ground truth systems.

- **Project Goal: Develop AGV and robot arm communications to allow NIST to develop standardized test methods for Mobile Manipulators.**

[1]Bostelman, R., Hong, T., Marvel, J. (n.d.). *Performance measurement of mobile manipulators*.

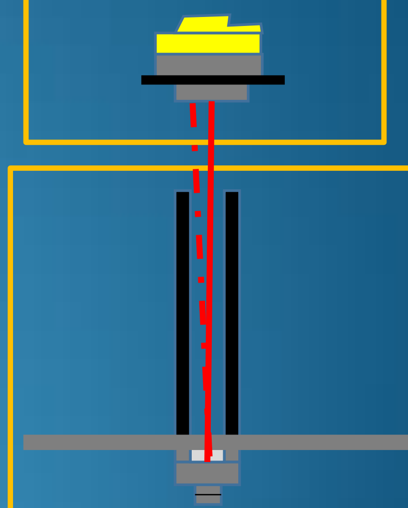
Universal Robot Arm (UR10)

Automated Guided Vehicle (AGV)



Reconfigurable Mobile Manipulator Artifact (RMMA)

Retroreflective Laser Emitter & Sensor

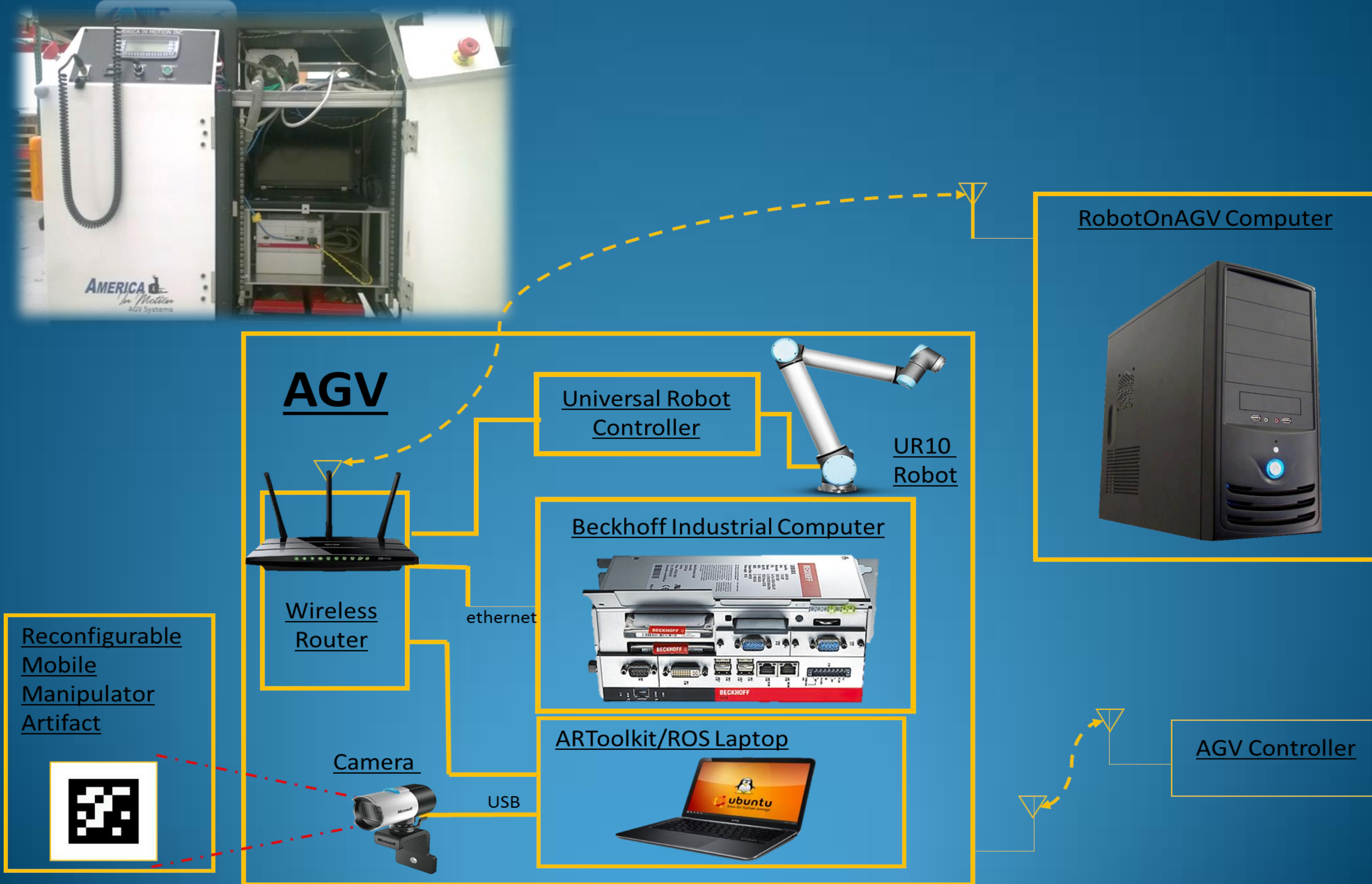


Reflector Target

Project Tasks

Industrial PC and ARToolkit Camera Sensor Integration

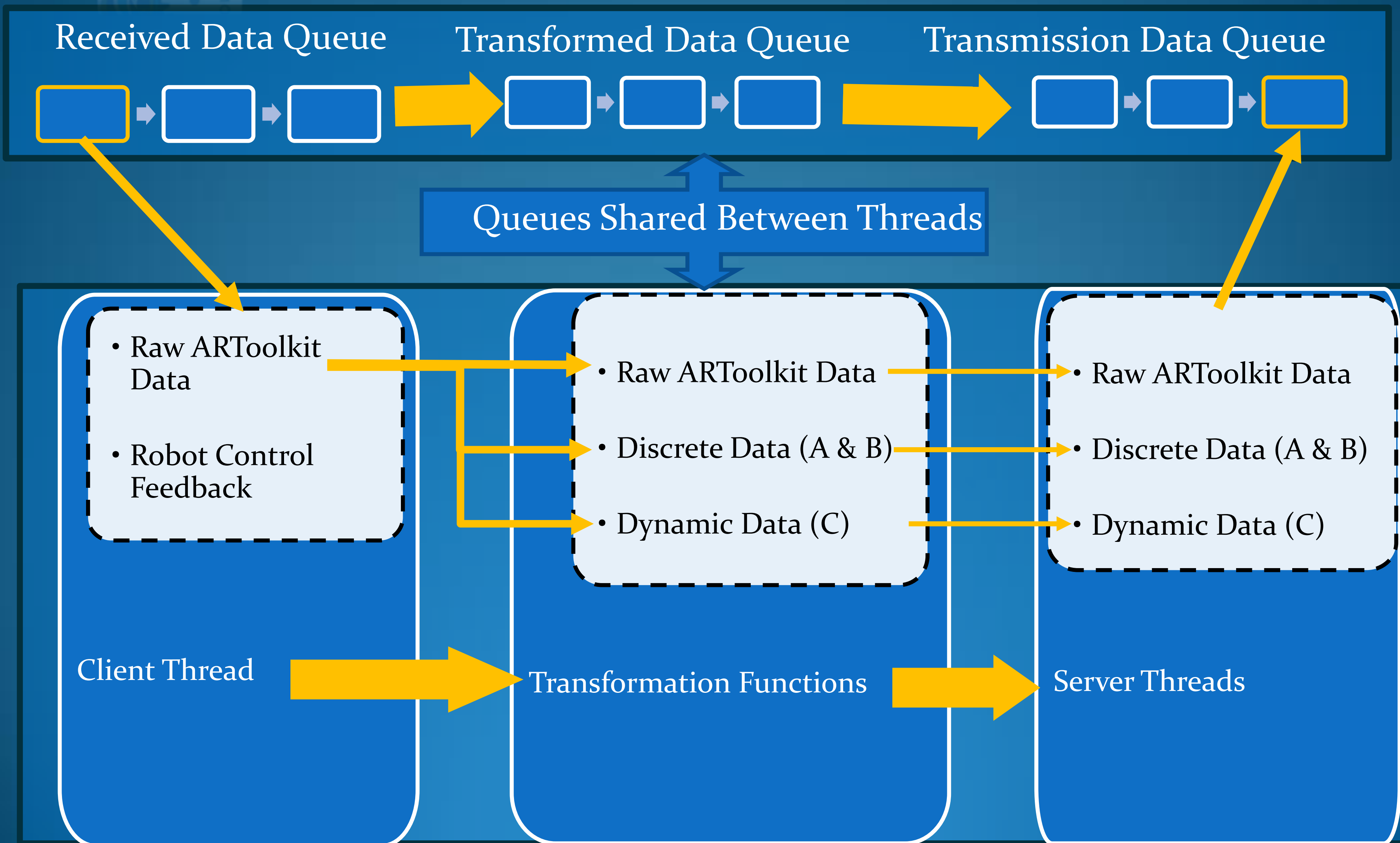
1. **Integration and Calibration of ARToolkit Camera System**
2. **Development of "Mobile Manipulator Communications Manager" Software**
3. **Implementation of Static Cases**
4. **Development of Orientation Conversion for Dynamic Case**



AGV
Universal Robot Controller
UR10 Robot
Beckhoff Industrial Computer
Wireless Router
ethernet
ARToolkit/ROS Laptop
Camera
USB
RobotOnAGV Computer
AGV Controller
Reconfigurable Mobile Manipulator Artifact

Successes

- **Computer Science Education at Salisbury University enabled:**
  - Rapid understanding and utilization of algorithms and data structures.
  - Excellence in code conventions and documentation
  - Ability to interpret pre-written software packages
  - Ability to analyze learning resources for quick comprehension of new topics.


Received Data Queue
Transformed Data Queue
Transmission Data Queue
Queues Shared Between Threads
• Raw ARToolkit Data
• Robot Control Feedback
Client Thread
• Raw ARToolkit Data
• Discrete Data (A & B)
• Dynamic Data (C)
Transformation Functions
• Raw ARToolkit Data
• Discrete Data (A & B)
• Dynamic Data (C)
Server Threads

Video: Static Case (A)

C:\Windows\system32\cmd.exe

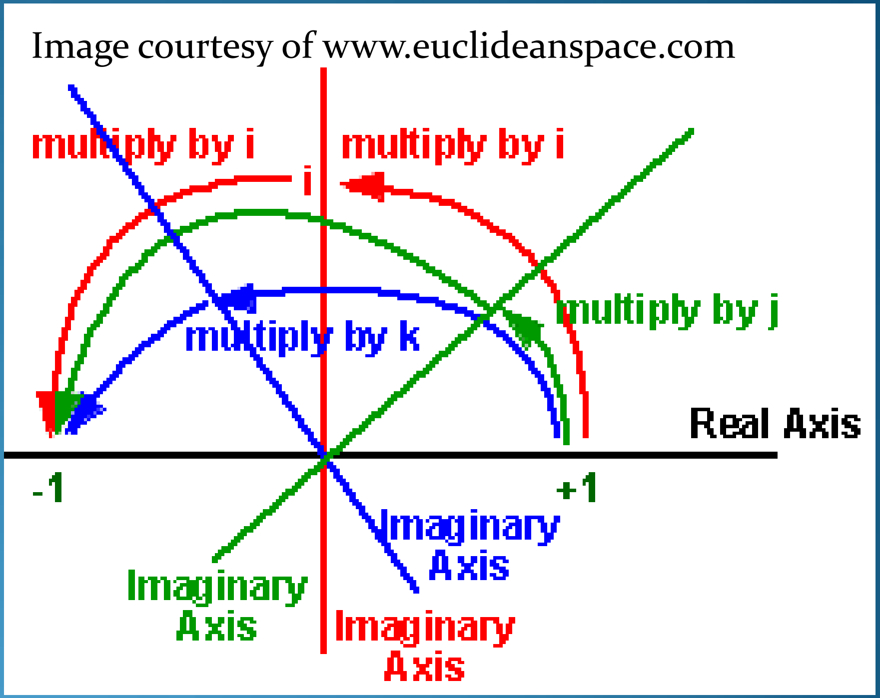
```
------------------------------------------------------------------
Time Stopped: 4.652465 AGV Velocity: 0.008583
------------------------------------------------------------------
Recieved
Timestamp: 1438192893.150789 ID: 1
Time Stopped: 4.753854AGV Velocity: 0.018118
Pattern 1: SQUARE Marker Roll 0: 0 DEGREES Start: 0
ROS Angle: 0.219664 ROS Z Pos: 1.286479

------------------------------------------------------------------
Time Stopped: 4.753854 AGV Velocity: 0.018118
------------------------------------------------------------------
Recieved
Timestamp: 1438192893.356153 ID: 1
Time Stopped: 4.857764AGV Velocity: 0.010961
Pattern 1: SQUARE Marker Roll 0: 0 DEGREES Start: 0
ROS Angle: 0.183710 ROS Z Pos: 1.287947

------------------------------------------------------------------
Time Stopped: 4.857764 AGV Velocity: 0.010961
------------------------------------------------------------------
Recieved
Timestamp: 1438192893.558316 ID: 1
Time Stopped: 4.966506AGV Velocity: 0.003559
Pattern 1: SQUARE Marker Roll 0: 0 DEGREES Start: 0
ROS Angle: 0.195026 ROS Z Pos: 1.286534

------------------------------------------------------------------
Time Stopped: 4.966506 AGV Velocity: 0.003559
------------------------------------------------------------------
Recieved
Timestamp: 1438192893.758239 ID: 1
Time Stopped: 5.072931AGV Velocity: 0.000911
Pattern 1: SQUARE Marker Roll 0: 0 DEGREES Start: 1
ROS Angle: 0.145498 ROS Z Pos: 1.287531

------------------------------------------------------------------
Time Stopped: 5.072931 AGV Velocity: 0.000911
------------------------------------------------------------------
Recieved
Timestamp: 1438192893.954671 ID: 1
Time Stopped: 5.172973AGV Velocity: 0.006897
Pattern 1: SQUARE Marker Roll 0: 0 DEGREES Start: 1
ROS Angle: 0.252092 ROS Z Pos: 1.287360
```

Challenges

- Dynamic nature of research
  - Required ability to shift focus
  - Analyze the practicality of pursuing certain challenges.
- Learning about Quaternions and 3D rotations
  - New abstract concept
  - Required extensive self-study and assistance from mentors.
- Learning experimental procedure for calibration tests
  - Design performance experiements to suit needed analysis.

Scenario C: Dynamic Case

Quaternion Conversion



- ARToolkit computes the marker orientation in the quaternion number system.

- Quaternion number system consists of
  - Imaginary components i, j, k
  - A real component w.
  - Quaternion representations of angles avoid computational problems such as gimbal lock.

- The Robot arm controller uses Euler angles (roll, pitch, yaw) to understand the arm's orientation.

Acknowledgements

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  - Justin Goh
  - Robert Walsh

Thank You for Listening!

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Sources Cited

[1]Bostelman, R., Hong, T., Marvel, J., & Foufou, S. (n.d.). *Performance measurement of mobile manipulators*.

[2] About ROS. (n.d.). Retrieved from ROS website: http://www.ros.org/about-ros/

[3] ARToolkit. (n.d.). Retrieved from http://www.hitl.washington.edu/artoolkit/

[4] Baker, M. (n.d.). Maths - Quaternions. Retrieved from Euclidean Space website: http://www.euclideanspace.com/maths/algebra/realNormedAlgebra