engineering laboratory

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

Augmented Reality Marker Tracking for Multi-Robot Registration

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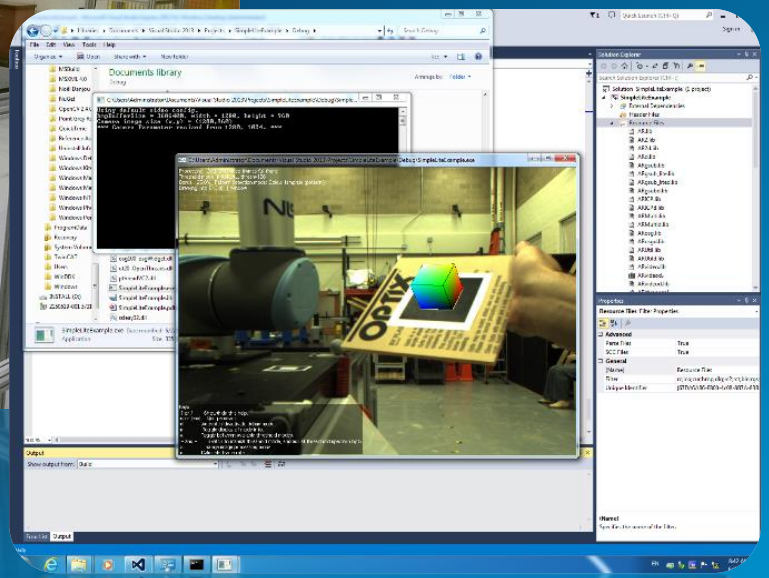

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NIST SURF Program

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

Project Outline

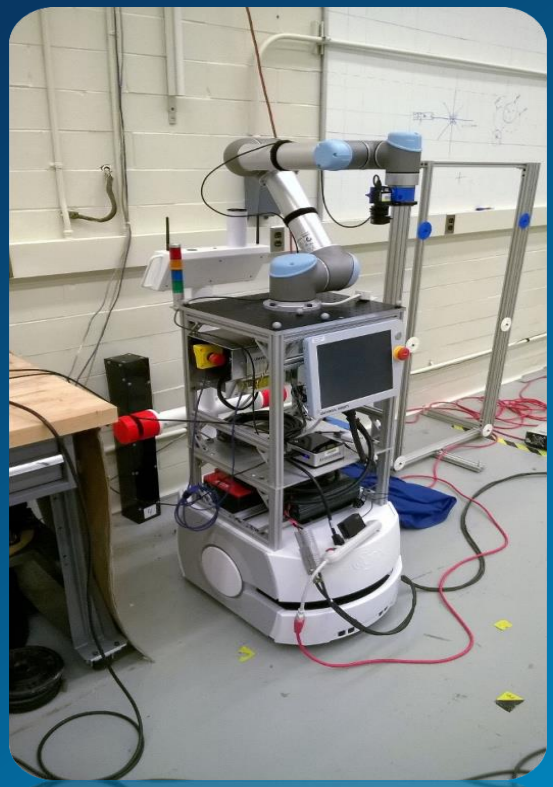
Project Objective: ARToolkit SDK Integration and Calibration

1. Introduction to Mobile Manipulator Testing
2. AR Marker Registration Method Overview
3. ARToolkit Software Architecture
4. ARToolkit Pose Server Software Development
5. Camera Tracking Calibration and Testing
6. Conclusion: Advanced Mobile Manipulator Registration

Introduction to Mobile Manipulator Testing

- ASTM Standards Committee F45 on driverless automatic guided vehicles (AGVs)

- <u>Elements of Standard</u>
  - Terminology
  - Performance standards
  - ***Test Methods***



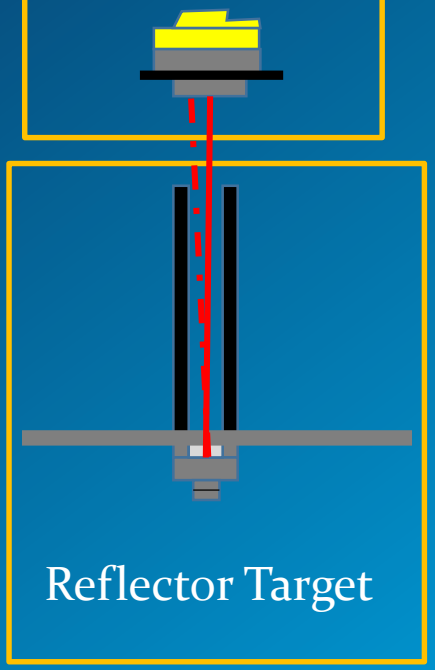
- Objective: Develop simple, accurate, and cost effective test methods for Mobile Manipulators

Introduction to Mobile Manipulator Testing

Universal Robot Arm (UR10)

Automatic Guided Vehicle (AGV)

Retroreflective Laser Emitter & Sensor

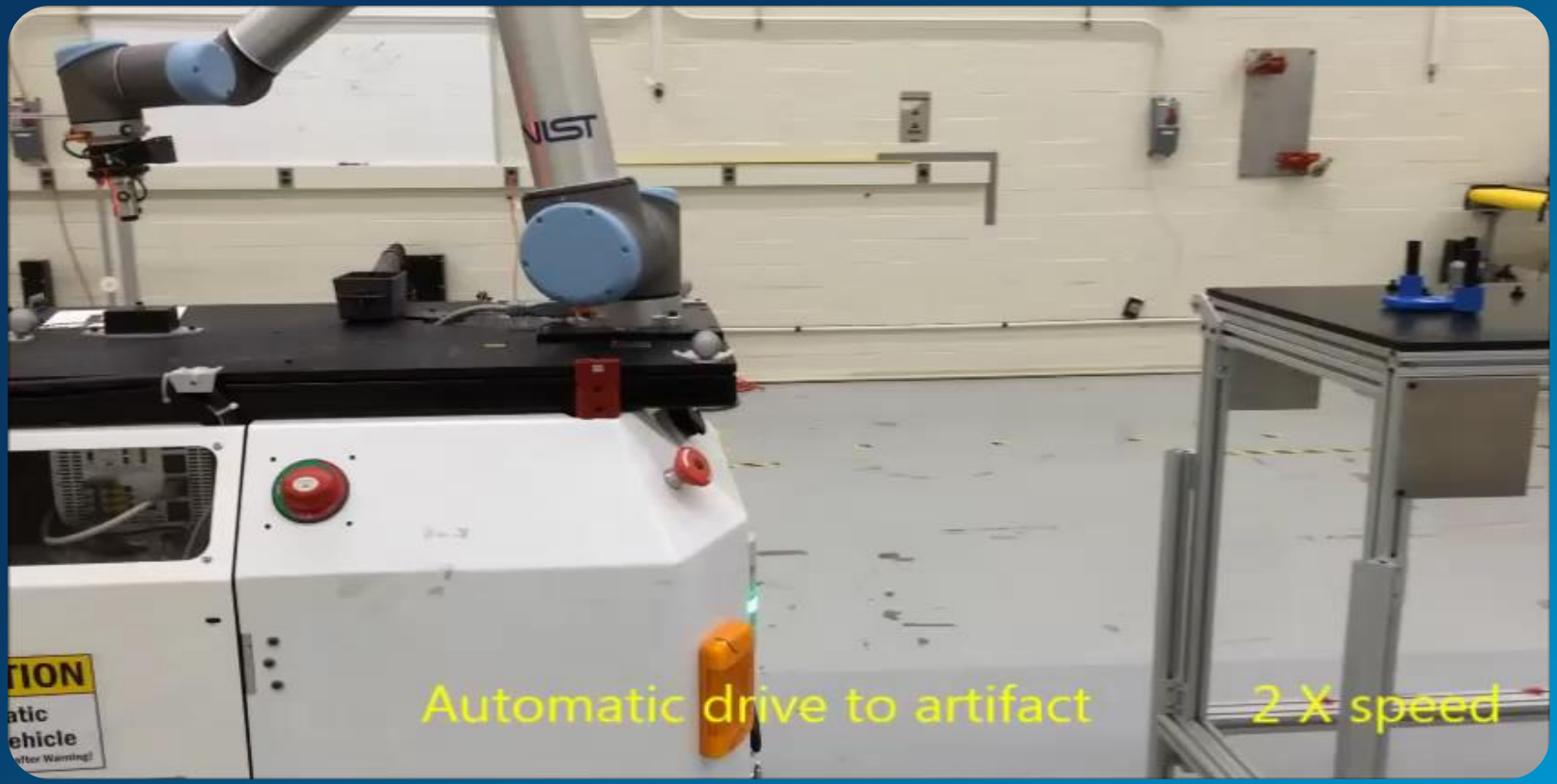


Reflector Target

Reconfigurable Mobile Manipulator Artifact (RMMA)

Manipulator Registration Methods

- Example Method:
  - Laser-Based Fine and Bisect Search of Reflective Targets
- Problem:
  - Can we develop faster or more accurate registration methods?



AR Marker Registration Overview

Point Grey Research Blackfly USB 3.0 Camera

UR 10 Manipulator

RMMA

AGV

CVC600 Controller

Beckhoff IPC--*ARToolkit*

UR 10 Controller

Router

AGV Navigation

Remote UR10 Control

Successes

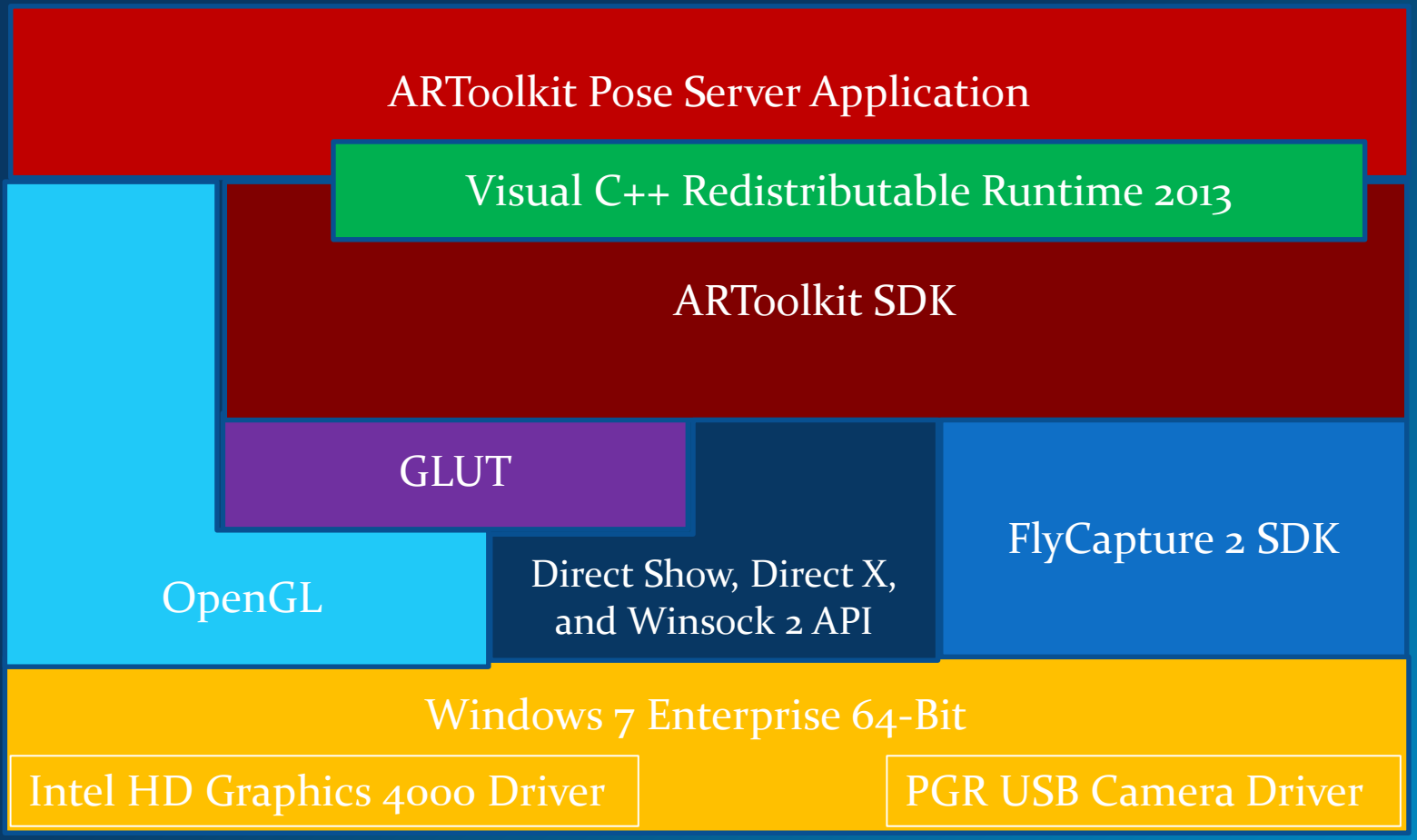
- **Mathematics Education at Salisbury University enabled:**
  - Ability to rapidly grasp new concepts related to 3D rotations and projective transformations used to model camera calibration.
  - Ability to choose system configurations and designs needed for task.
  - Mathematical experimentation needed for research.

Challenges

- Finding a method of documentation and organization that is most effective.
- Need more practice in executing experimental procedure.
- Some difficulties understanding various calibration philosophies.

ARToolkit Software Architecture

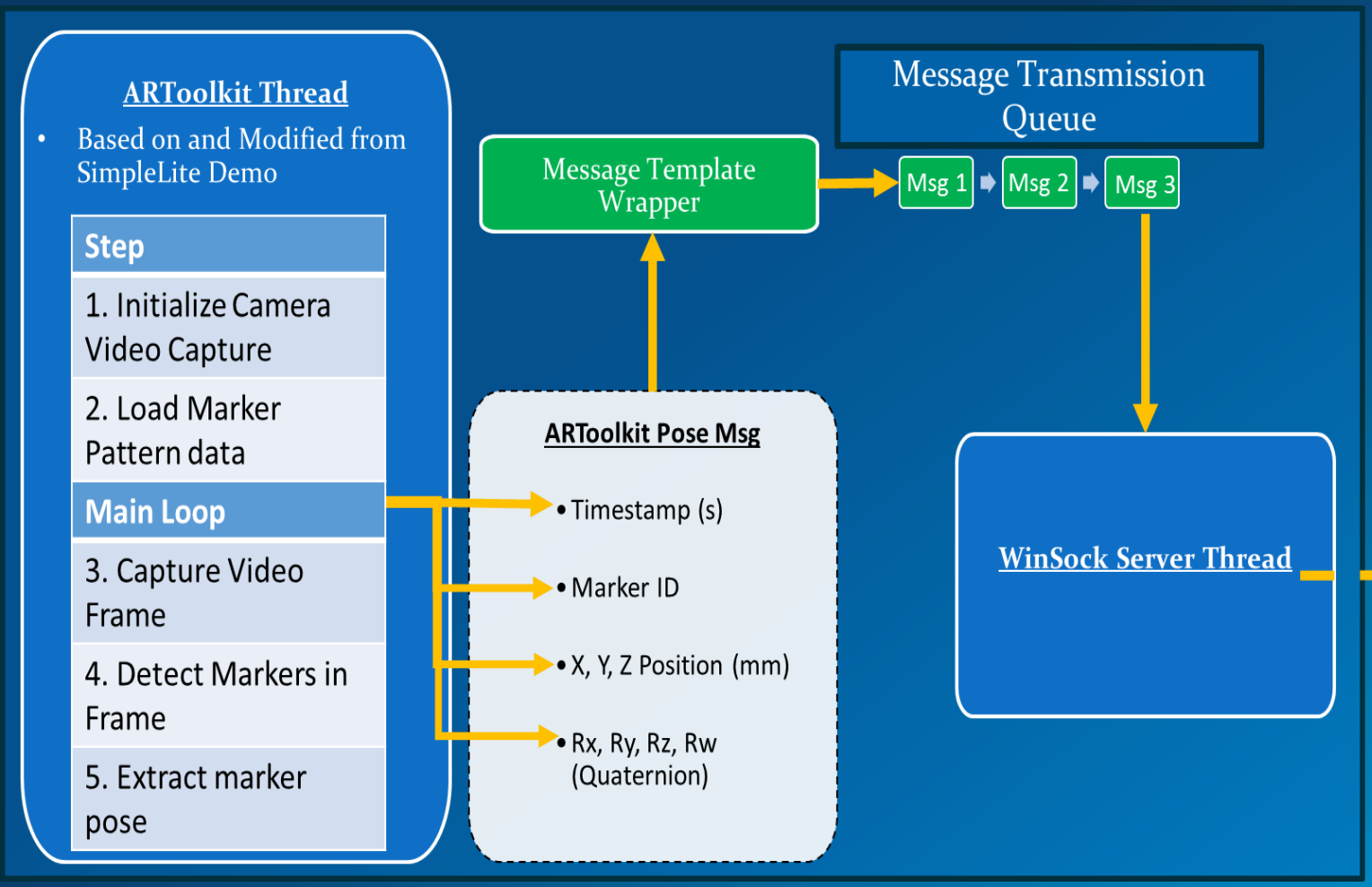
Implemented Architecture for Mobile Manipulator



- Based on ARToolkit Architecture Diagram from HIT Lab website https://www.hitl.washington.edu/artoolkit/documentation/devframework.htm

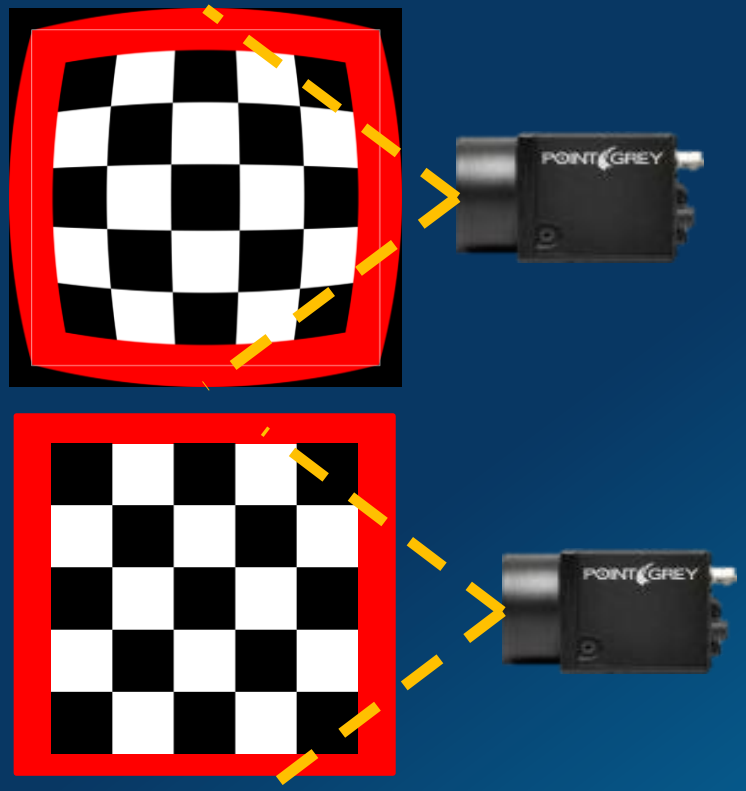
ARToolkit Pose Server Software Development

- Custom program used to implement and assess ARToolkit marker position and orientation (pose) tracking measurements.



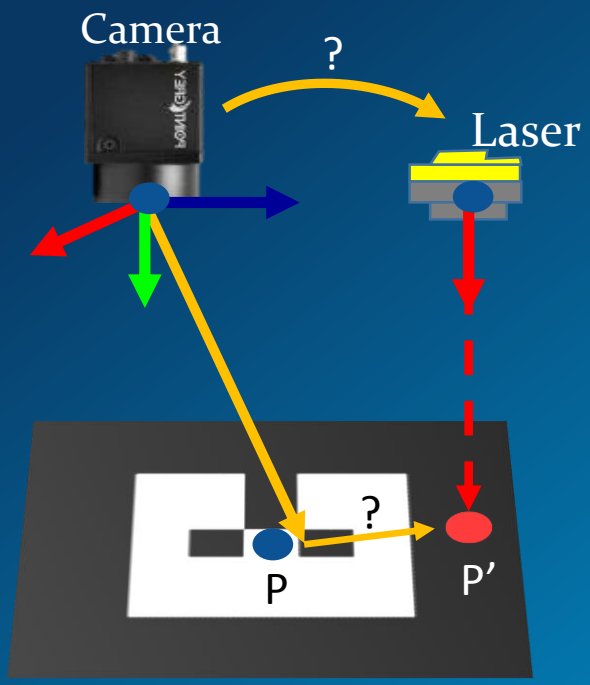
Camera Calibration Problem Overview

1. Intrinsic Lens Barrel Distortion, or "Fish-eye effect"

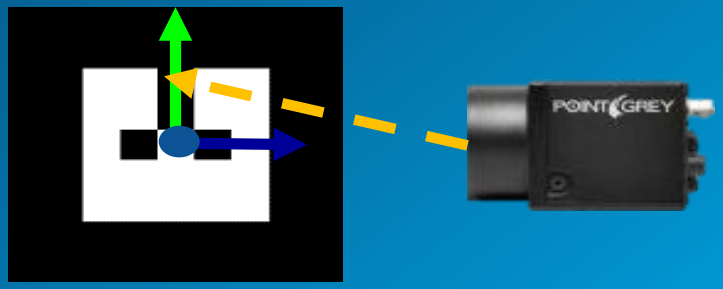


- Calib_Camera—Calibration Program Included with ARToolkit SDK.

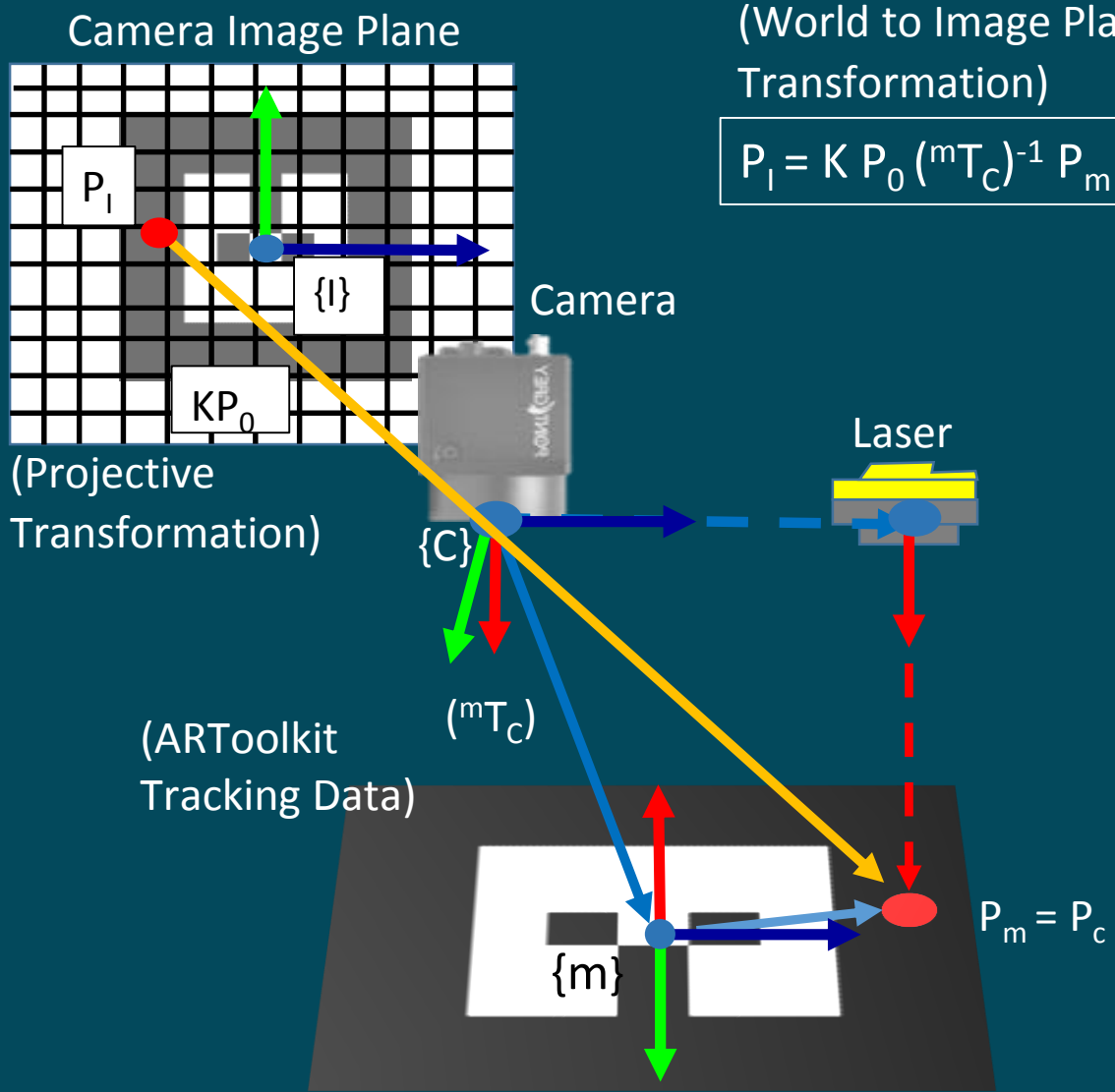
2. Camera to End Effector Offset



3. Camera Measurement Error



Manipulator Vision Coordinate System



Two Approaches to Calibration:

1. Constrain system to reveal unknown values.
2. Assume a general model and solve an optimization problem.

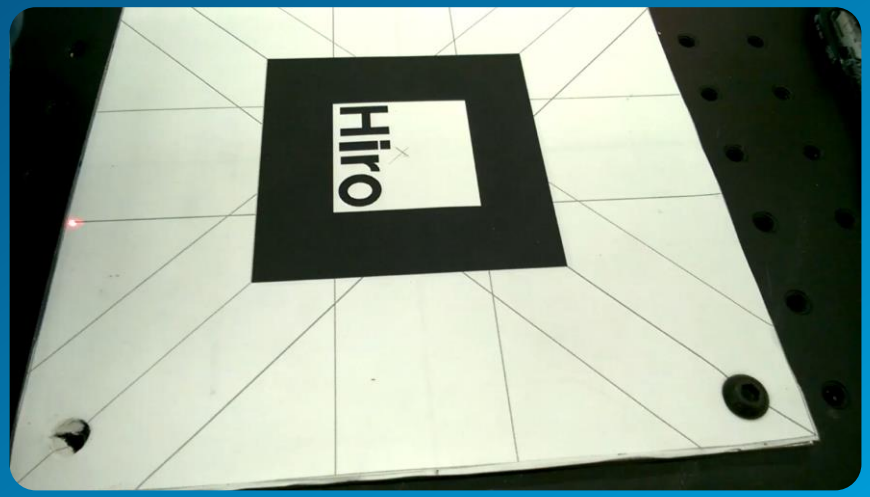
ARToolkit Camera Offset Calibration

- Ground Truth:
  - Manipulator X and Y position, as measured by the robot controller.
  - Laser centered on the marker origin.
- Procedure:
  - Rotate camera about marker origin.
  - Record position at set increments.
  - Average resultant distances between vertical angles made with origin axis.
- Parameters:
  - Measurement Range: ±180^0
  - Increments: 15^0
  - Sample Size: 100

Offset Result: 75.394 mm

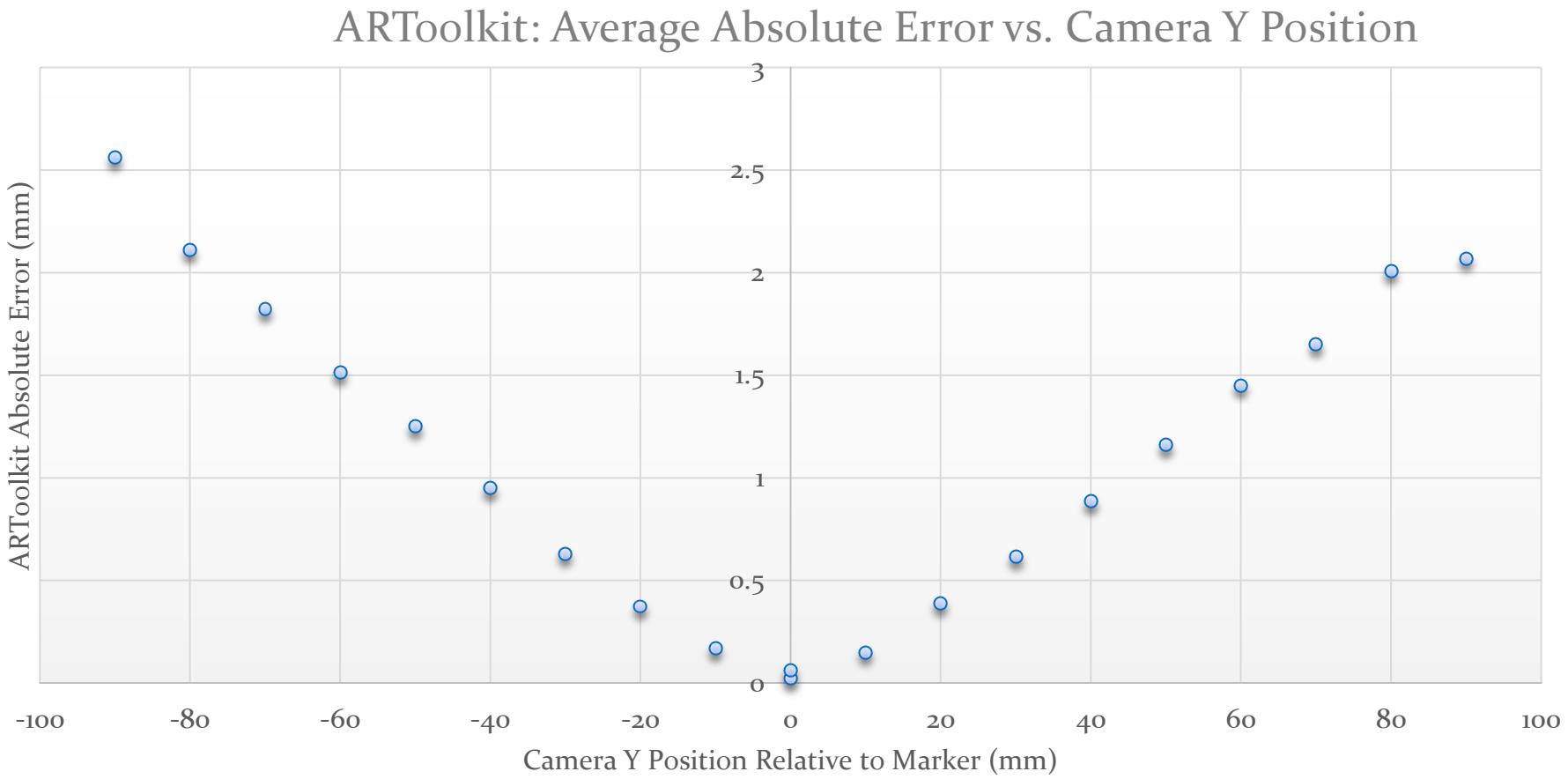
ARToolkit Camera Error Calibration

- Ground Truth:
  - Change in manipulator position. (± 0.2 mm)
  - Camera centered on marker origin.
  - Marker rotationally aligned with laser.
- Procedure:
  - Increment manipulator position along X and Y axis.
  - Record ARToolkit marker pose for each increment.
  - Calculate average absolute error.
- Parameters:
  - Measurement Range: ±100 mm
  - Increments: 10 mm
  - Samples: 100



ARToolkit Camera Error Calibration

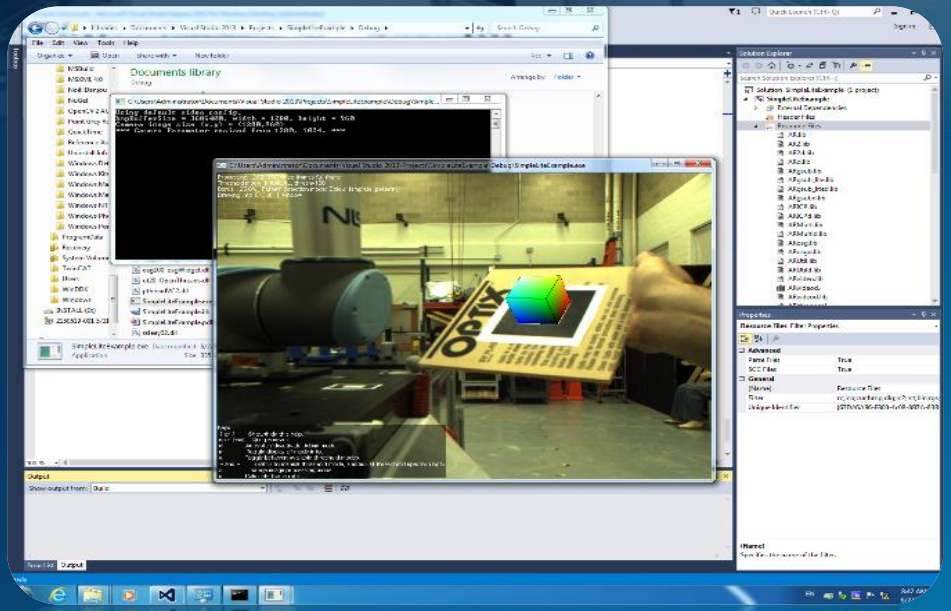
Results

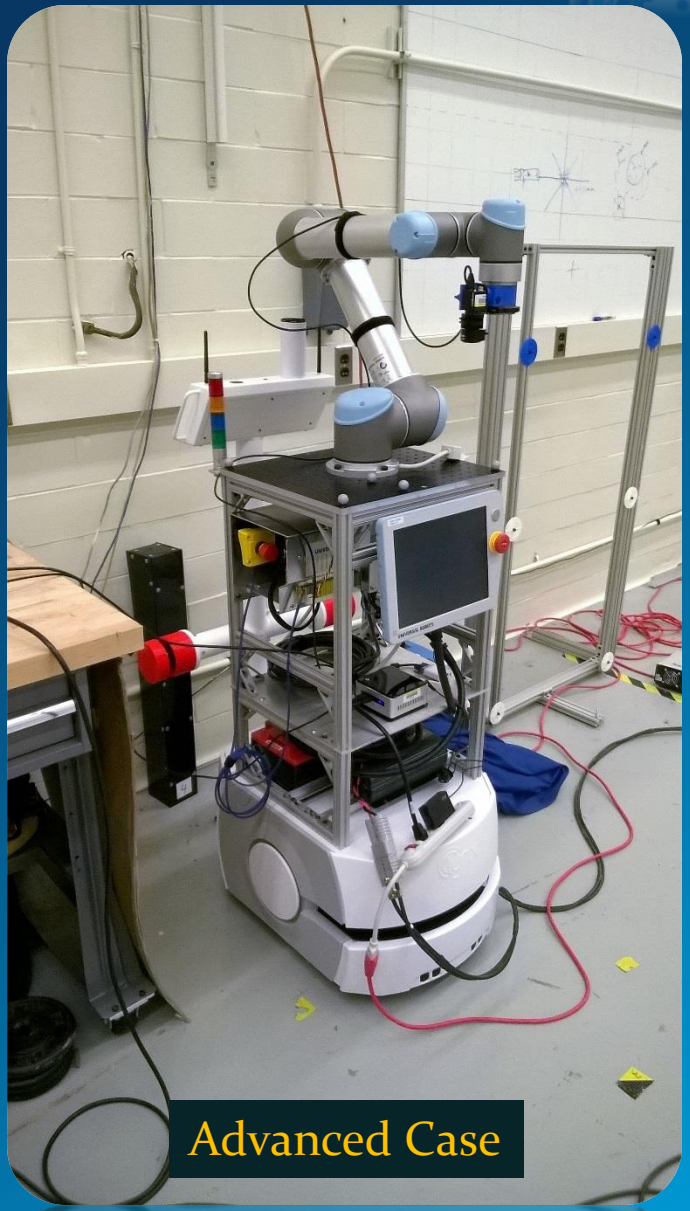


Standard Deviation for each measurement less than 0.03 mm

Conclusion

Traditional Case





Advanced Case

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Thank You for Listening!

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  Date: 6/10/2016
  Code Version: 5.3.2
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