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Evaluation and Optimization of Virtual Rigid Body

Project 14

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Mini Checkpoint Presentation
May 1st, 2014

MUSiiC Research Laboratory

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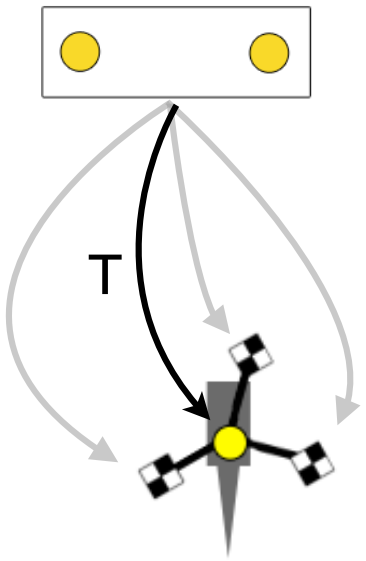
Recapitulation

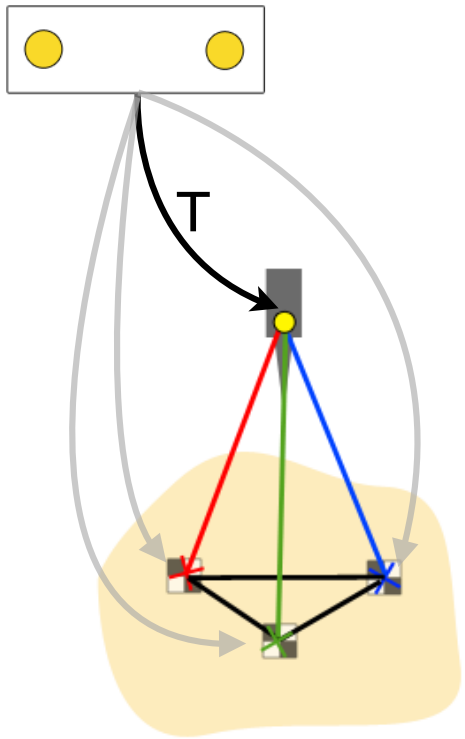
- Pose (T = [R, t]) of the surgical tool in optical tracker coordinates?

Conventional physical rigid body (PRB)

Optical Tracker
(MicronTracker)



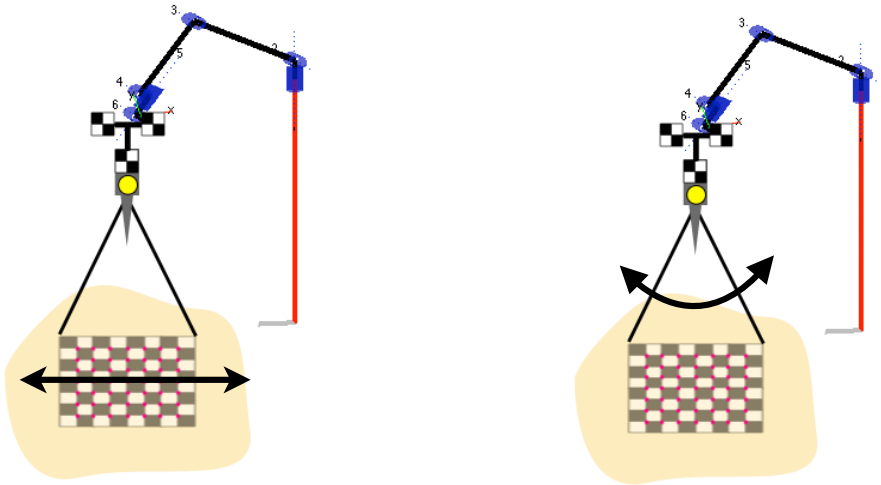
Virtual rigid body (VRB)



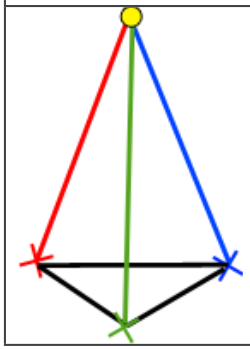
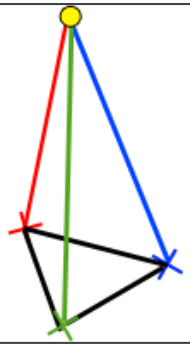
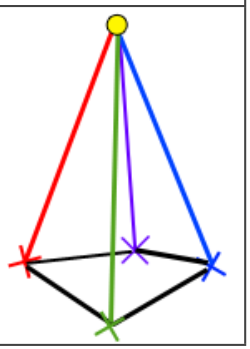
How do the two types of rigid body compare?

Recapitulation

- Investigate the operating condition of virtual rigid body including,
  - -Motion trajectory
    - -Translational, rotational, composite

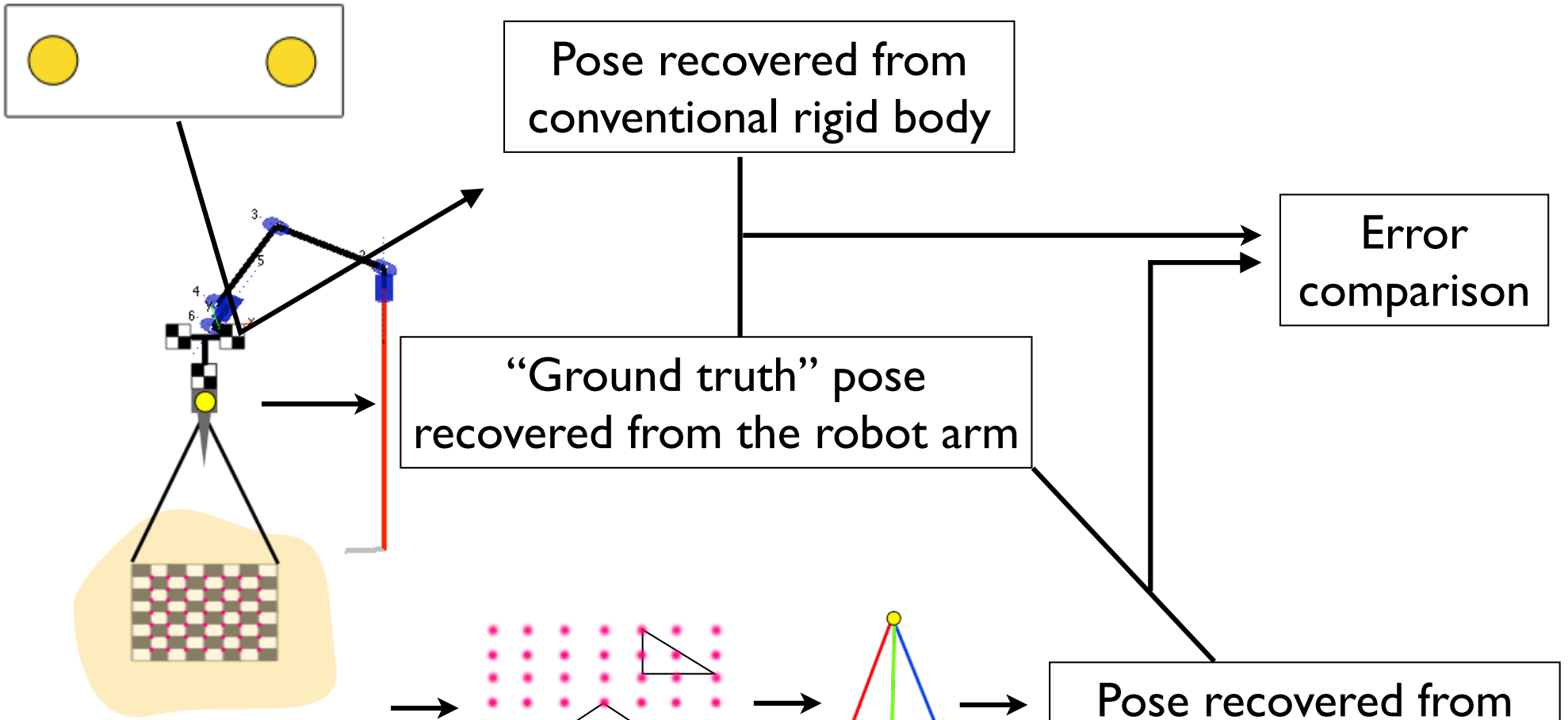


  - -Virtual rigid body characteristics

Typical model	Size	Shape	Number of Projections
			

Overall study design

For a given trajectory of movement



(Robot figure powered by Robotics Toolbox, Peter Corke)

Deliverables - modifications

Original

- Minimum (Mar 31st) - Pipeline Setup
  1. Virtual rigid body (VRB) grid
  2. Detection component
  3. Processing component
  4. Robot component

- Expected (Apr 23rd) - Experiment/Analysis
  - Run pipeline for data collection
  - Comparison between virtual and physical rigid body
  - Optimal design of virtual rigid body

- Maximum (Apr 30th) - Application
  - Demonstration of virtual rigid body in laparoscopy setting
  - Documentation

Modified

- Minimum (Mar 31st) - Experimental Pipeline Setup
  1. Virtual rigid body (VRB) grid
  2. Detection component
  3. Processing component
  4. Robot component

- Expected (May 6th) - Experiment/Analysis
  - Run pipeline for data collection
  - Analysis pipeline
  - Comparison between virtual and physical rigid body
  - Optimal design of virtual rigid body

- Maximum (May 8th) - Application
  - ~~Demonstration of virtual rigid body in laparoscopy setting~~
  - Documentation

Deliverables

- Minimum (Mar 31st) - Experimental Pipeline Setup ✔
  1. Virtual rigid body (VRB) grid ✔
  2. Detection component ✔
  3. Processing component ✔
  4. Robot component ✔

- Expected (Apr 23rd) - Experiment/Analysis ⚠ (by 05/06)
  - Run pipeline for data collection ✔
  - Analysis pipeline ✔
  - Comparison between virtual and physical rigid body ⚠
  - Optimal design of virtual rigid body ⚠

- Maximum (Apr 30th) - Application ⚠ (by 05/08)
  - ~~Demonstration of virtual rigid body in laparoscopy setting~~
  - Documentation ⚠

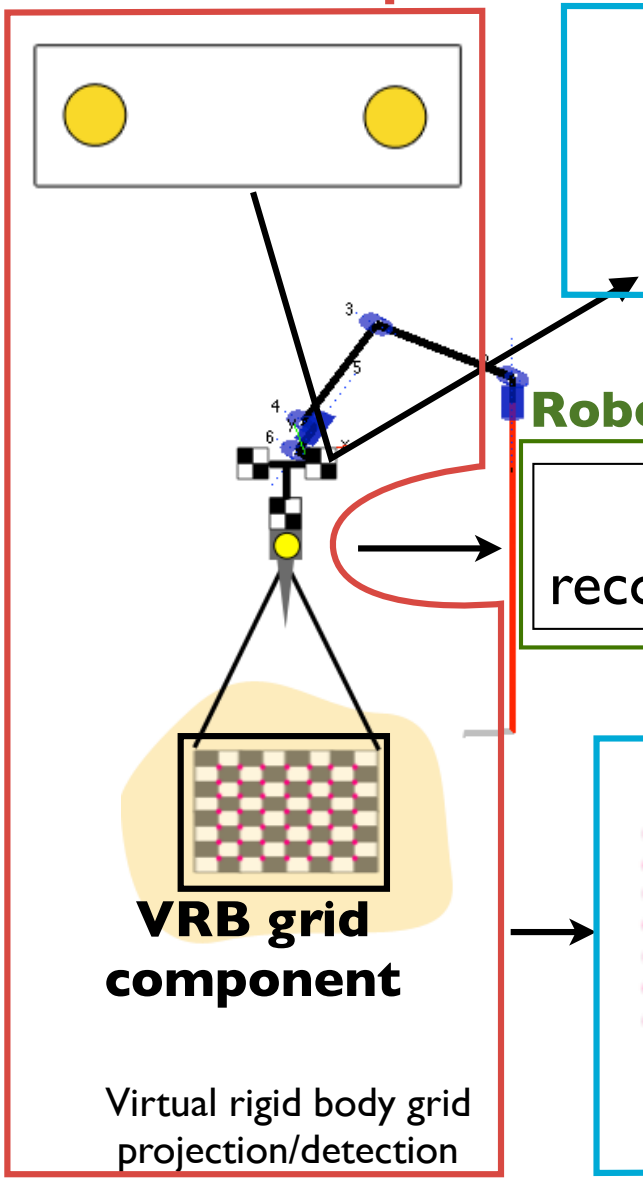
✔ complete
⚠ delayed
~~abc~~ abandoned

Experimental Pipeline

For a given trajectory of movement

Detection component

Processing component



Robot component

VRB grid component

Virtual rigid body grid projection/detection

Pose recovered from conventional rigid body

"Ground truth" pose recovered from the robot arm

Error comparison

Grid processing/ Defining fiducials

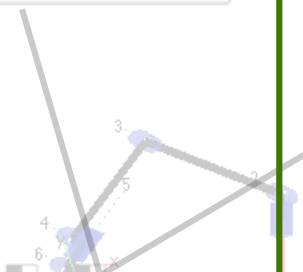
Model fitting

Pose recovered from virtual rigid body

Analysis considerations

Trajectory types

For a given trajectory of movement



Error comparison

Pose recovered from conventional rigid body

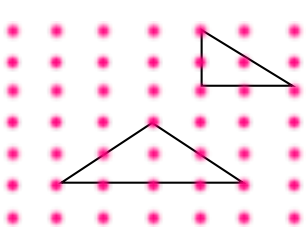
Error comparison

"Ground truth" pose recovered from the robot arm

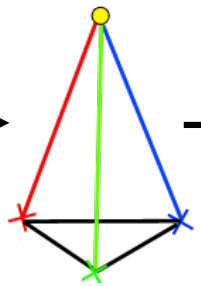
VRB configurations

VRB grid component

Virtual rigid body grid projection/detection



Grid processing/ Defining fiducials



Model fitting

Pose recovered from virtual rigid body

Trajectory types

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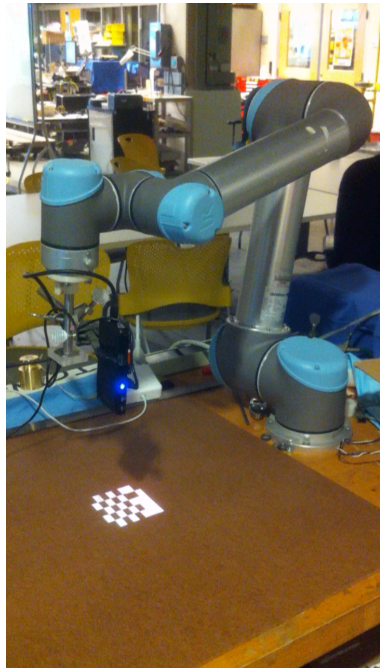
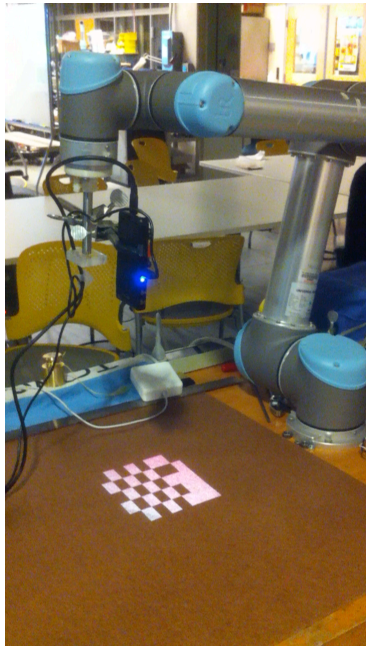
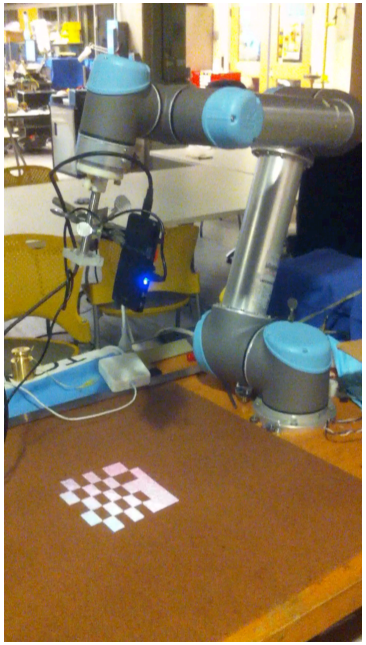
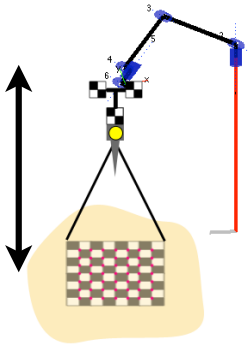
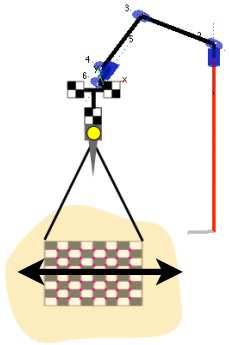
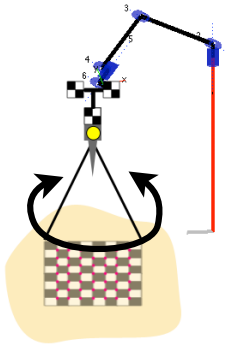
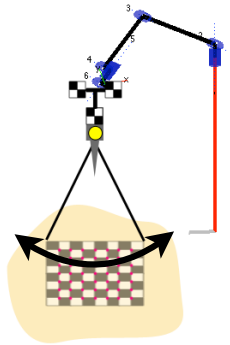
- Simple trajectories
  - translation & rotation
  - along z-axis & x or y axis



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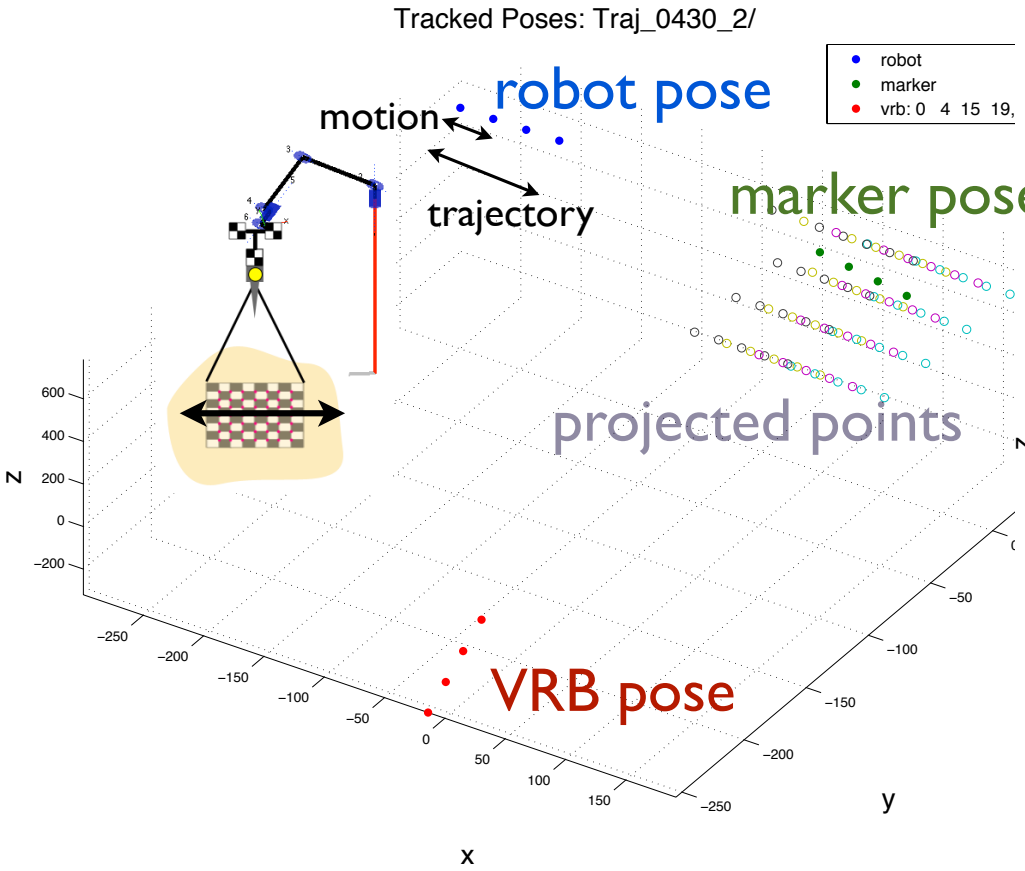
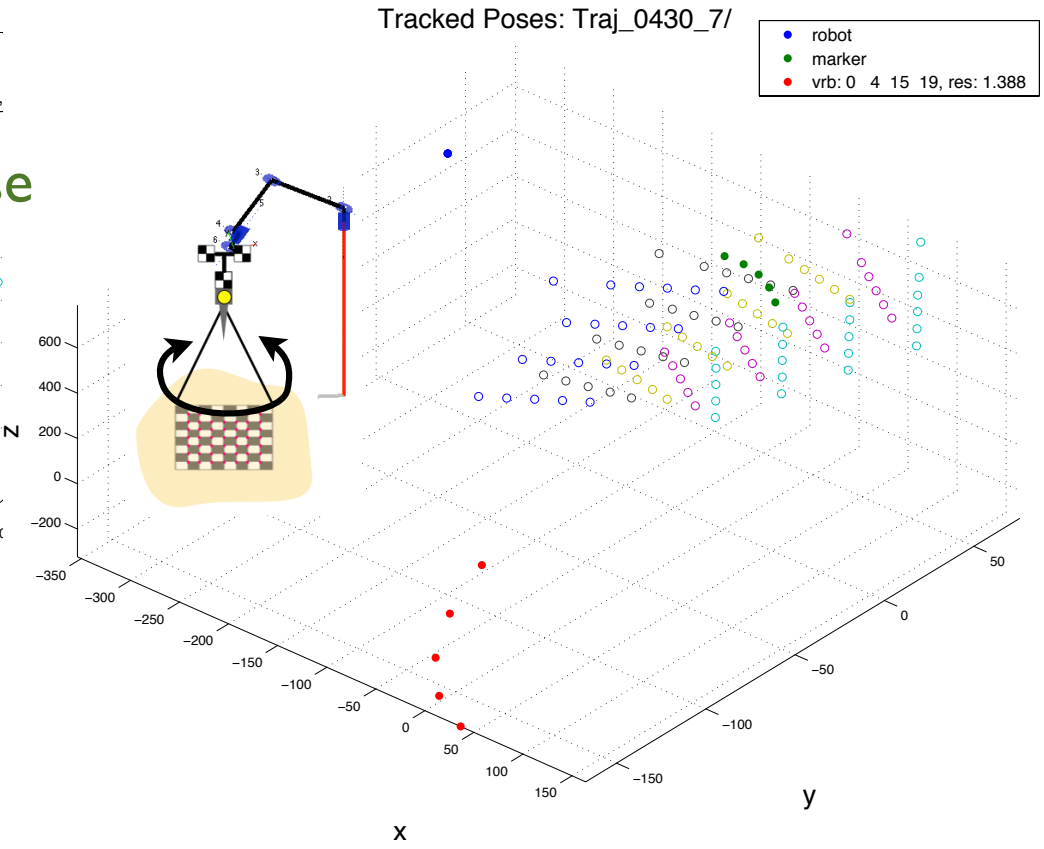
Trajectory types

- Trajectory
  - a set of "waypoints", or smaller motions.
  - all combinations of motions are analyzed

- Analysis
1. Trajectory types
2. Error comparison
3. VRB configurations





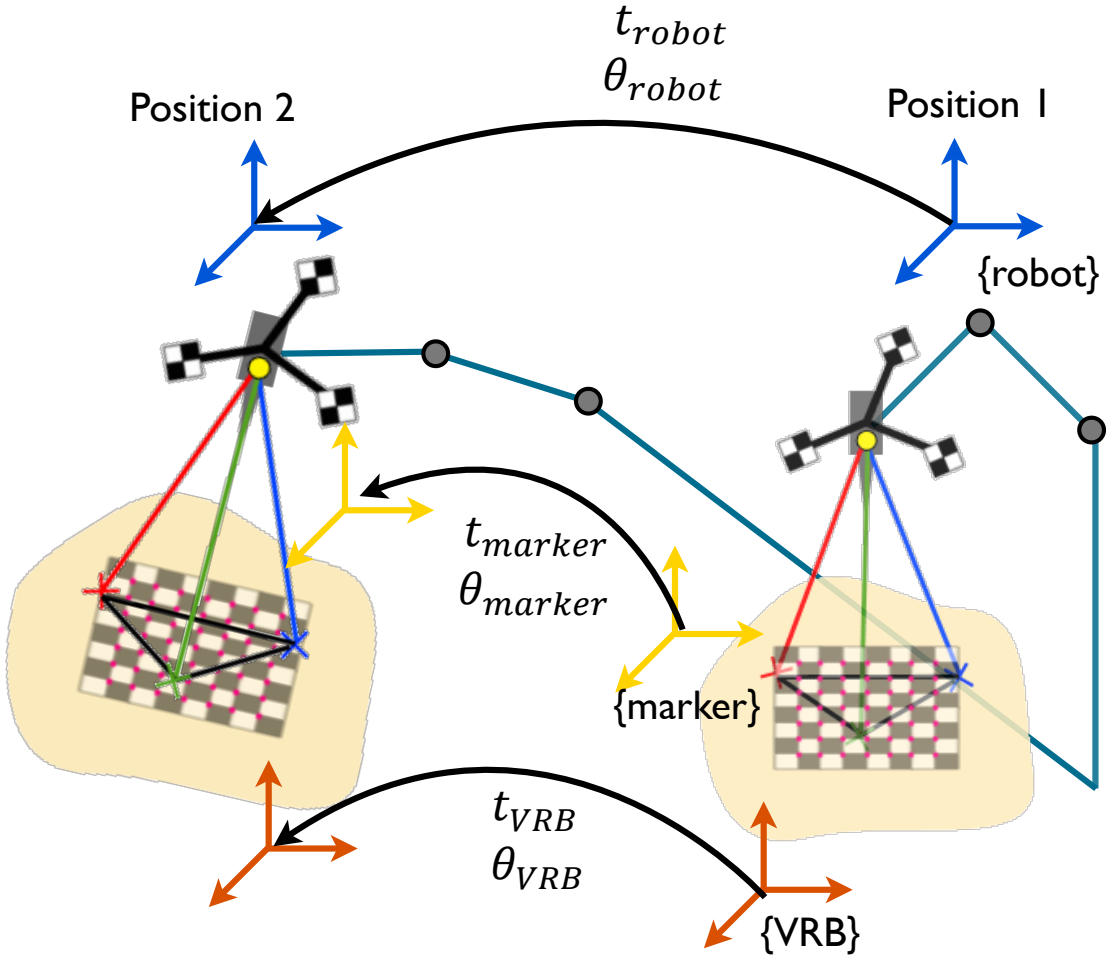
Error comparison

- Relative motion
  - Relative motion consists of translation (t) and rotation (θ)
  - Invariants: rigidly attached coordinates have same t and θ

- Error metrics $(\Delta t, \Delta\theta)$
  - Robot as the ground truth

$$\Delta t_{VRB} = |t_{VRB} - t_{robot}|$$
$$\Delta\theta_{VRB} = |\theta_{VRB} - \theta_{robot}|$$

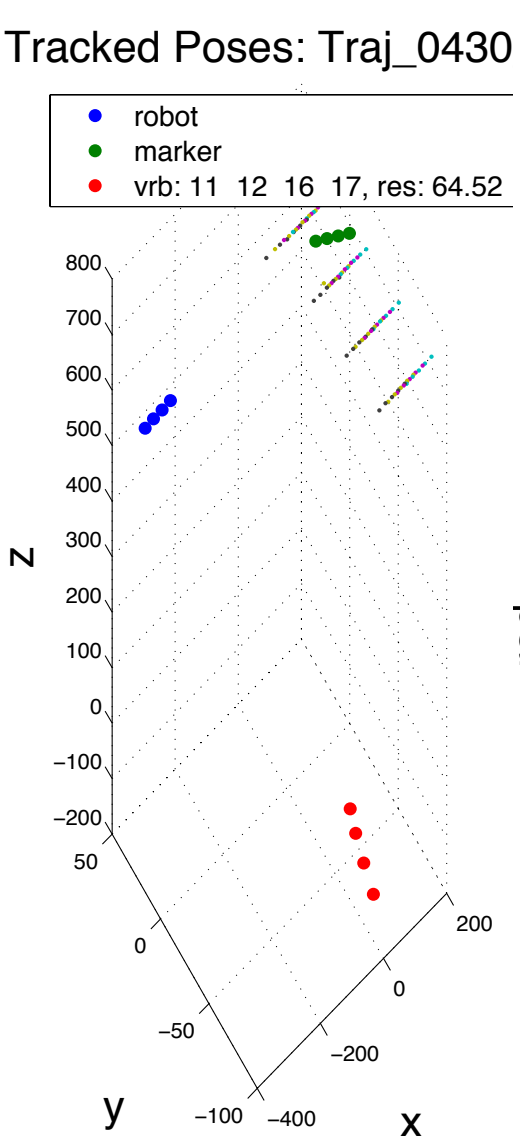
$$\Delta t_{marker} = |t_{marker} - t_{robot}|$$
$$\Delta\theta_{marker} = |\theta_{marker} - \theta_{robot}|$$

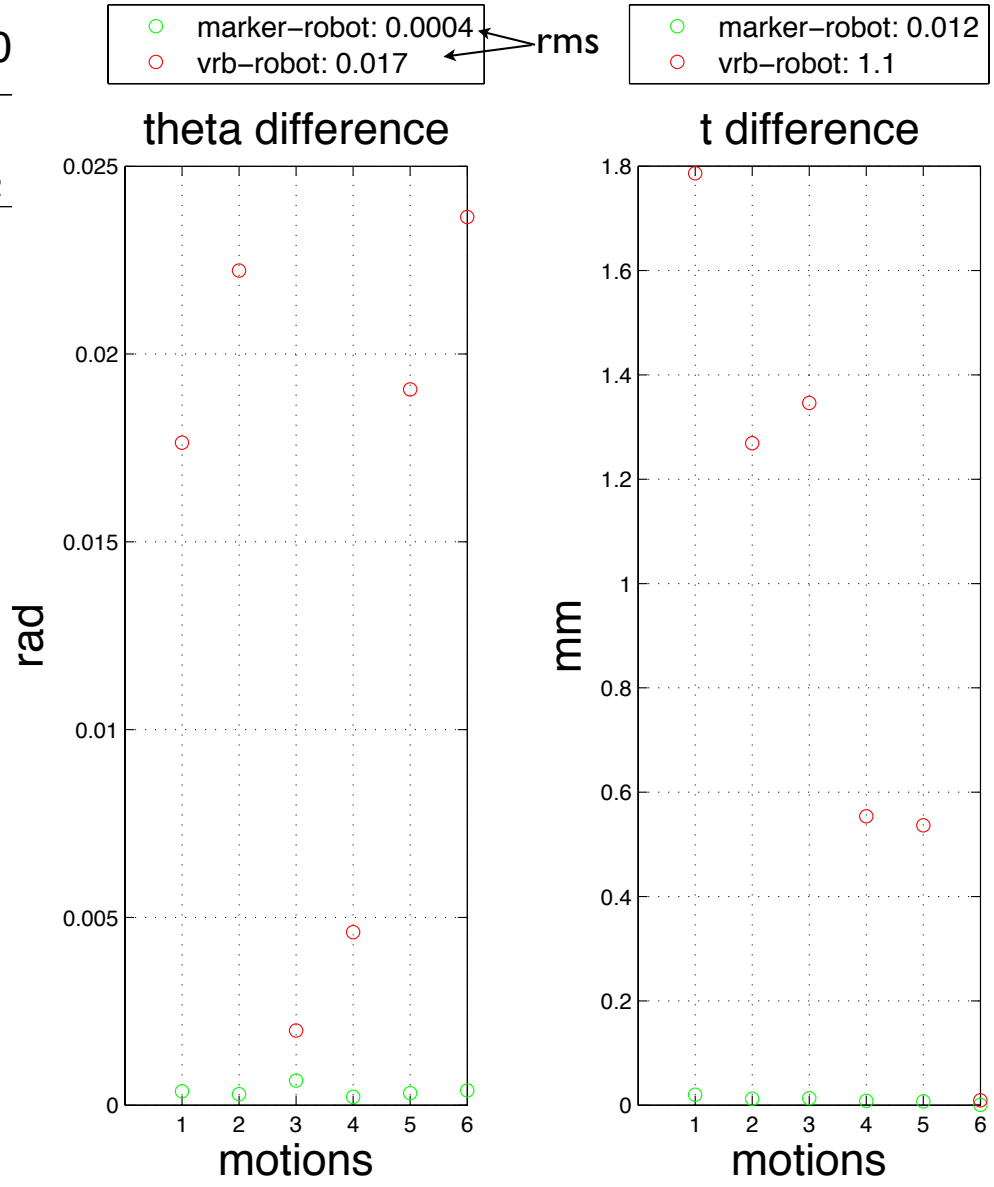


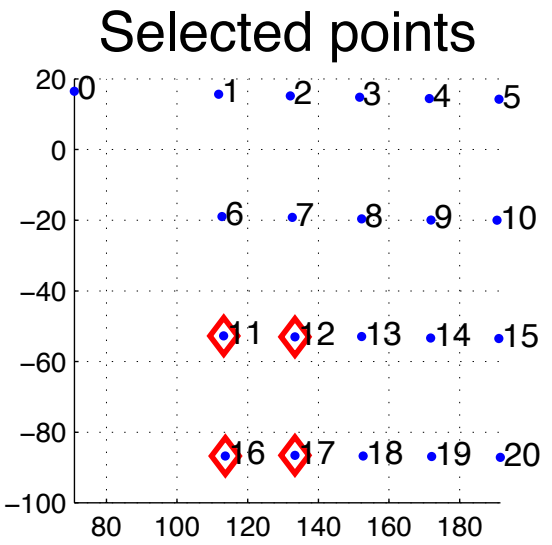
- Invariants as error metric, suggested by Alexis

Error comparison

- $\Delta t, \Delta\theta$ error computed for all relative motion







- Analysis
  1. Trajectory types
  2. Error comparison
  3. VRB configurations

VRB configurations

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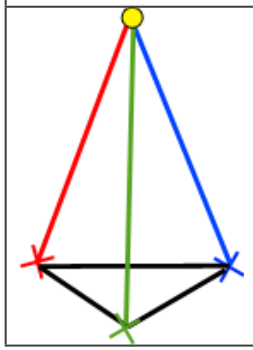
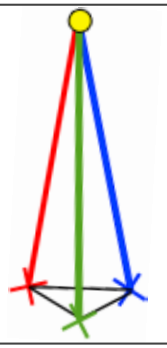
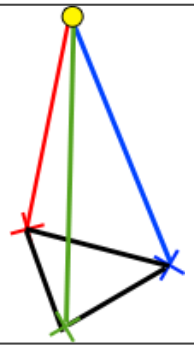
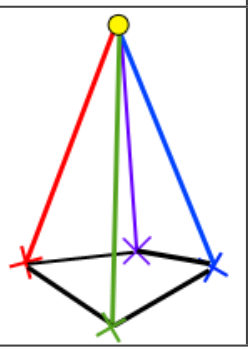
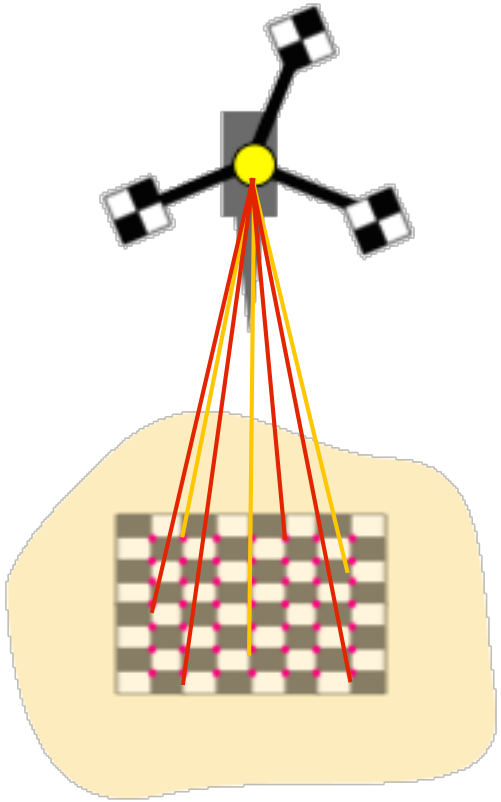
- Analysis
1. Trajectory types
2. Error comparison
3. VRB configurations

- What VRB configurations promote higher tracking accuracy?

Typical model	Size	Shape	Number of Projections
			



VRB configurations

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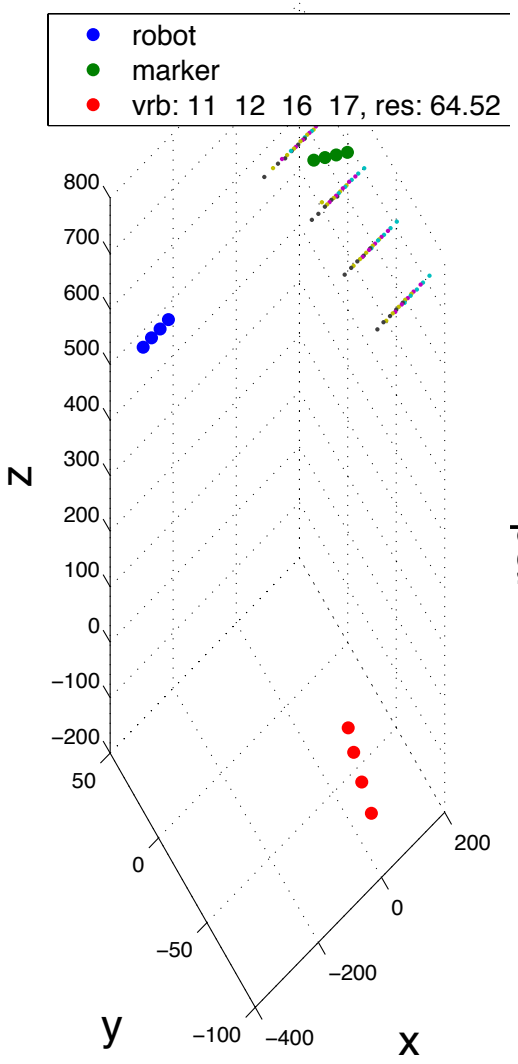
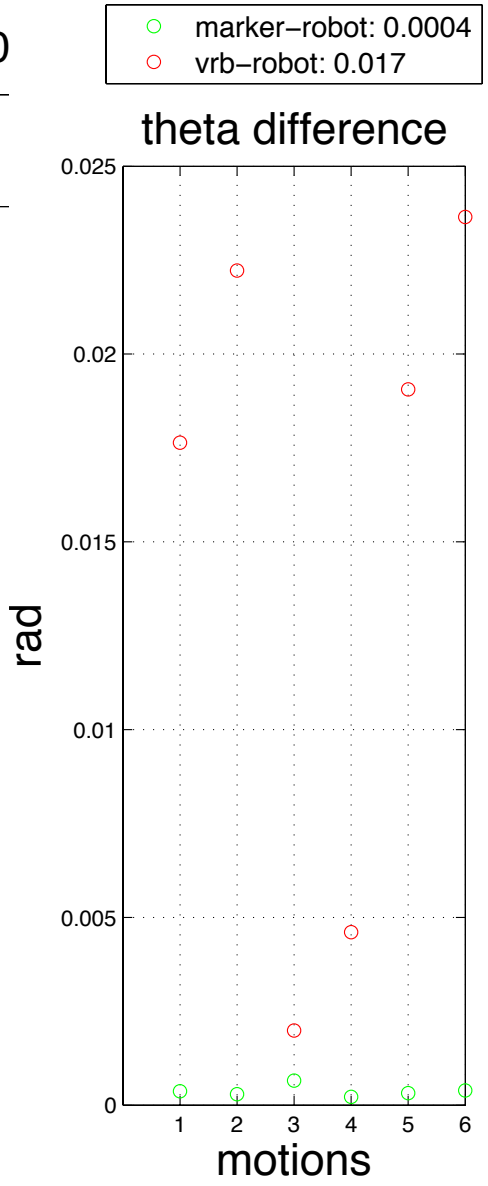
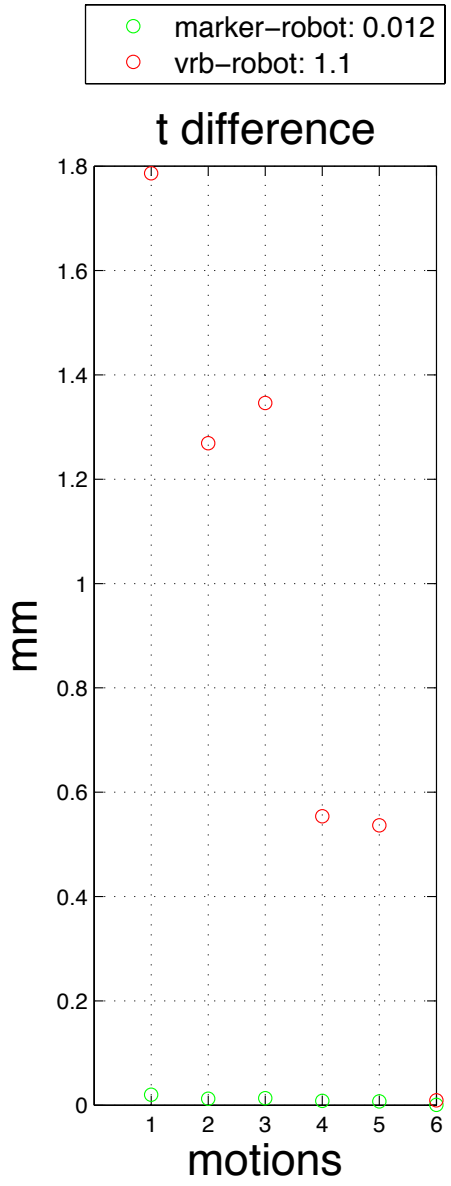
- Analysis
  1. Trajectory types
  2. Error comparison
  3. VRB configurations

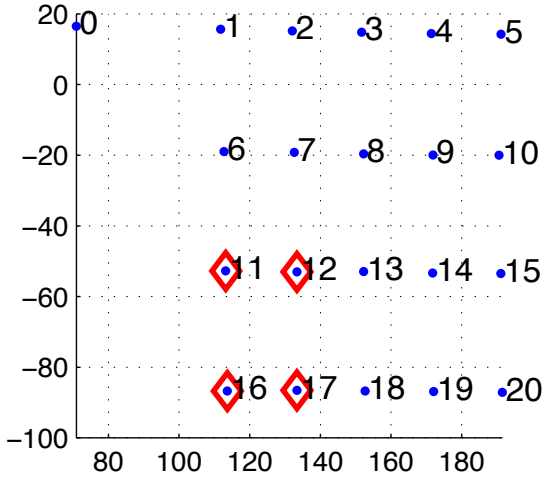
Tracked Poses: Traj_0430







Selected points



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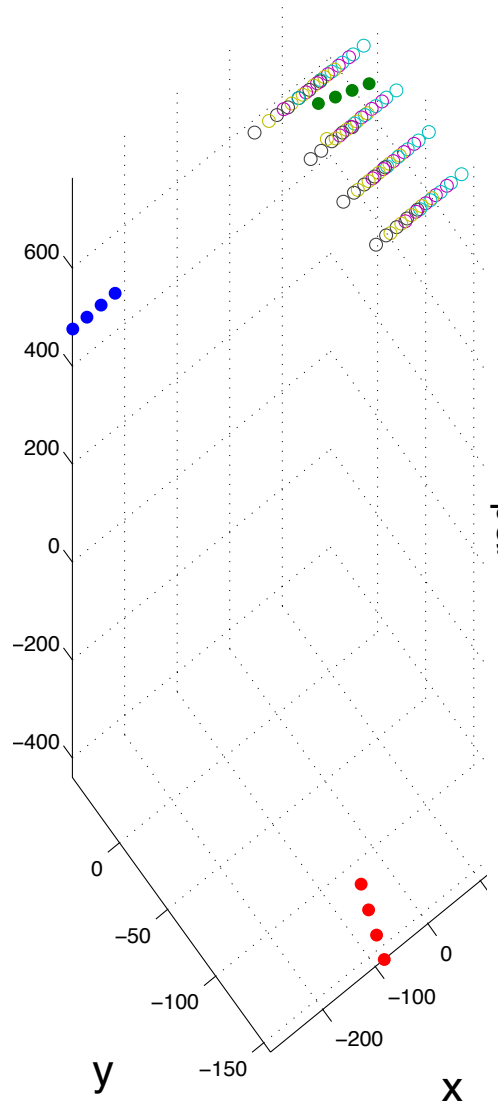
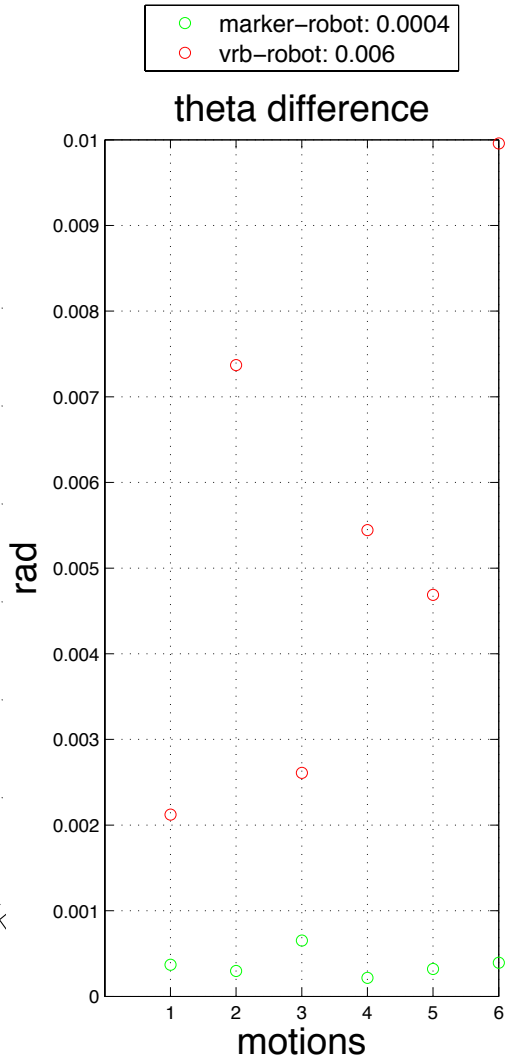
VRB configurations

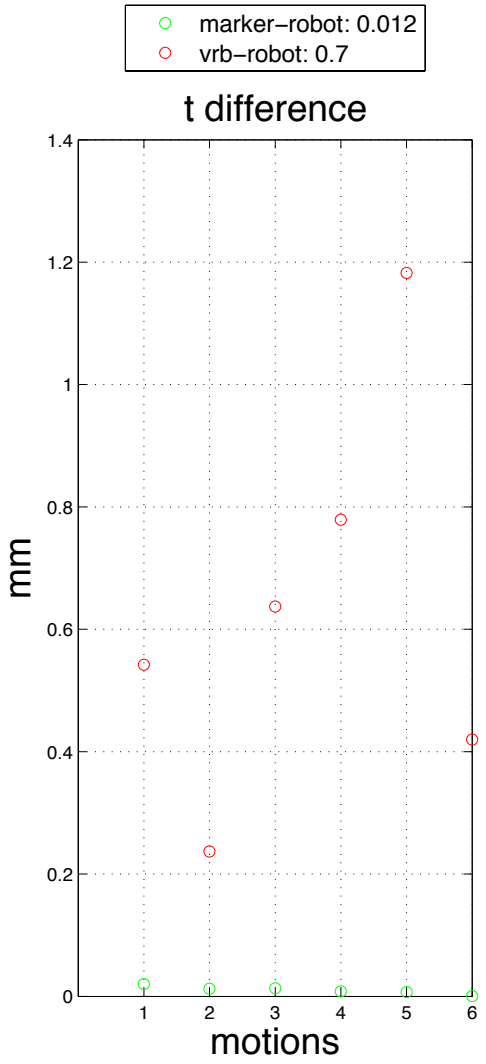
- Analysis
  1. Trajectory types
  2. Error comparison
  3. VRB configurations

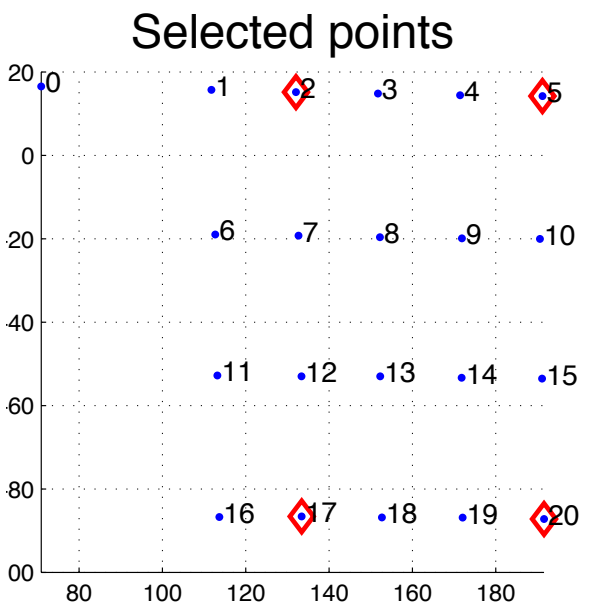
- Size

Tracked Poses: Traj_0430_2/



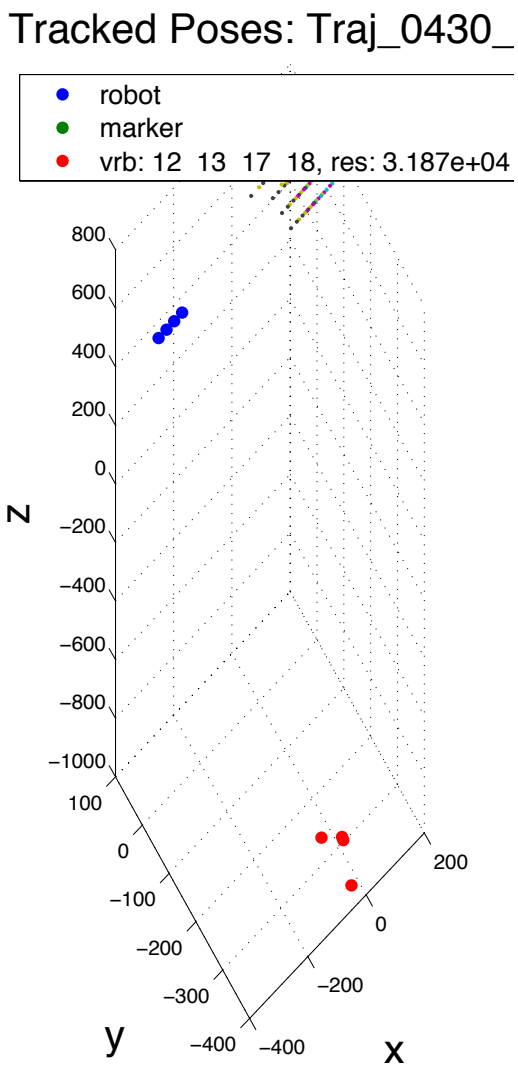


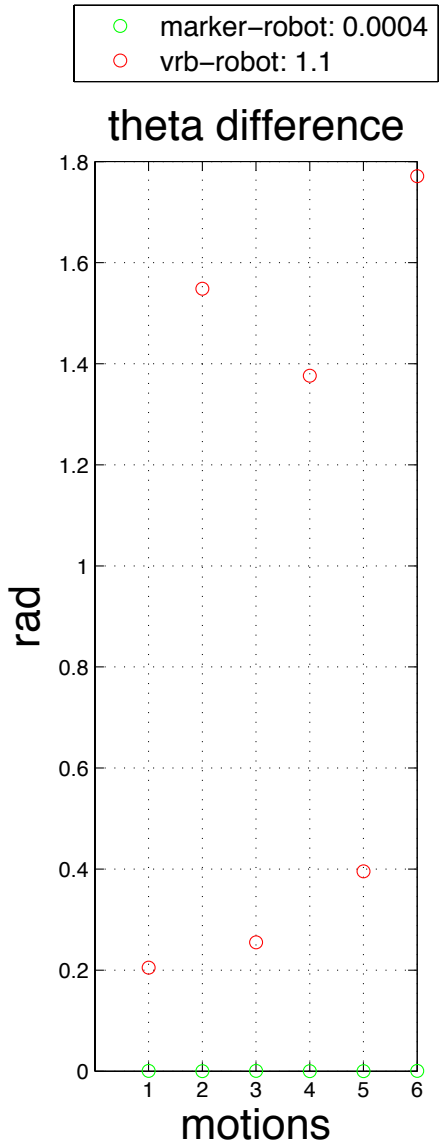


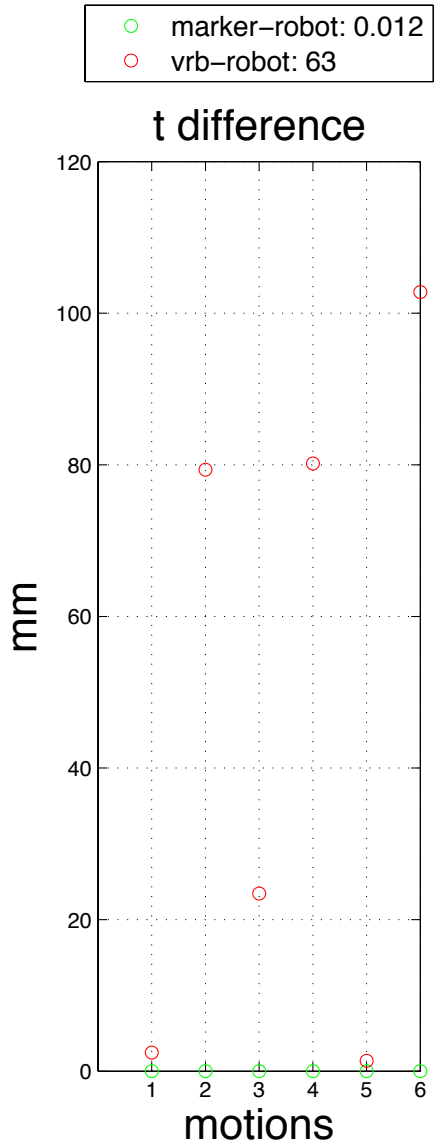


VRB configurations

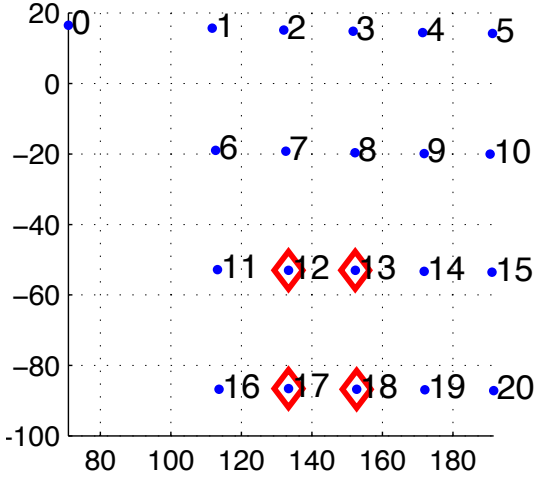
- Shape





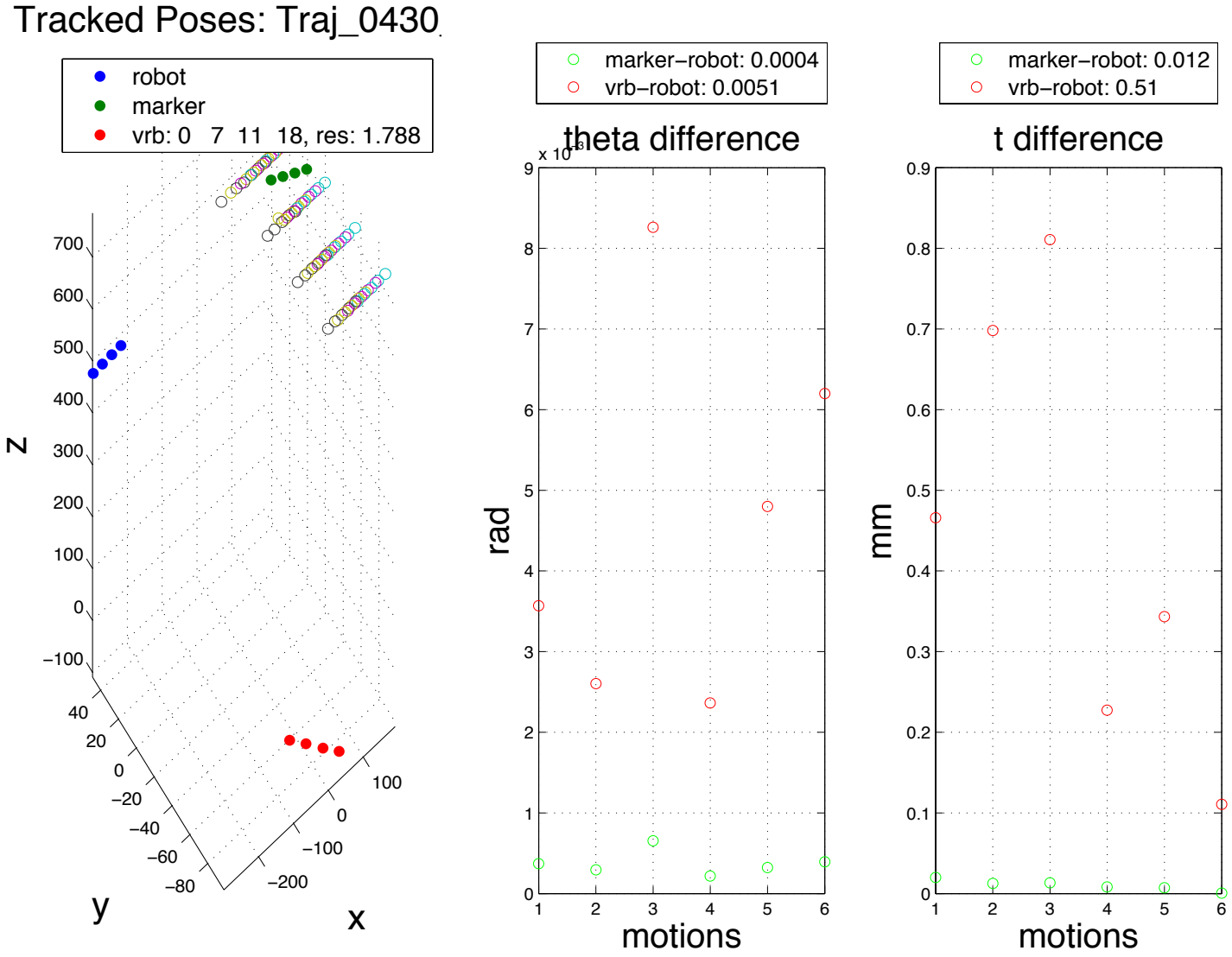


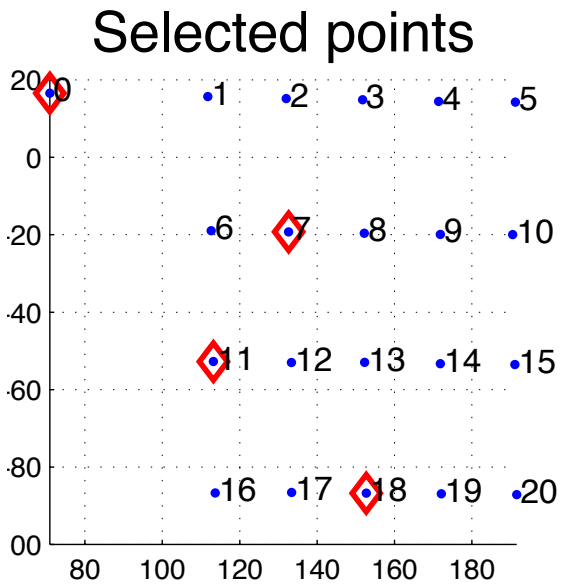
- Analysis
  1. Trajectory types
  2. Error comparison
  3. VRB configurations



VRB configurations

- Shape





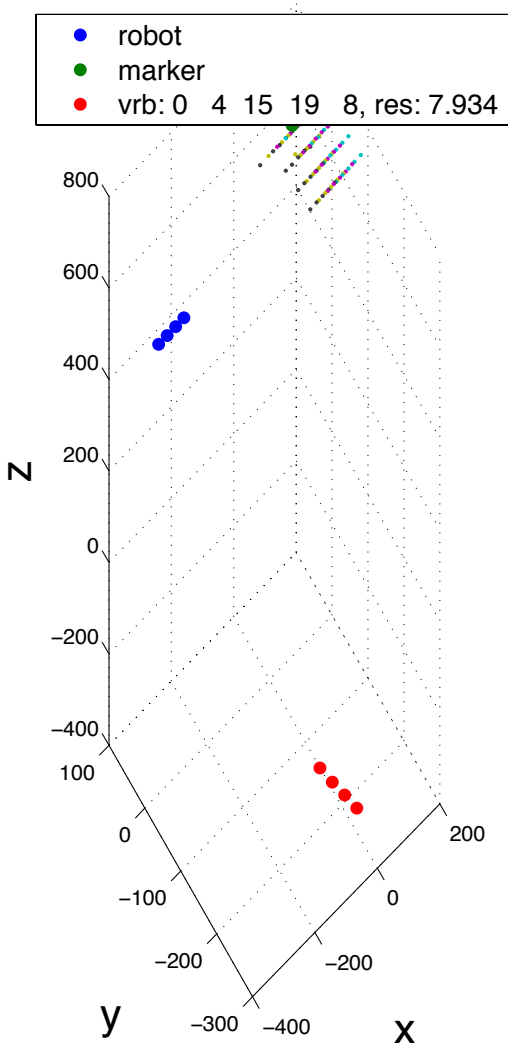
- Analysis
1. Trajectory types
2. Error comparison
3. VRB configurations

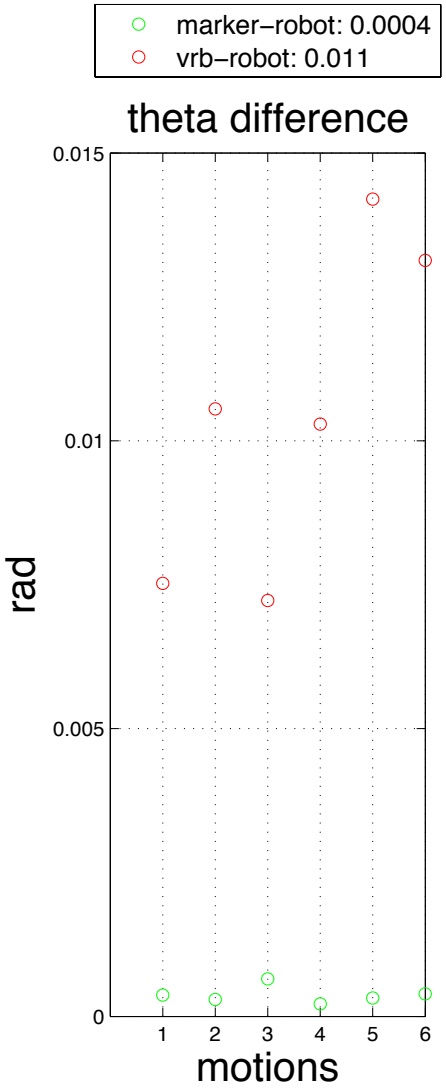
VRB configurations

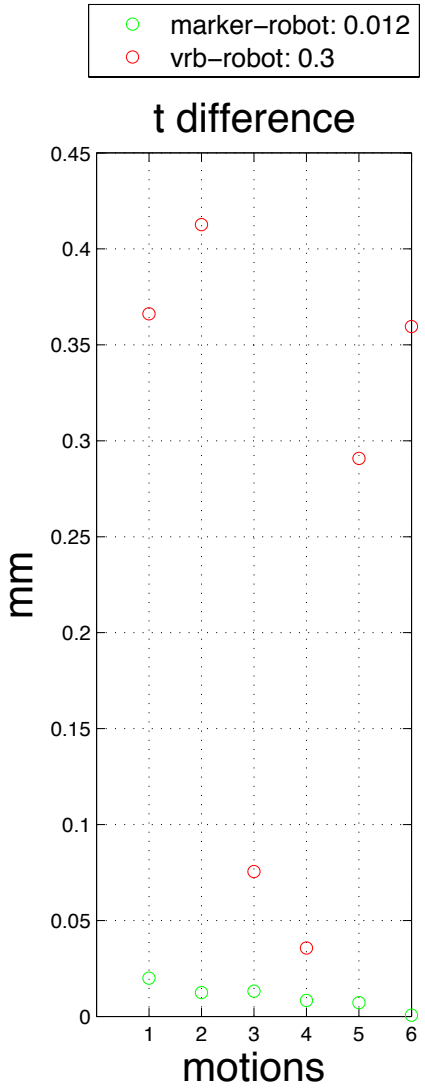
- Analysis
  1. Trajectory types
  2. Error comparison
  3. VRB configurations

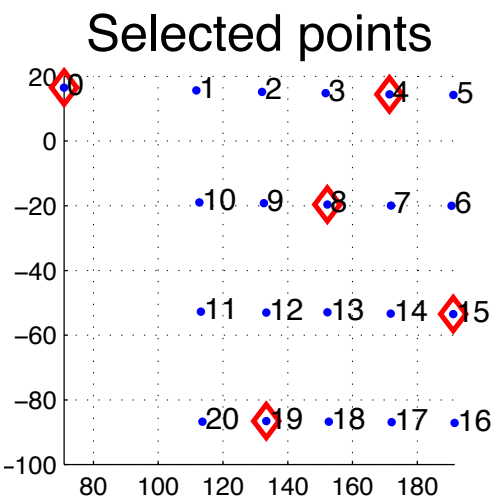
- Number

Tracked Poses: Traj_0430









Status

- Current state
  - Experimental and analysis tools and data are available.

- Difficulties
  - VRB is not performing as well as expected
  - The patterns of accuracy vs. VRB configurations are unclear.

Dependency Check

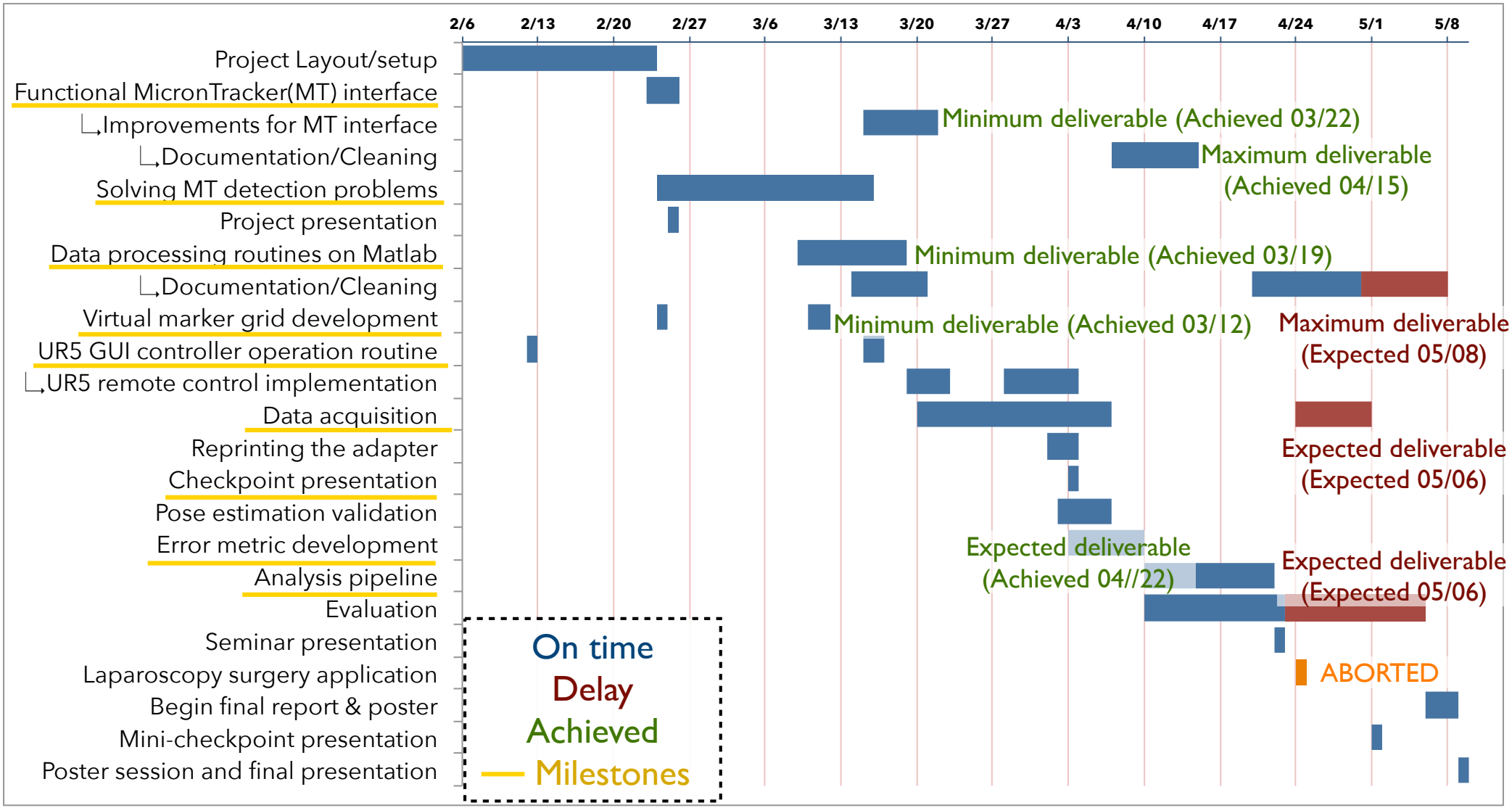
- Hardware
  - MicronTracker
  - Universal Robots robot arm and controller
  - Robot - projector adapter ⚠ Broke → ✔Reprinted
  - Laptop

- Commercial Software
  - MicronTracker software development kit
  - Universal Robots control system

- Internal algorithm and software
  - VRB pose estimation (Alexis)
  - Rotational and translational error metrics (Alexis)

- Miscellaneous
  - Access to Hackerman hall Robotorium

Gantt Chart


2/6
2/13
2/20
2/27
3/6
3/13
3/20
3/27
4/3
4/10
4/17
4/24
5/1
5/8
Project Layout/setup
Functional MicronTracker(MT) interface
Improvements for MT interface
Documentation/Cleaning
Solving MT detection problems
Project presentation
Data processing routines on Matlab
Documentation/Cleaning
Virtual marker grid development
UR5 GUI controller operation routine
UR5 remote control implementation
Data acquisition
Reprinting the adapter
Checkpoint presentation
Pose estimation validation
Error metric development
Analysis pipeline
Evaluation
Seminar presentation
Laparoscopy surgery application
Begin final report & poster
Mini-checkpoint presentation
Poster session and final presentation
Minimum deliverable (Achieved 03/22)
Maximum deliverable (Achieved 04/15)
Minimum deliverable (Achieved 03/19)
Minimum deliverable (Achieved 03/12)
Maximum deliverable (Expected 05/08)
Expected deliverable (Expected 05/06)
Expected deliverable (Achieved 04//22)
Expected deliverable (Expected 05/06)
ABORTED
On time
Delay
Achieved
Milestones

Questions?