Evaluation and Optimization of Virtual Rigid Body

Project 14

David Lee (dslee@cis.jhu.edu)
Mentors: Alexis Cheng, Dr. Emad M. Boctor

Mini Checkpoint Presentation
May 1st, 2014
Recapitulation

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

Conventional physical rigid body (PRB)

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

<table>
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<tr>
<th>Typical model</th>
<th>Size</th>
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Overall study design

For a given trajectory of movement

Pose recovered from conventional rigid body

"Ground truth" pose recovered from the robot arm

Error comparison

Pose recovered from virtual rigid body

Virtual rigid body grid projection/detection

Grid processing/Defining a marker

Model fitting

(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

Pose recovered from conventional rigid body

“Ground truth” pose recovered from the robot arm

VRB grid component

Virtual rigid body grid projection/detection

Grid processing/Defining fiducials

Model fitting

Pose recovered from virtual rigid body

Error comparison
Analysis considerations

Trajectory types

For a given trajectory of movement

Pose recovered from conventional rigid body

“Ground truth” pose recovered from the robot arm

Error comparison

Error comparison

Pose recovered from virtual rigid body

Grid processing/Defining fiducials

Model fitting

VRB configurations

Virtual rigid body grid projection/detection

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Trajectory types

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

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

Tracked Poses: Traj_0430_2/

Tracked Poses: Traj_0430_7/

Motion

Trajectory

Robot pose

Marker pose

Projected points

VRB pose
Error comparison

• Relative motion
  - Relative motion consists of translation ($t$) and rotation ($\theta$)
  - Invariants: rigidly attached coordinates have same $t$ and $\theta$

• 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

• Δt, Δθ error computed for all relative motion

Tracked Poses: Traj_0430

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

Analysis

- Error comparison

- vrb: 11 12 16 17
- res: 64.52
VRB configurations

• What VRB configurations promote higher tracking accuracy?

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![VRB configurations diagram](image)
VRB configurations

Tracked Poses: Traj_0430

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

Selected points

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• Size

Tracked Poses: Traj_0430_2/

VRB configurations

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

• Analysis

Selected points
VRB configurations

- Shape

Tracked Poses: Traj_0430_

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

Selected points

vrb: 12  13  17  18, res: 3.187e+04

marker robot

x

y

z

θ difference

t difference

θ difference

t difference

rad

mm

Selected points

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VRB configurations

• Shape

Tracked Poses: Traj_0430.

- robot
- marker
- vrb: 0 7 11 18, res: 1.788

Selected points

*Analysis*

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

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VRB configurations

- **Number**

Tracked Poses: Traj_0430

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

Selected points

```
Tracked Poses: Traj_0430
```

```
vrb: 0   4  15  19   8, res: 7.934
```

• Evaluation and optimization of virtual rigid body
• 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
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Questions?