Virtual Rigid Body: Design Optimization and Performance Analysis

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Project Synopsis

1. Pipeline was constructed for repeatable and consistent acquisition of optical tracking data from virtual and conventional rigid body.
2. Designs of virtual rigid body (VRB) were configured.
3. Performance of VRB from different configurations was evaluated, and compared with that of conventional rigid body.

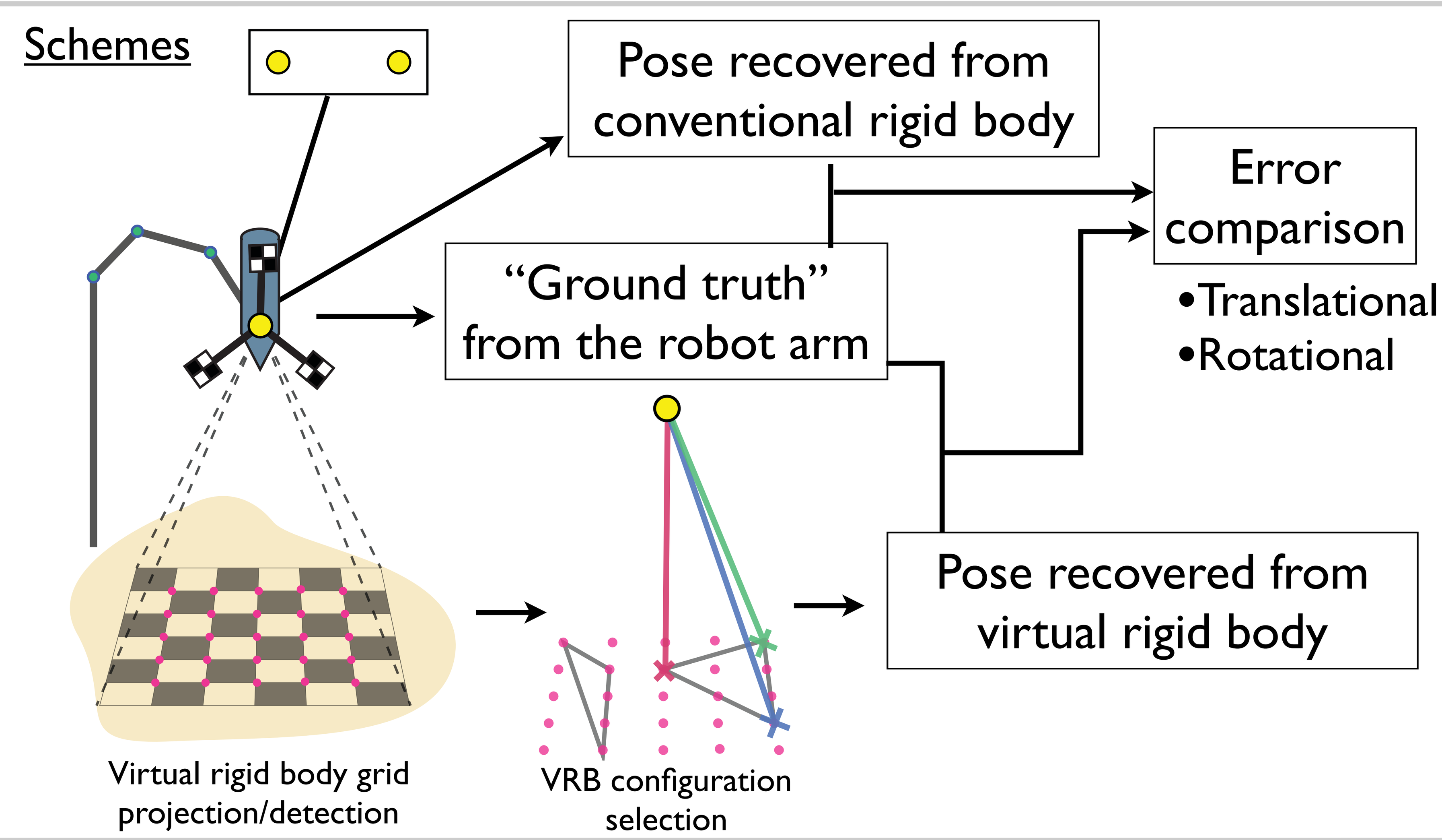
The Problem

- In laparoscopic setting where a surgical tool has to be tracked within very restricted space, conventional optical tracking is limited.
  - Physical fiducials interfere with surrounding environment
  - Narrower fiducial distribution → limited tracking accuracy
  - Easily slips out of camera's field of view
- Using projected light pattern as fiducials addresses such problems: "*virtual*" rigid body (VRB), recently coined by (Cheng et al., 2014).
- VRB accuracy under different operating conditions has not been extensively analyzed.
  - Ex) Geometric configuration of VRB, tool movement trajectories

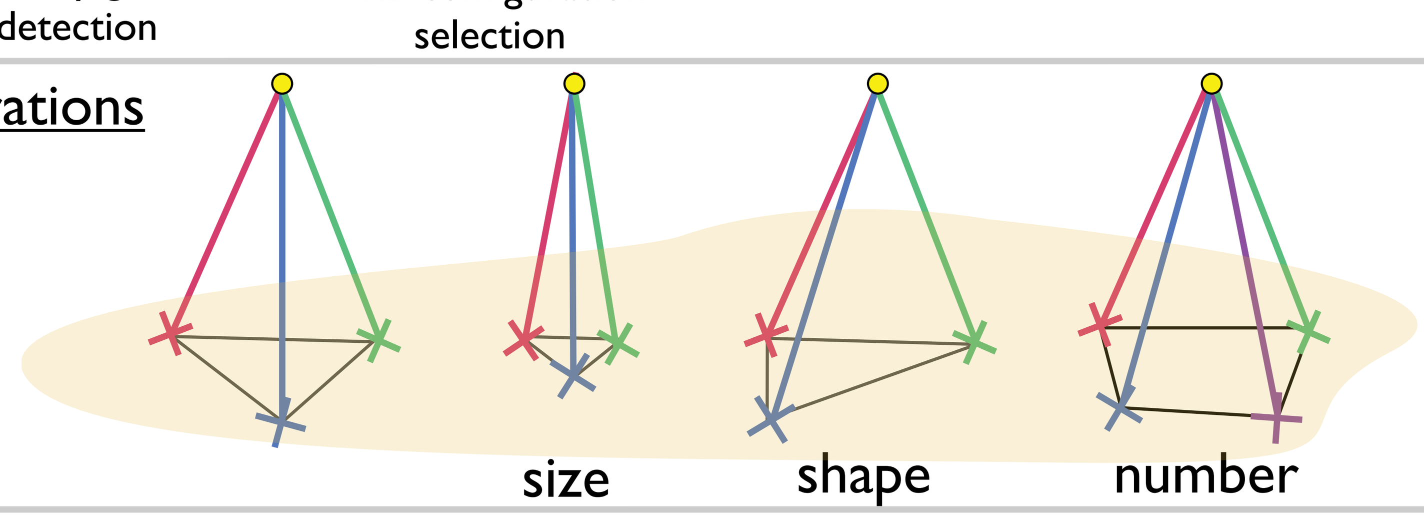
The Solution

1. Develop a pipeline for repeatable, consistent experiments.
   - Robot arm: programmable "ground truth" movements
   - MicronTracker: unified optical tracking platform for fiducial detection
2. For simple trajectories, compare translational and rotational errors of poses recovered from physical marker, and from VRB of several designs.

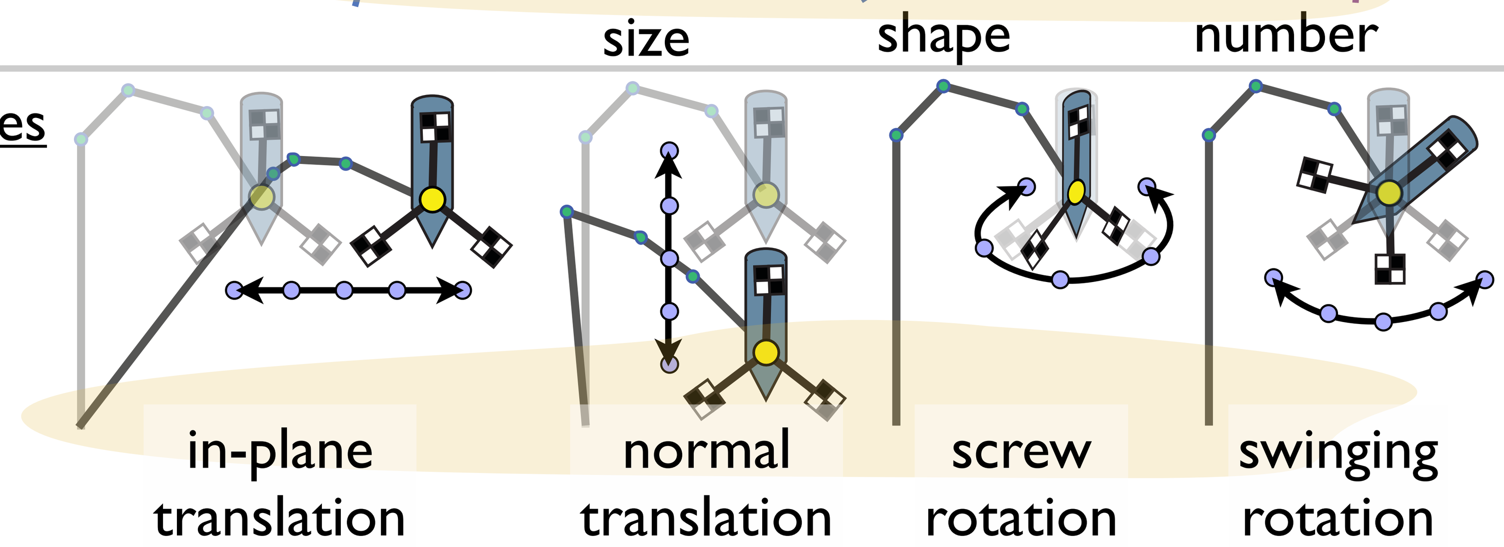
<u>Schemes</u>



<u>VRB configurations</u>



<u>Trajectories</u>



<u>Error definition for each motion</u>

For $F_{ij} = [R, \vec{t}]$ between poses i and j,

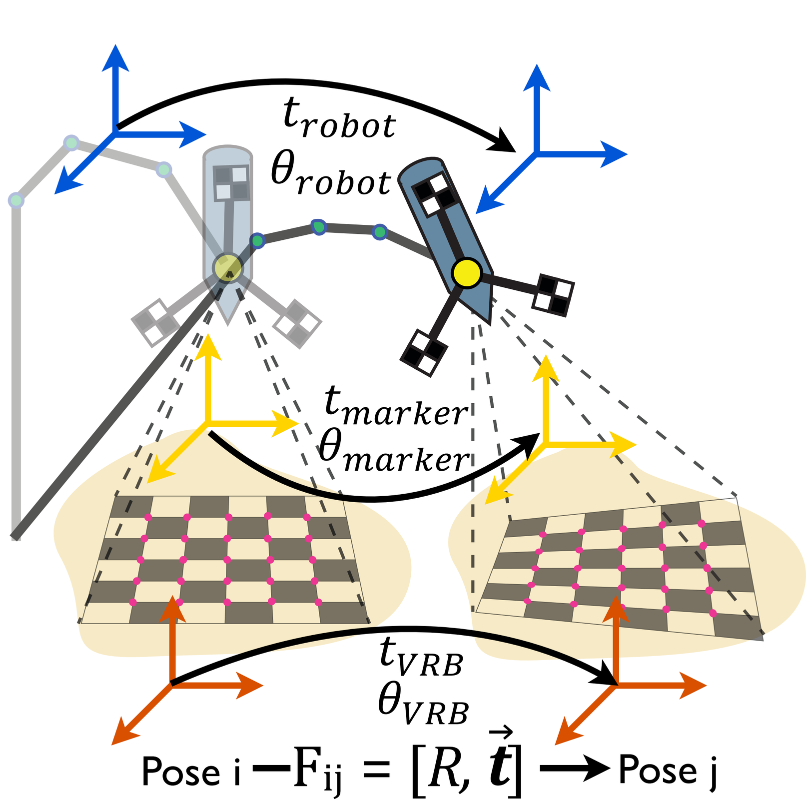
$$\theta = \arccos((trace(R) - 1)/2)$$
$$t = |\vec{t}|$$

For translation,

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

For rotation,

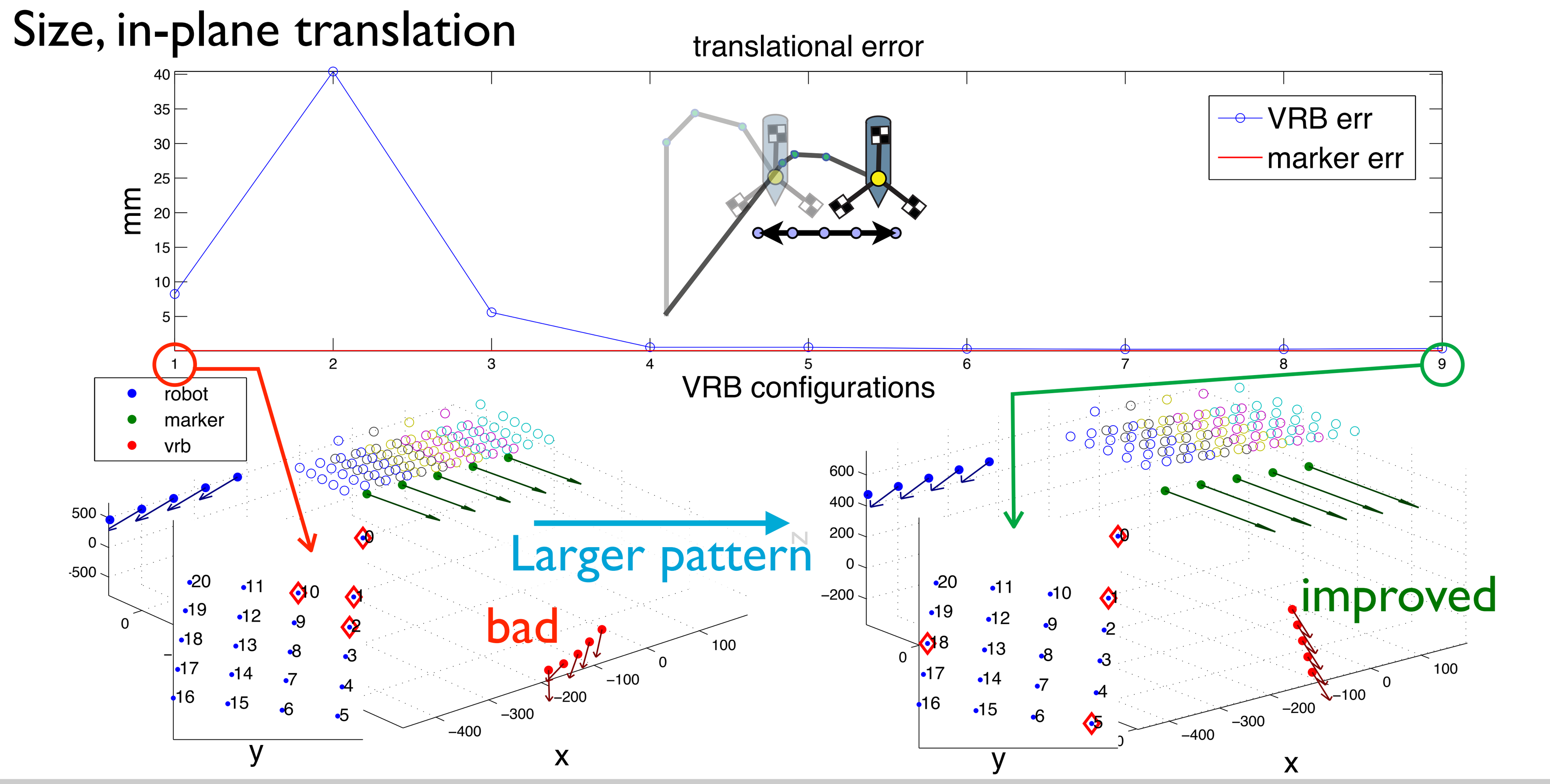
$$\Delta\theta_{marker} = |\theta_{marker} - \theta_{robot}|$$
$$\Delta\theta_{VRB} = |\theta_{VRB} - \theta_{robot}|$$



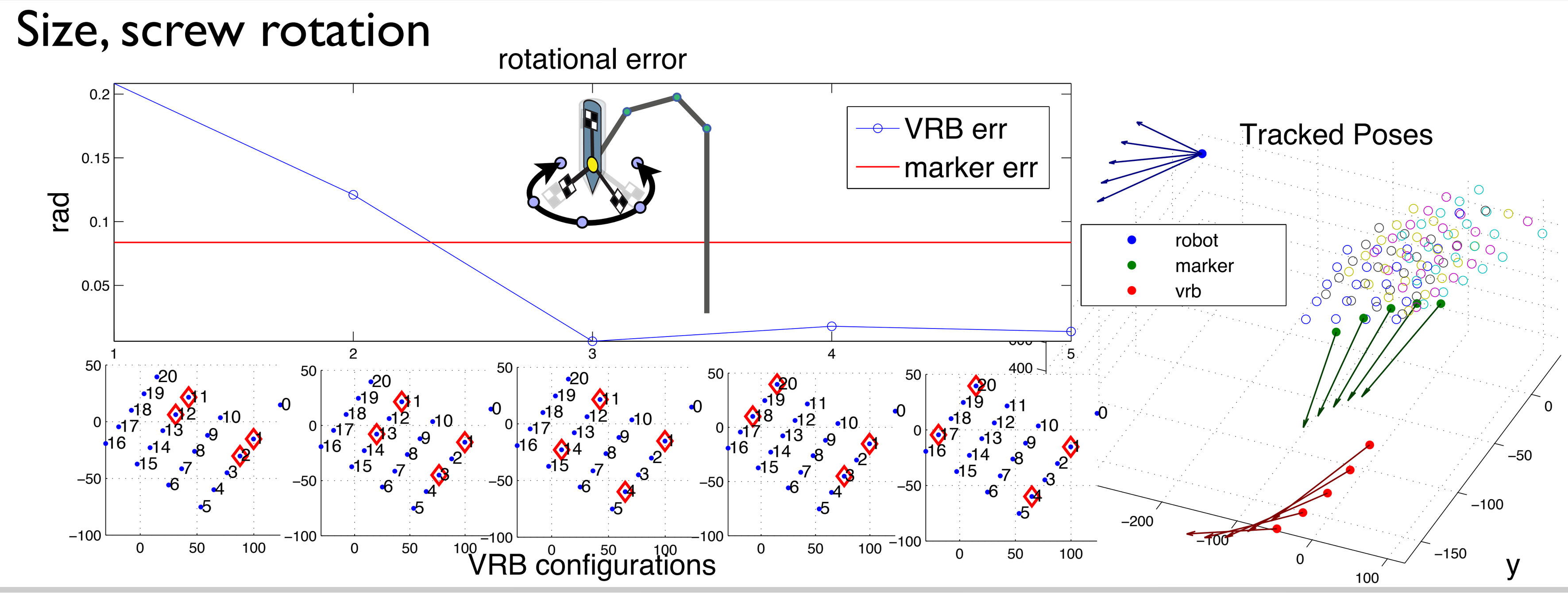
Outcomes and Results

- VRB performed comparably with conventional rigid bodies.
  - For <u>translational</u> motion, conventional rigid body performed better. (0.04 vs. 0.6 mm)
  - For <u>rotational</u> motion, VRB performed better. (0.052 vs. 0.097 rad)
- VRB configurations vs. accuracy pattern was qualitatively observed.
  - Tracking accuracy generally increases with bigger projection.
    - farther from the centroid of selected virtual fiducials
    - farther from each other

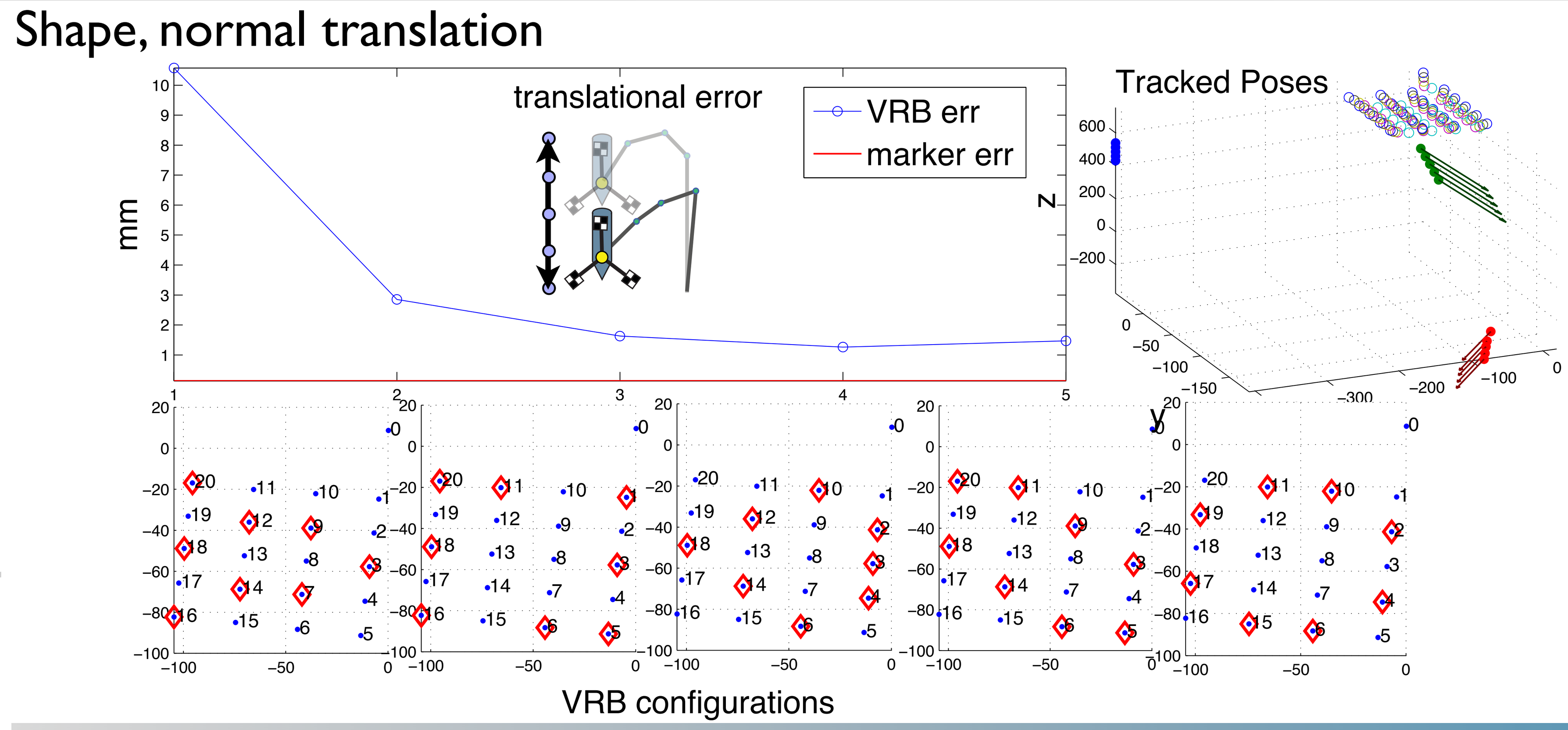
Size, in-plane translation



Size, screw rotation



Shape, normal translation



Future Work

- Quantitative analysis of VRB configurations
- Analysis on composite motions
- More robust error metrics
- External detection method for projected patterns

Lesson Learned

- Better understanding of optical tracking and errors
- Knowledge on robot arms
- Presentation skills and necessity for learning
- A taste of designing and running a research project

Literature

- Cheng et. al., *Virtual Rigid Body*, CARS, 2014
- West et. al., *Designing Optically Tracked Instruments*, IEEE Med. Img., 2004
- J.A.Sánchez-Margallo, *Technical Evaluation of Optical Tracker*, CLIP, 2012

Acknowledgements

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