Project 16: Da Vinci Intelligent Surgical Assistance

Chris Paxton

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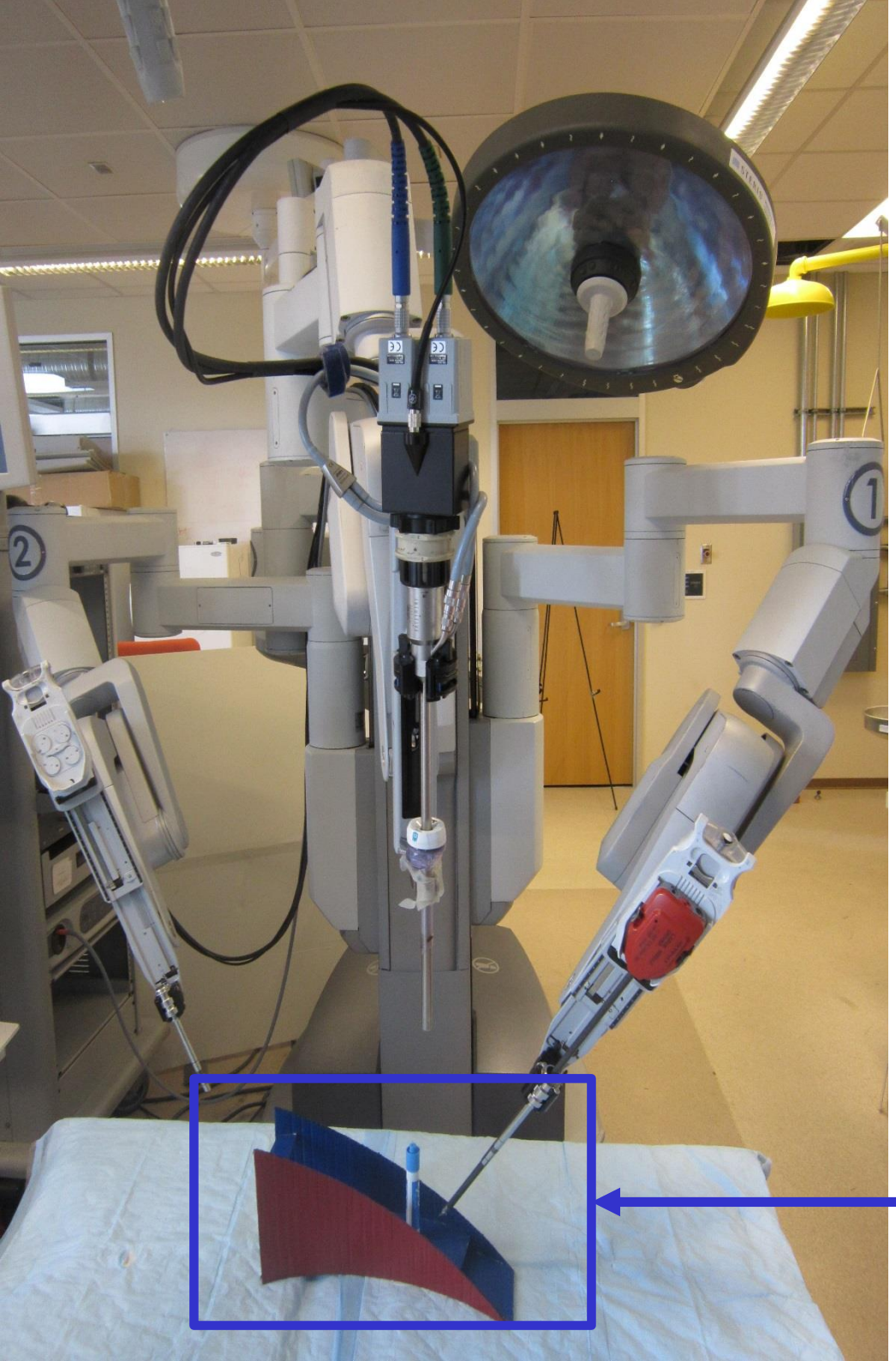


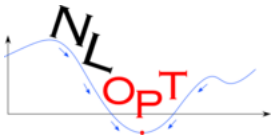
Goals

- Learning from demonstration how to perform tasks (IOC)
- Collaborative execution of a simple pick and place task
- Collaborative execution of a robotic suturing task

Dependencies

- Access to Da Vinci robot for experiments
- Access to surgical data, with video, camera positions, and robot kinematics
- Workstation with simulation capabilities for developing software

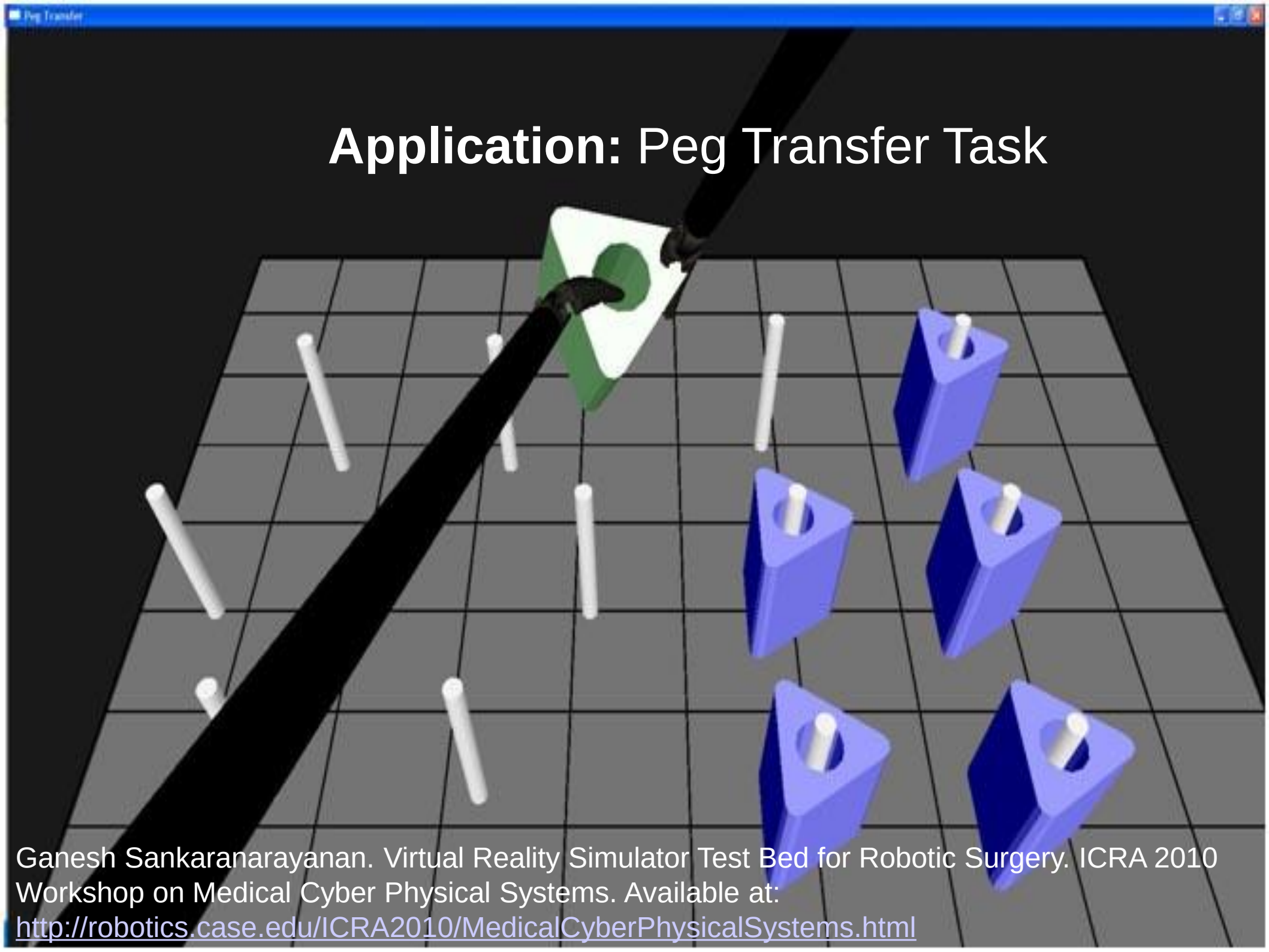
- OpenCV
- Gazebo
- ROS
- NLOPT (or other numerical optimization toolkit)
- ISI BB API



Specific Aims

- Formalize methods for modeling tasks and predicting user intentions
- Extract scene information from Da Vinci data
- Develop software to model portions of tasks
- Apply methods to simple test example
- Apply methods to Da Vinci example

Application: Peg Transfer Task



Ganesh Sankaranarayanan. Virtual Reality Simulator Test Bed for Robotic Surgery. ICRA 2010 Workshop on Medical Cyber Physical Systems. Available at: http://robotics.case.edu/ICRA2010/MedicalCyberPhysicalSystems.html

Deliverables

- **Minimum**
  - **Simple stereo** registration and reconstruction for collected Da Vinci video data *(done)*
  - **Planned approach** for modeling components of a procedure *(done)*
  - **IOC software** for computing task models *(in progress)*
  - **Simulation** peg transfer task set up, performed by human users *(in progress)*
- **Expected**
  - **Partial automation of peg transfer task**, running in the simulation environment *(in progress)*
  - **Tooltip-based stereo registration** to automatically register and extract visual features from collected Da Vinci data
- **Maximum**
  - **Partial automation of suturing task**
  - **Semi-automation toolkit** for use on other problems and on different robots *(in progress)*

Da Vinci Components

- **Complete:**
  - Loading kinematics data
  - Processing kinematics data and extracting specific gestures
  - Simple stereo calibration based on chessboard
- **Planned:**
  - Robust stereo registration
  - Implement IOC for suturing task

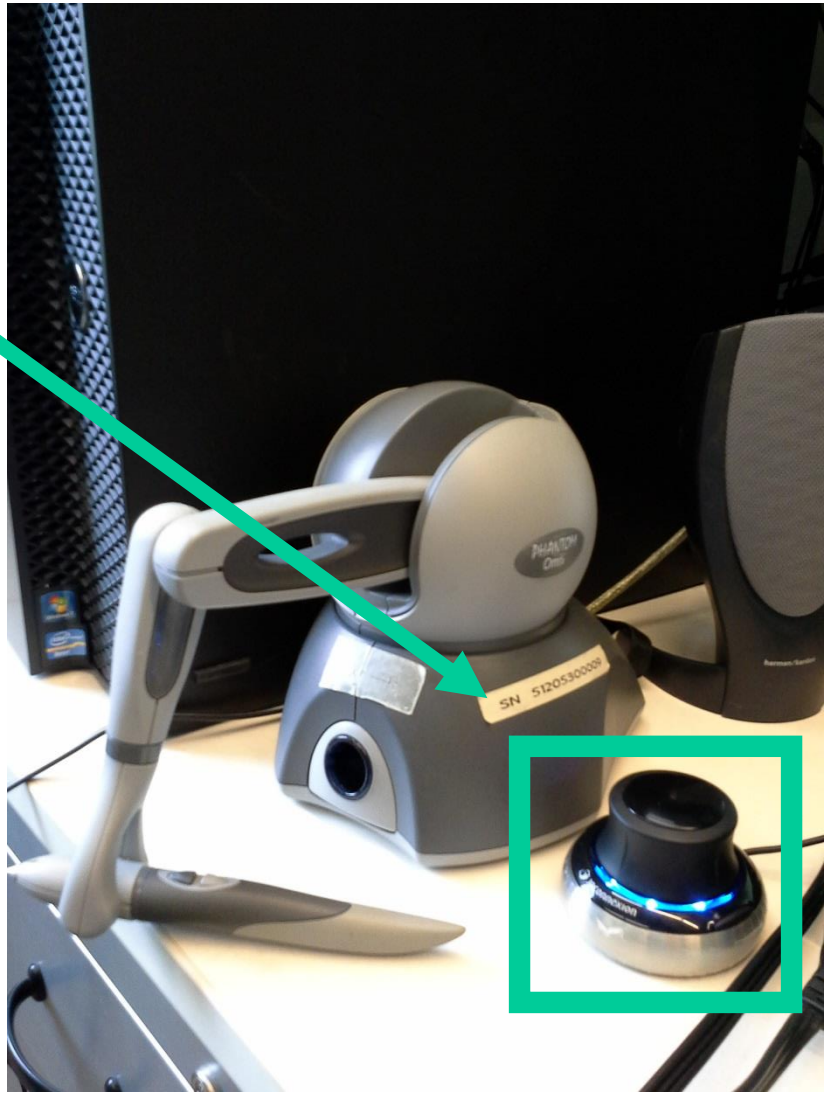
Delayed until summer: focusing on the simulation!

Updated Deliverables

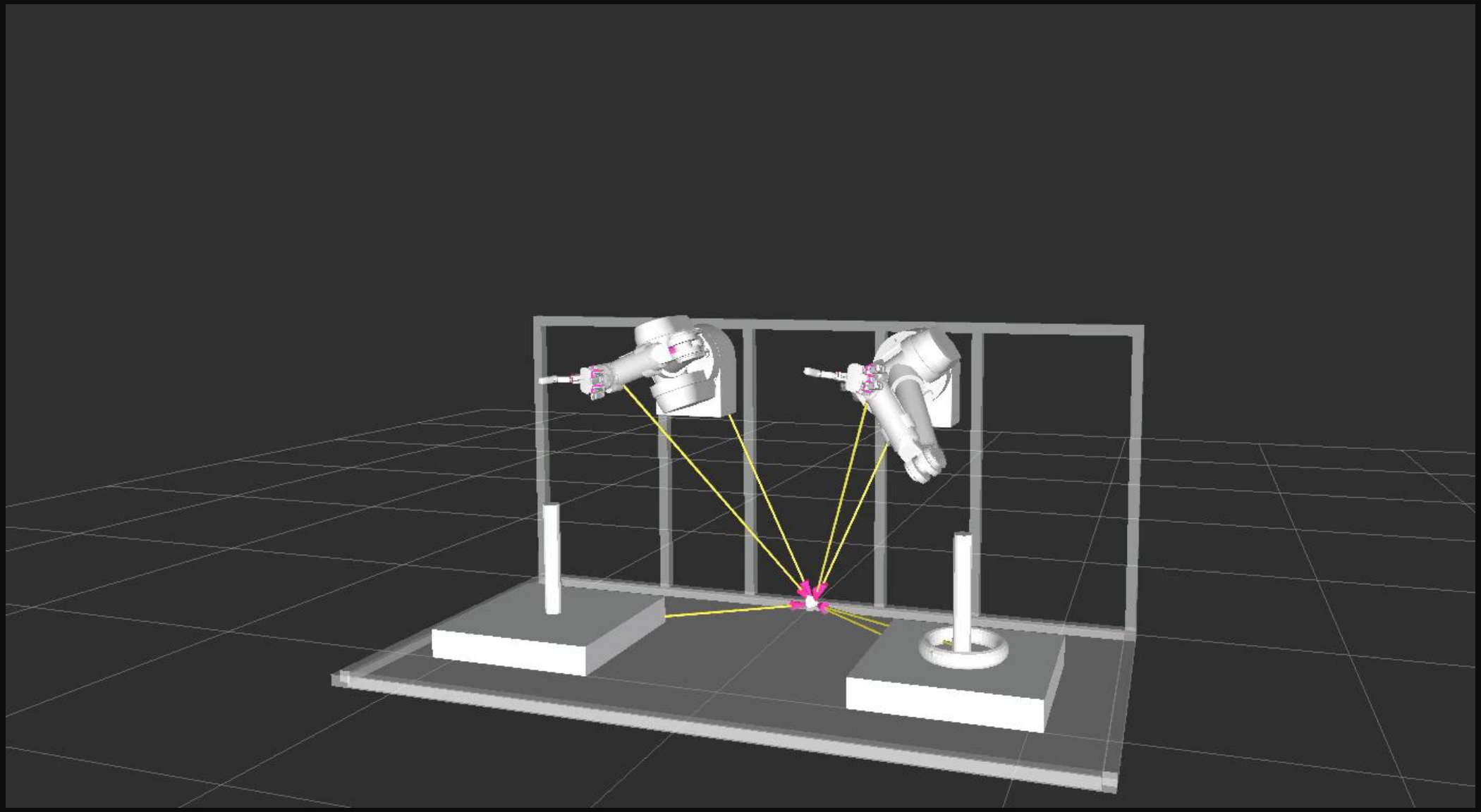
- **Minimum**
  - **Simple stereo** registration and reconstruction for collected Da Vinci video data *(done)*
  - **Planned approach** for modeling components of a procedure *(done)*
  - **IOC software** for computing task models *(in progress)*
  - **Simulation** peg transfer task set up, performed by human users *(in progress)*
- **Expected**
  - **Partial automation of peg transfer task**, running in the simulation environment *(in progress)*
  - **Semi-automation toolkit** for use on other problems and on different robots *(in progress)*
- **Maximum (delayed)**
  - **Partial automation of suturing task**
  - **Tooltip-based stereo registration** to automatically register and extract visual features from collected Da Vinci data

Controlling the Robot

- 3DConnexion Space Navigator mouse for robot control
  - X, Y, Z
  - roll, pitch, and yaw
- Buttons close the gripper in a preset way, switch current arm being controlled



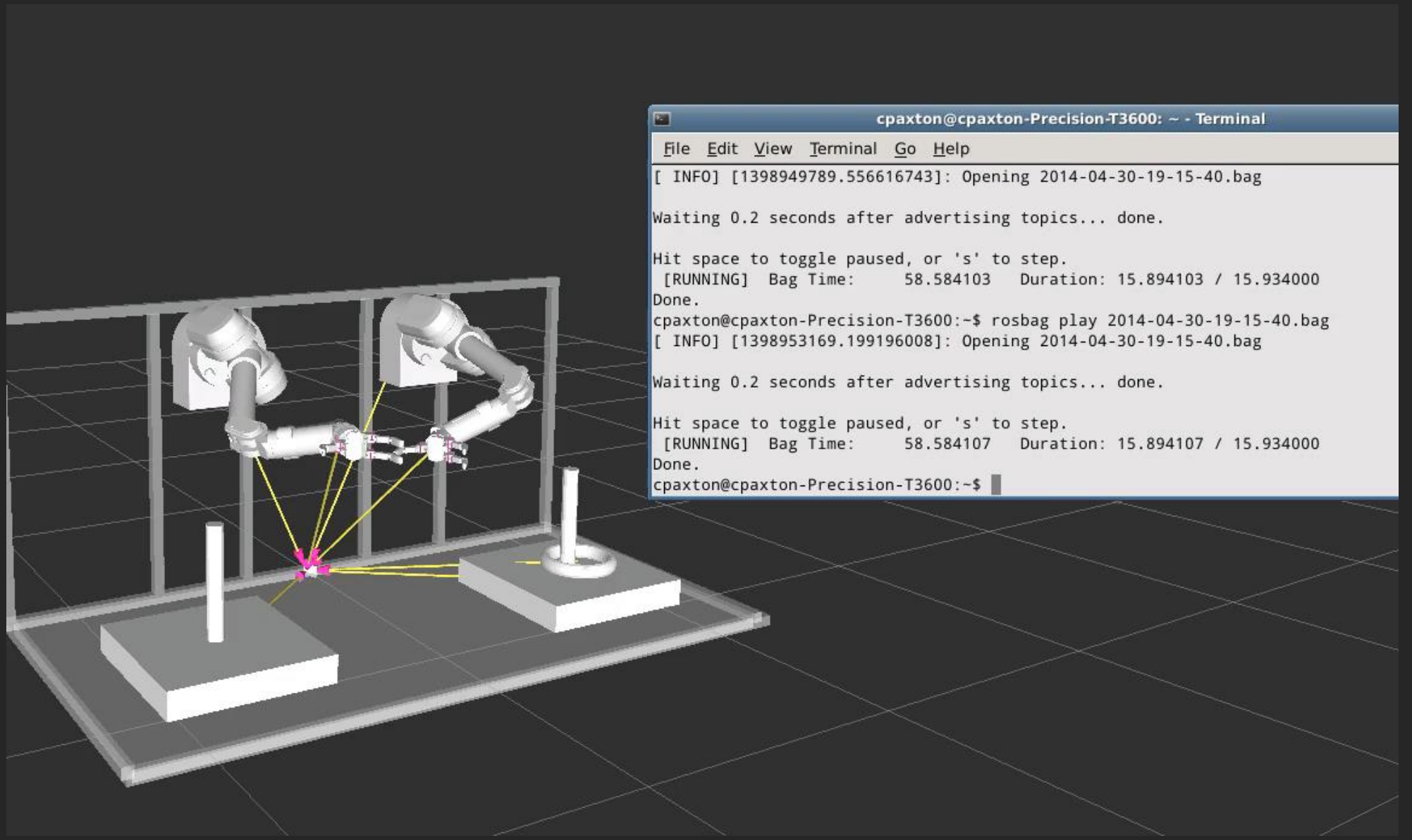
Peg Task Simulation



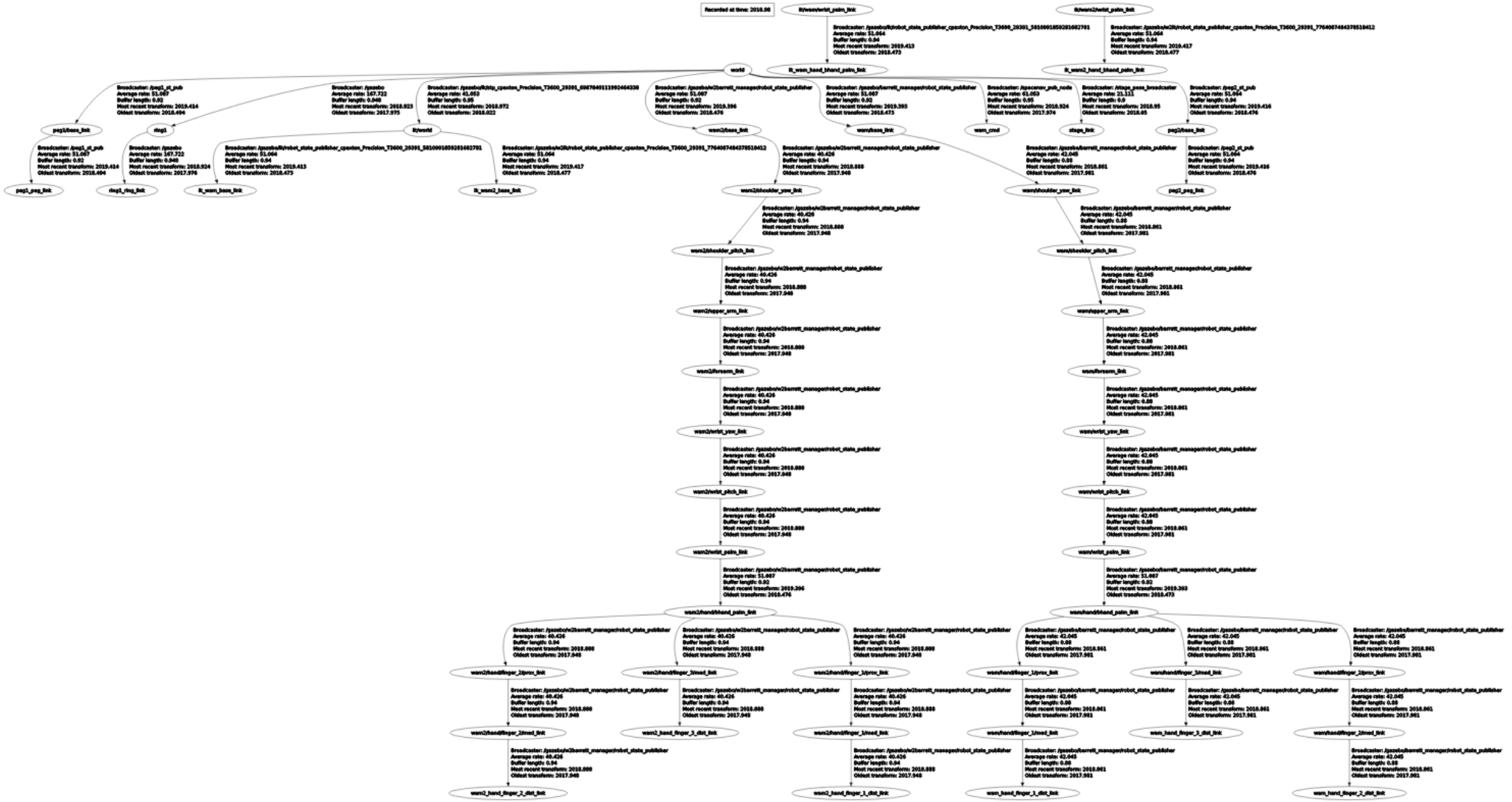
Recording: ROSBag

- Inverse kinematics commands published on ROS *topics*
- Command line utility can record these commands to be replayed later
- C++ and Python API exists for ROS bag files as well

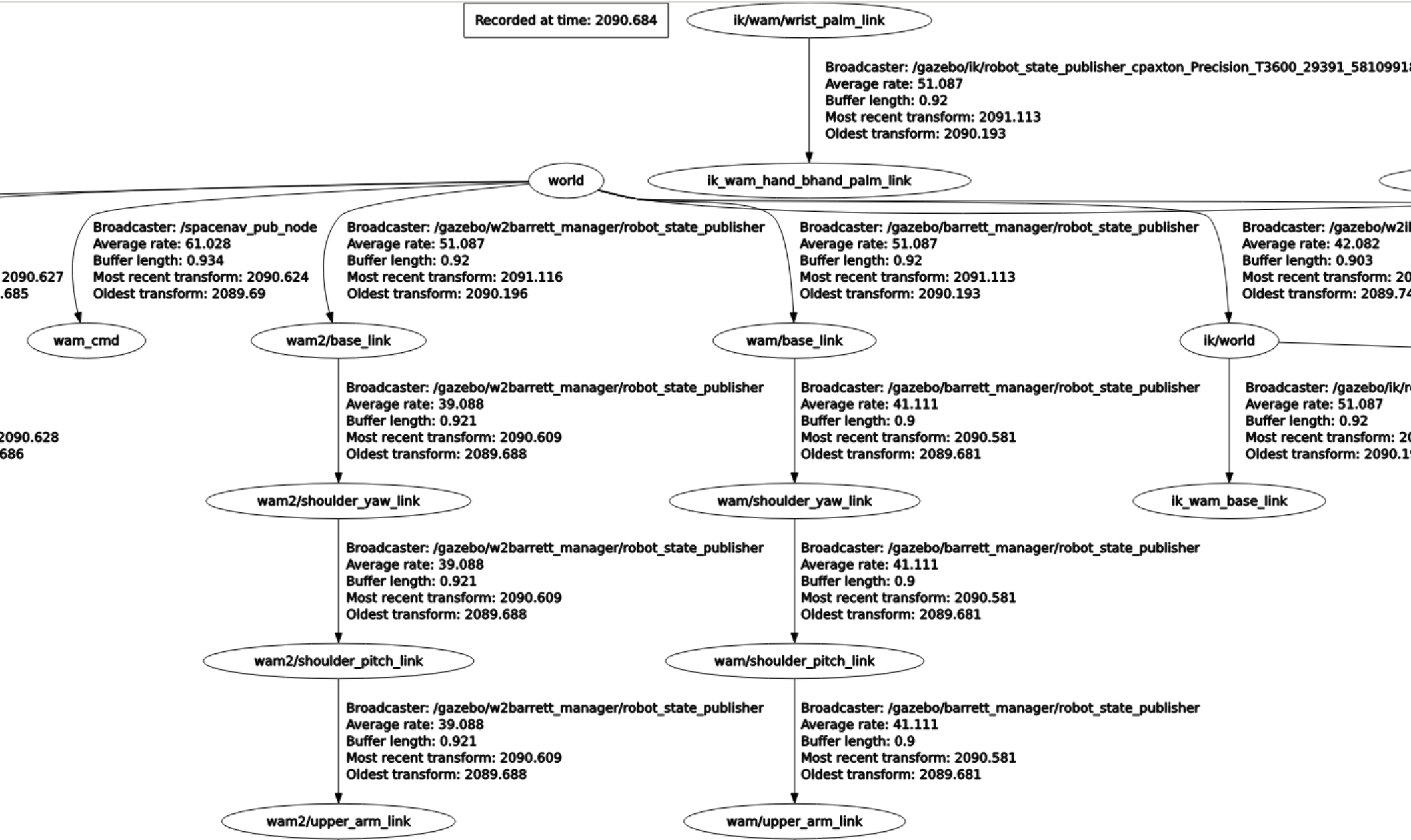
ROSBag Demo


cpaxton@cpaxton-Precision-T3600: ~ - Terminal
File Edit View Terminal Go Help
[INFO] [1398949789.556616743]: Opening 2014-04-30-19-15-40.bag
Waiting 0.2 seconds after advertising topics... done.
Hit space to toggle paused, or 's' to step.
[RUNNING] Bag Time: 58.584103 Duration: 15.894103 / 15.934000
Done.
cpaxton@cpaxton-Precision-T3600:~$ rosbag play 2014-04-30-19-15-40.bag
[INFO] [1398953169.199196008]: Opening 2014-04-30-19-15-40.bag
Waiting 0.2 seconds after advertising topics... done.
Hit space to toggle paused, or 's' to step.
[RUNNING] Bag Time: 58.584107 Duration: 15.894107 / 15.934000
Done.
cpaxton@cpaxton-Precision-T3600:~$

Features: TF Tree



Features: TF Tree



Plan: Inverse Optimal Control

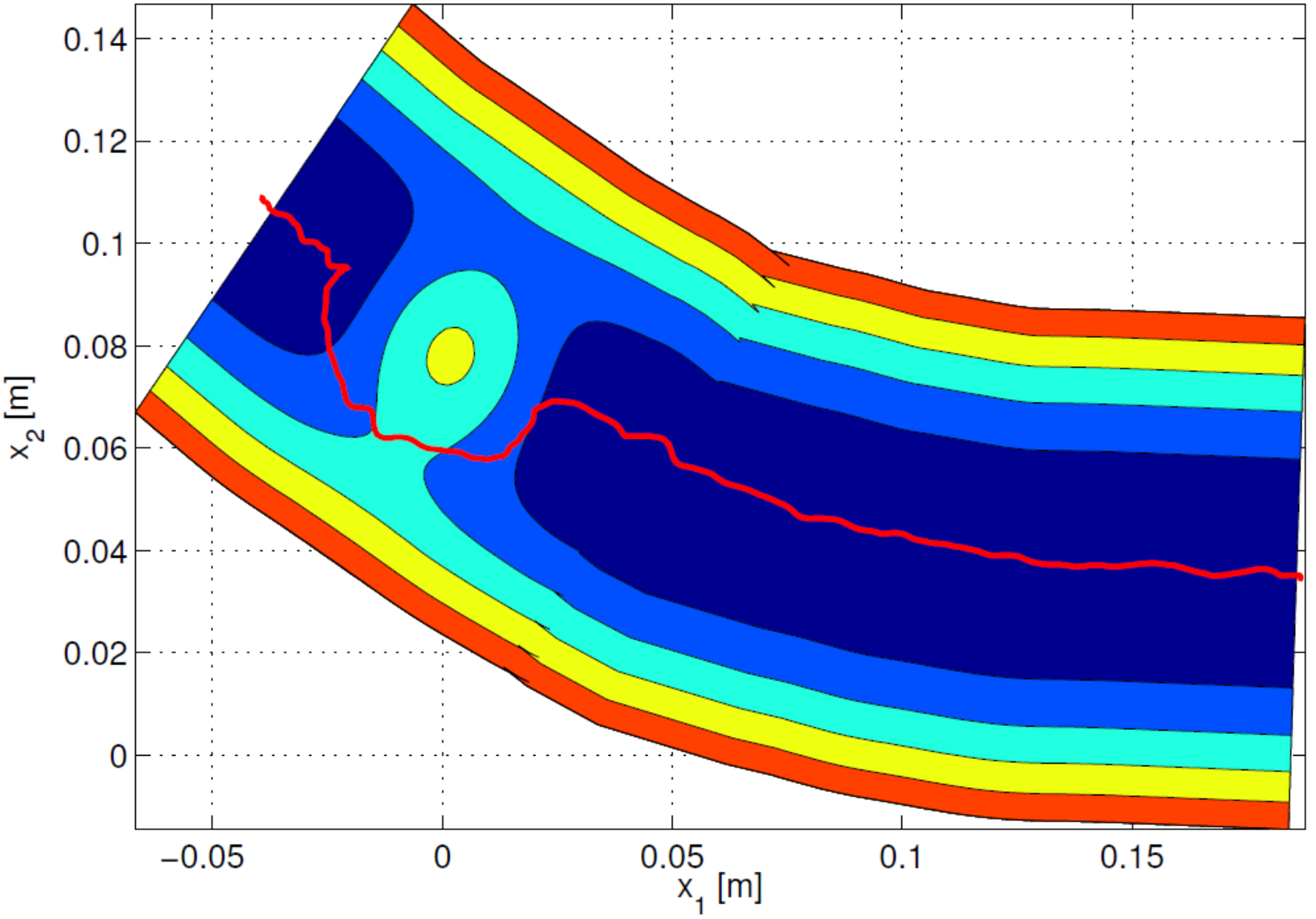
For all future states reached

$$P(S_i \mid S_{i-1}) \propto \frac{1}{Z} \sum_{j=i}^{n-1} e^{\theta f(S_j^d)}$$

The probability of choosing an action at a given state

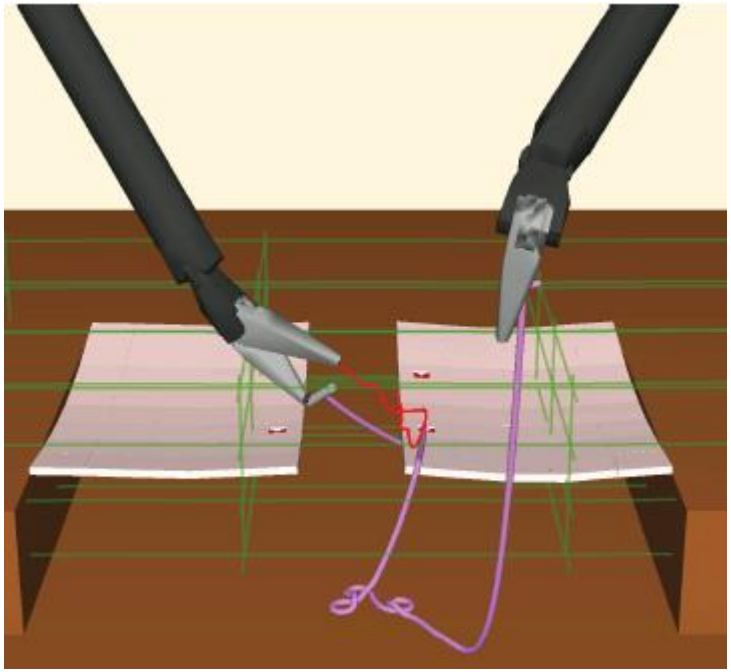
Weighted feature responses at that state

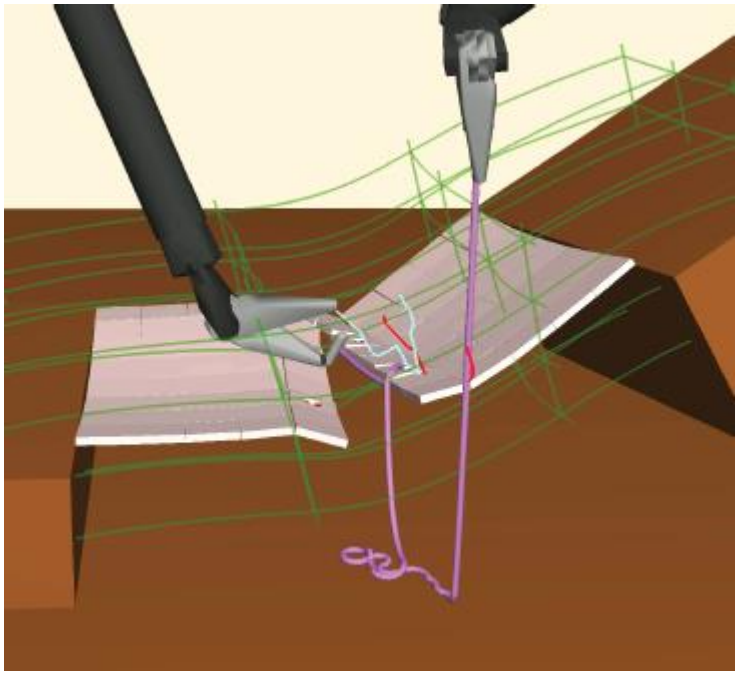
Plan: Learn Reward Function to adapt trajectory to new environment



Amir M. Ghalamzan E., Chris Paxton, Gregory Hager, and Luca Bascetta. Robot learning from demonstration: from imitation to emulation. Submitted to IROS, 2014.

Plan: Adapting a trajectory to a new environment





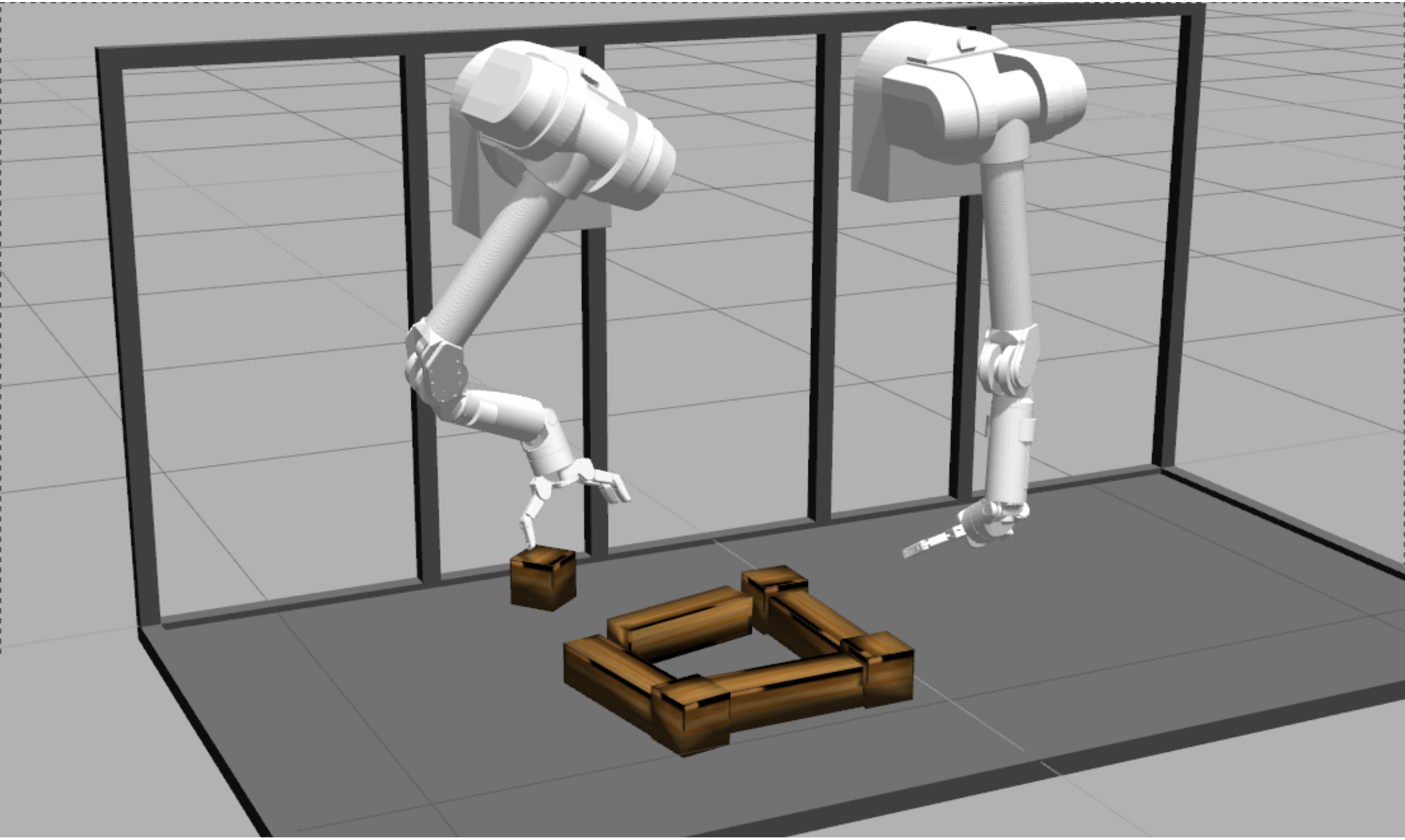
- Approach may be based off of work by Schulman et al. and Amir Masoud
- Extension of trajectory warping

John Schulman, Ankush Gupta, Sibi Venkatesan, Mallory Tayson-Frederick, and Pieter Abbeel. A case study of trajectory transfer through non-rigid registration for a simplied suturing scenario. In Intelligent Robots and Systems (IROS), 2013 IEEE/RSJ International Conference on, pages 4111{4117. IEEE, 2013.

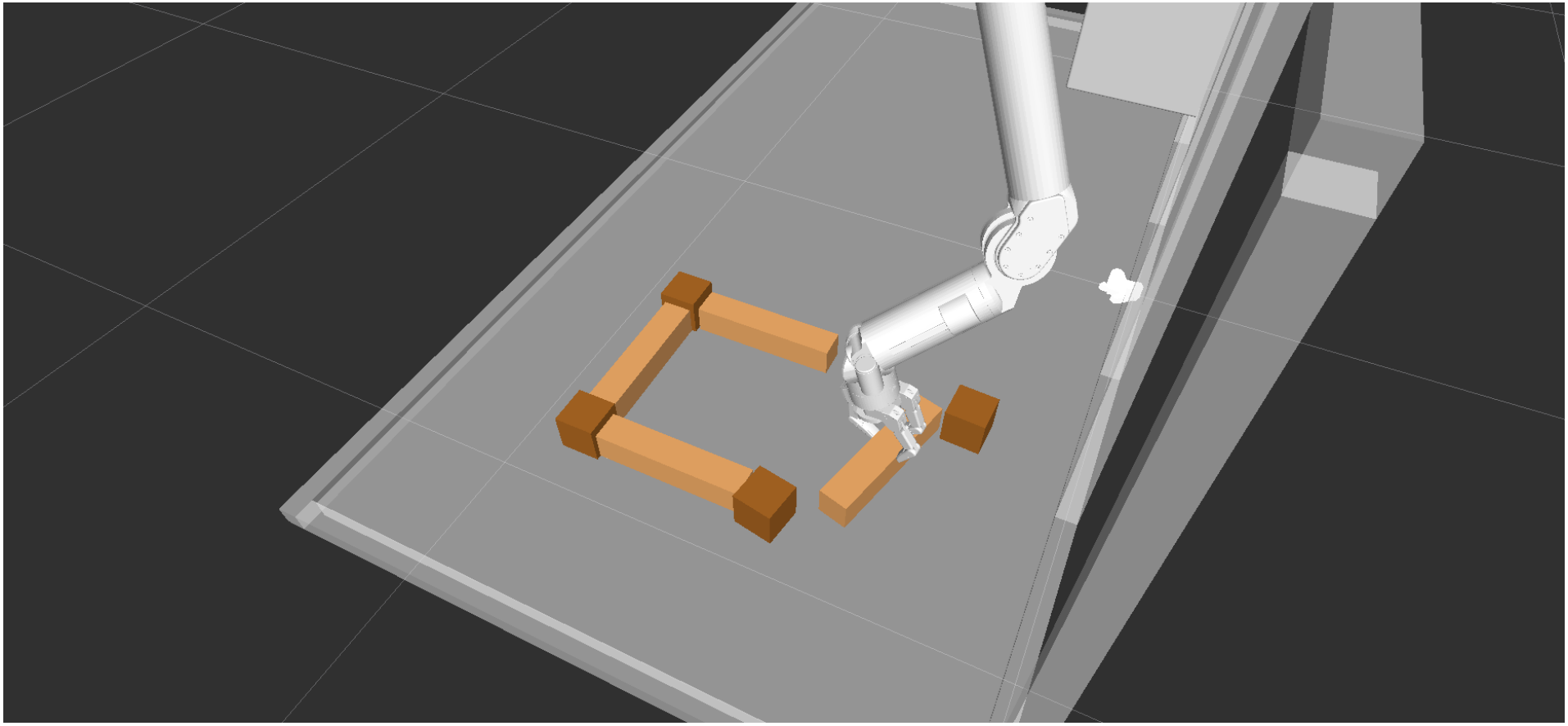
Collaboration Tools

- Documentation online: LCSR intranet wiki
  - Code has been successfully distributed to other members of CIRL
- Additional tasks:
  - Magnetic joints
  - Construction tasks

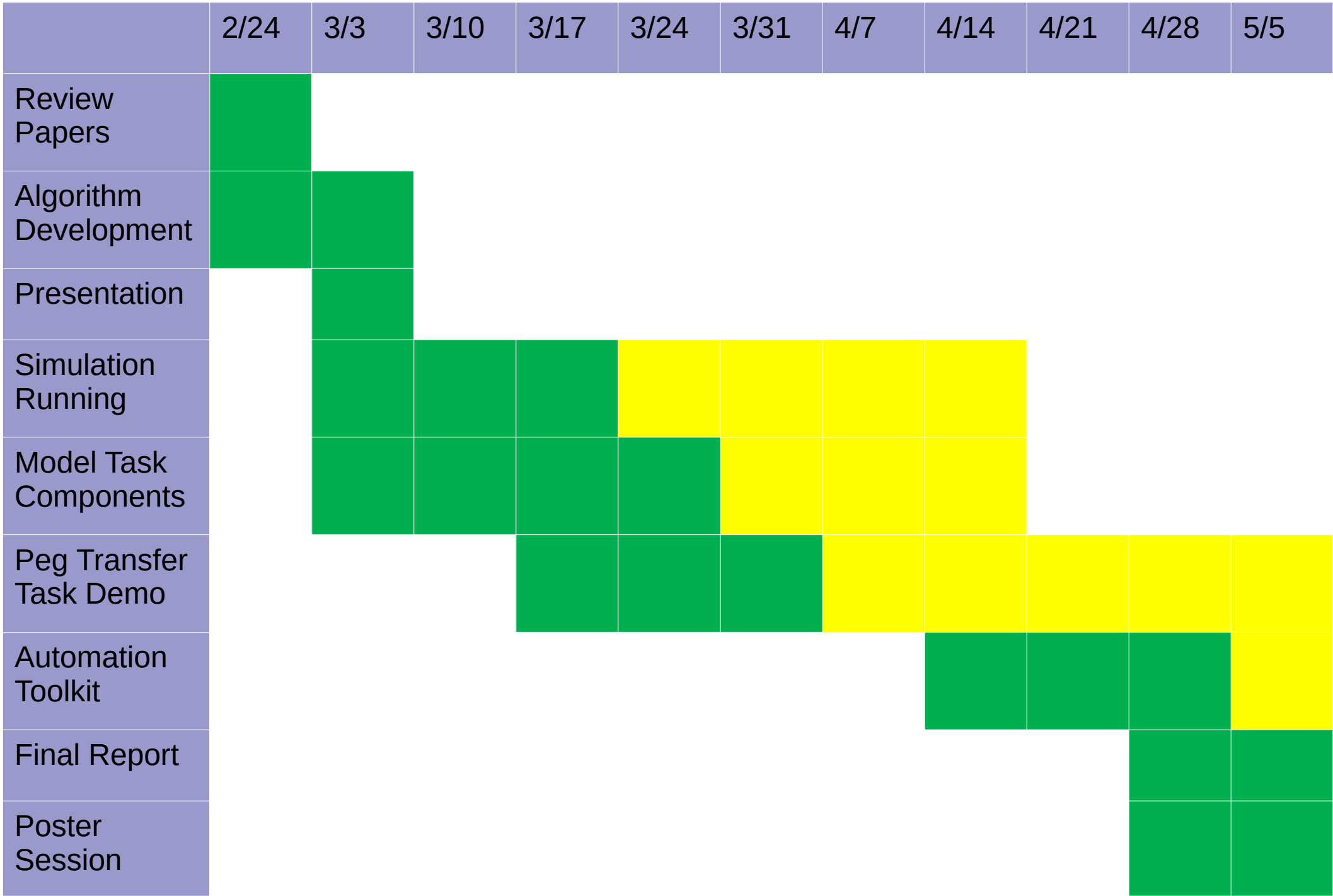
Construction Example



Construction Example: RVIZ UI



Current Timeline



Questions?