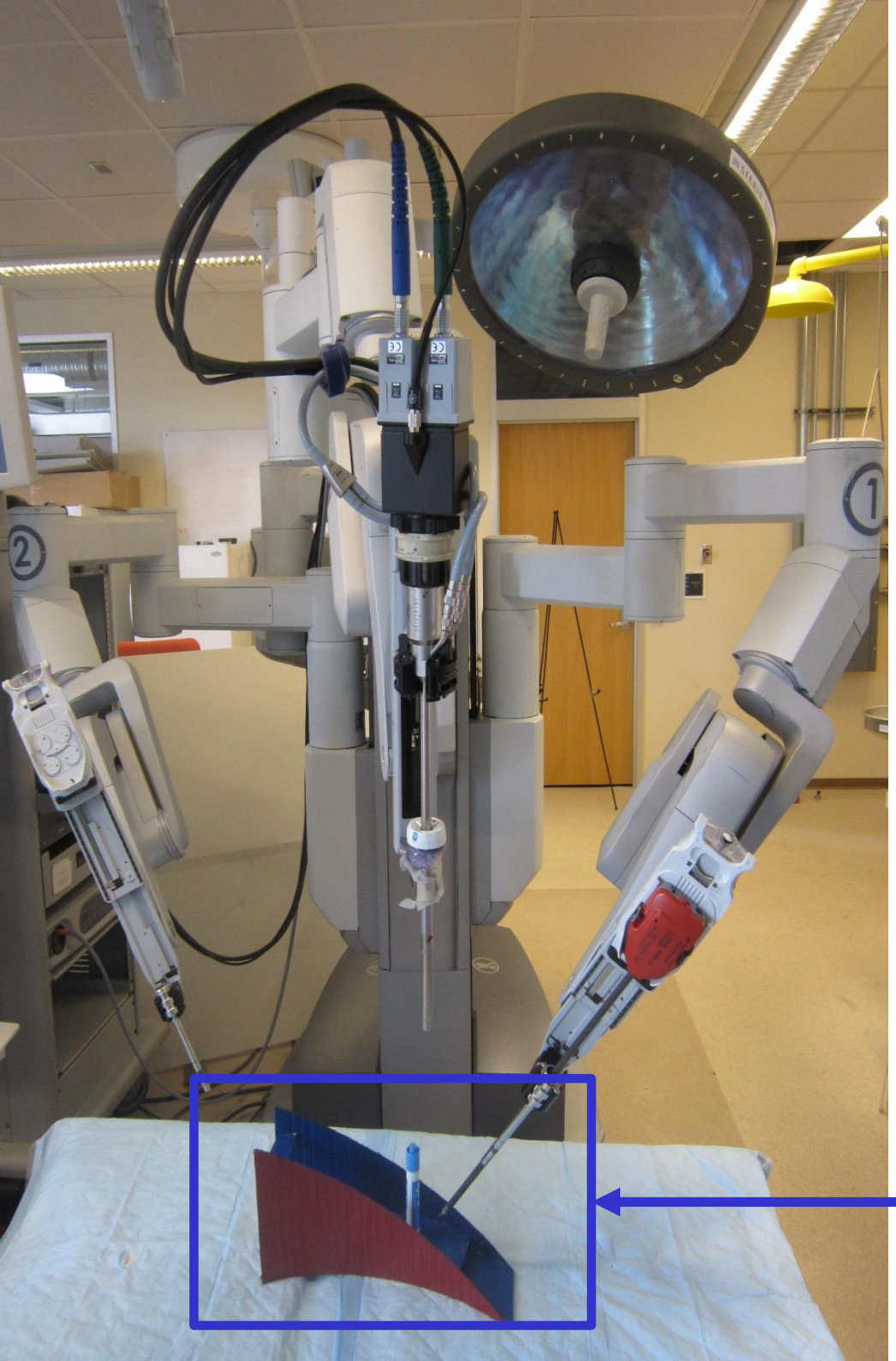
Project 16: Da Vinci Intelligent Surgical Assistance

Chris Paxton

Mentors: Kel Guerin, Jon Bohren, Prof. Greg Hager



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

Inverse Optimal Control

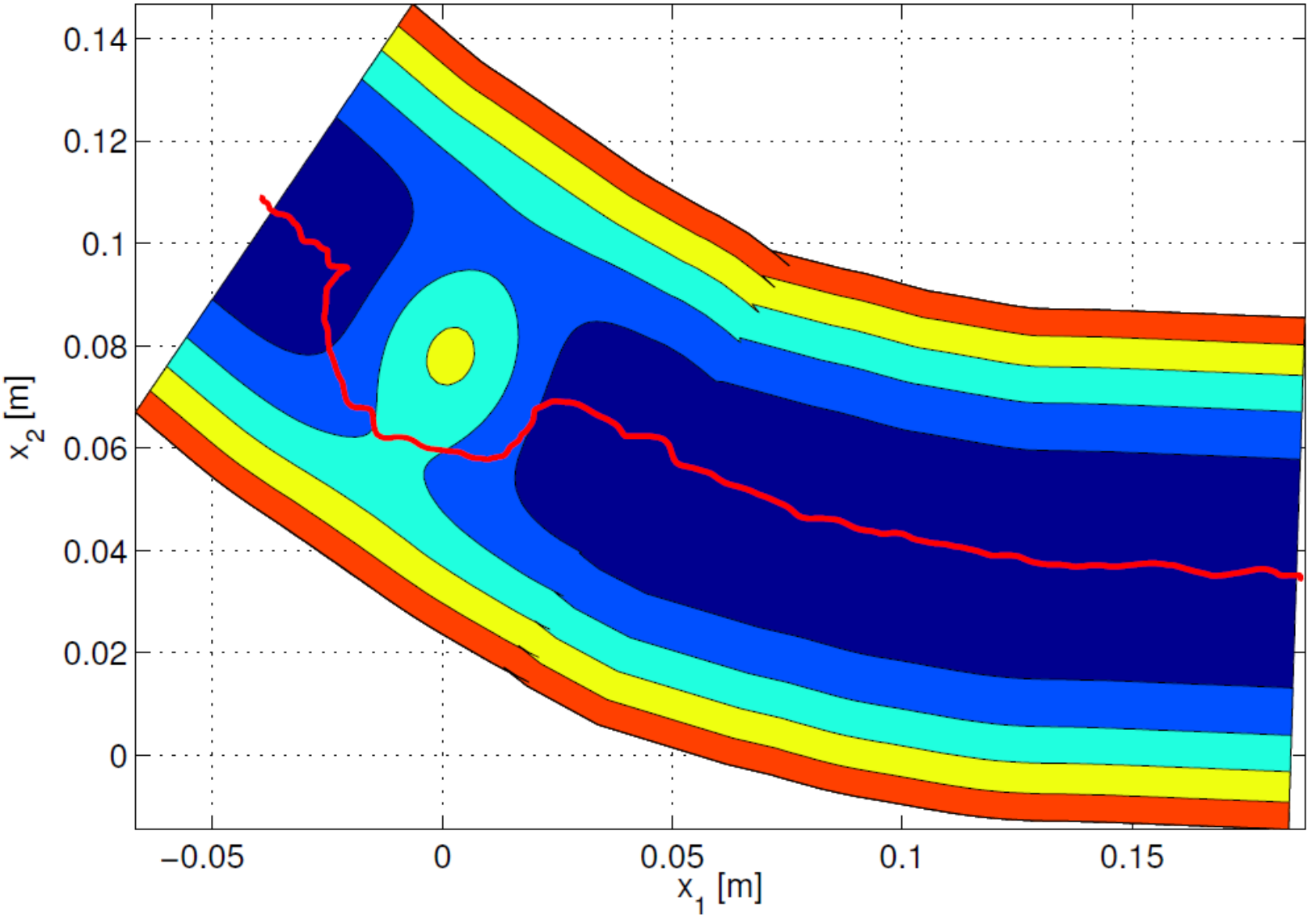
For all future states reached

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

The probability of choosing an action at a given state

Weighted feature responses at that state

Reward Function relates observed change in state to observed features of the environment.

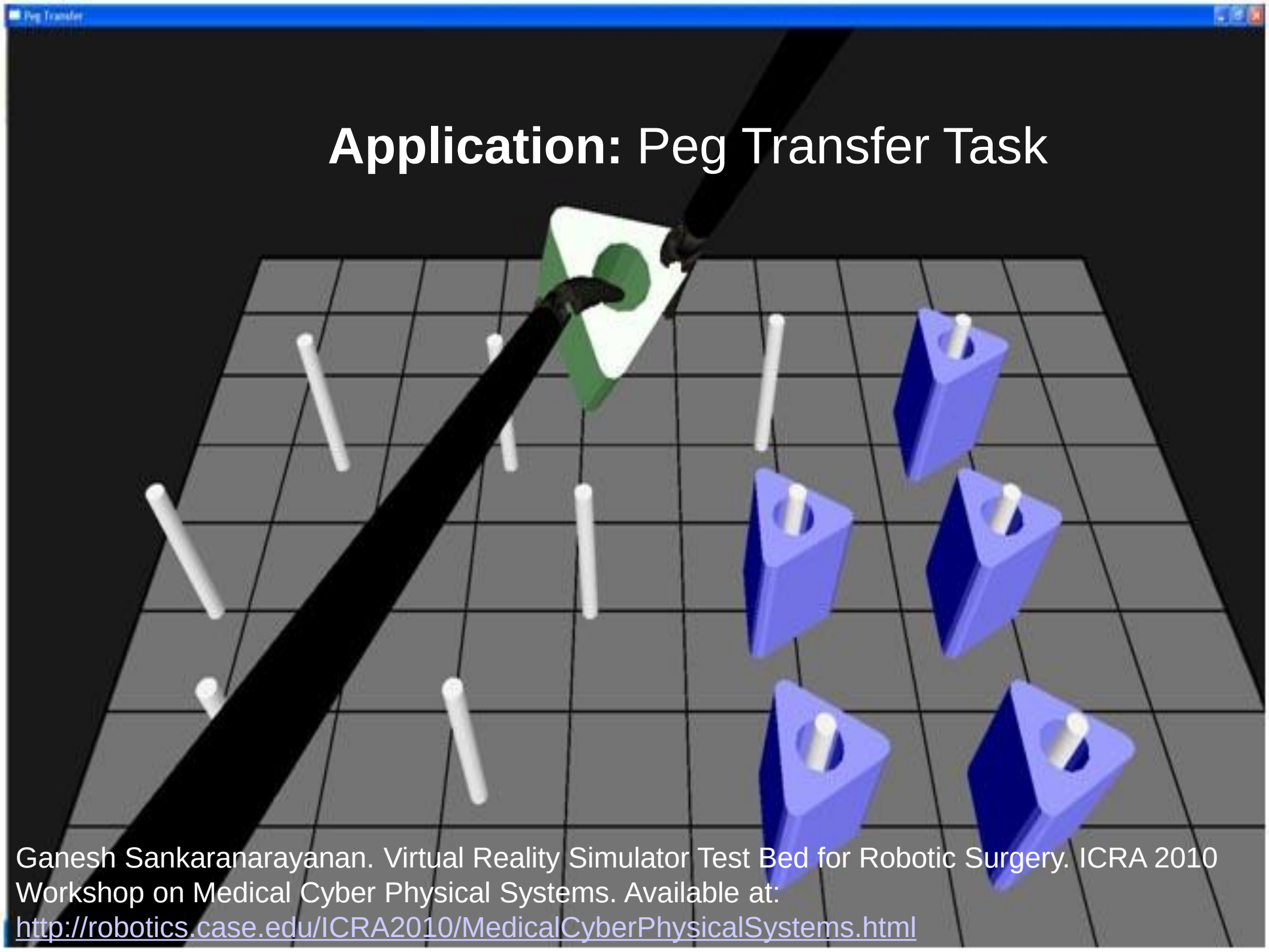


Amir M. Ghalamzan E., Chris Paxton, Gregory Hager, and Luca Bascetta. Robot learning from demonstration: from imitation to emulation. Submitted to IROS, 2014.

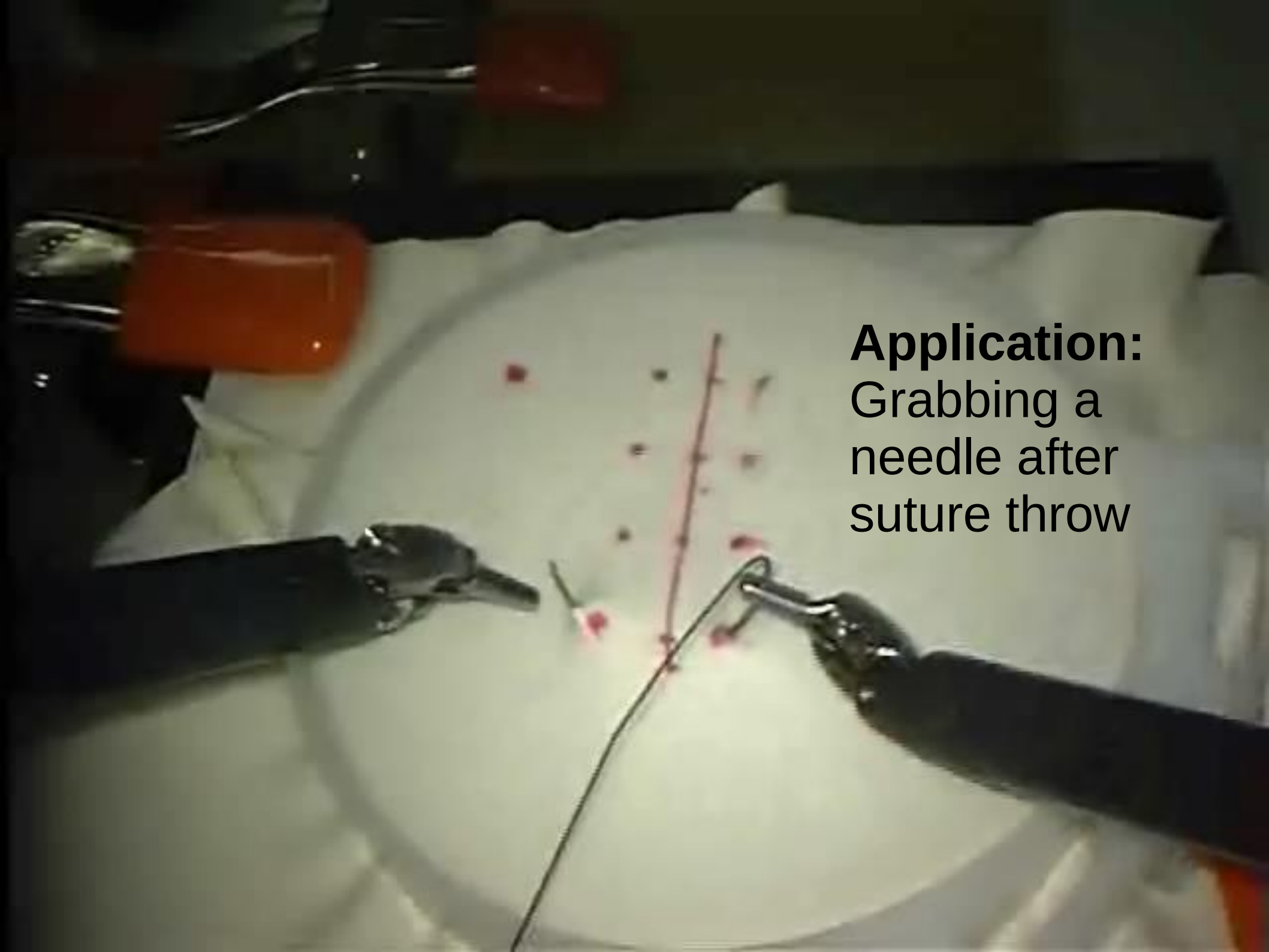
Specific Aims

- 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


Application:
Grabbing a needle after suture throw

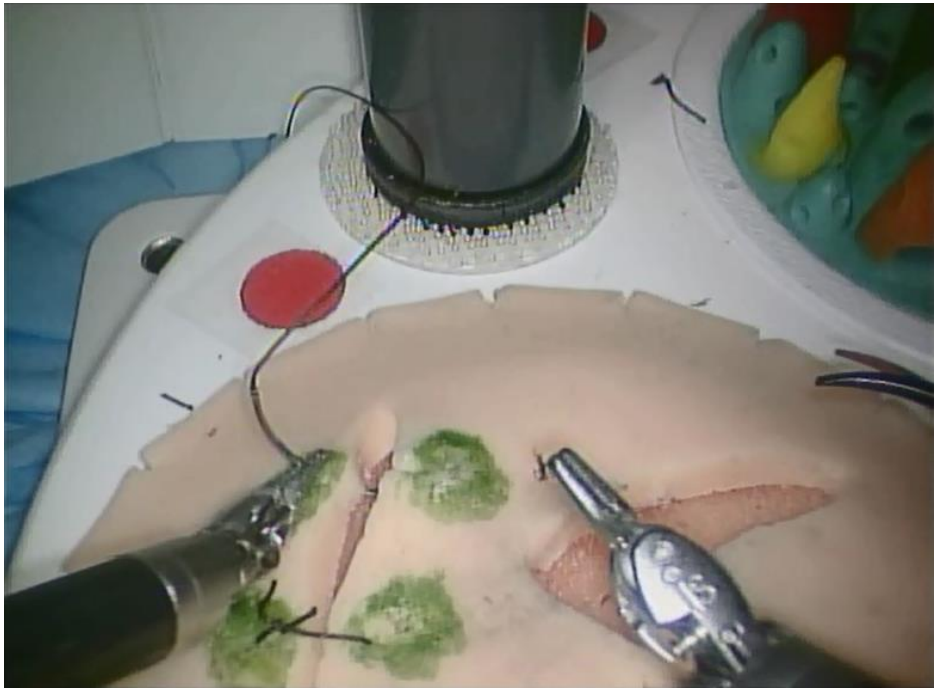
Deliverables

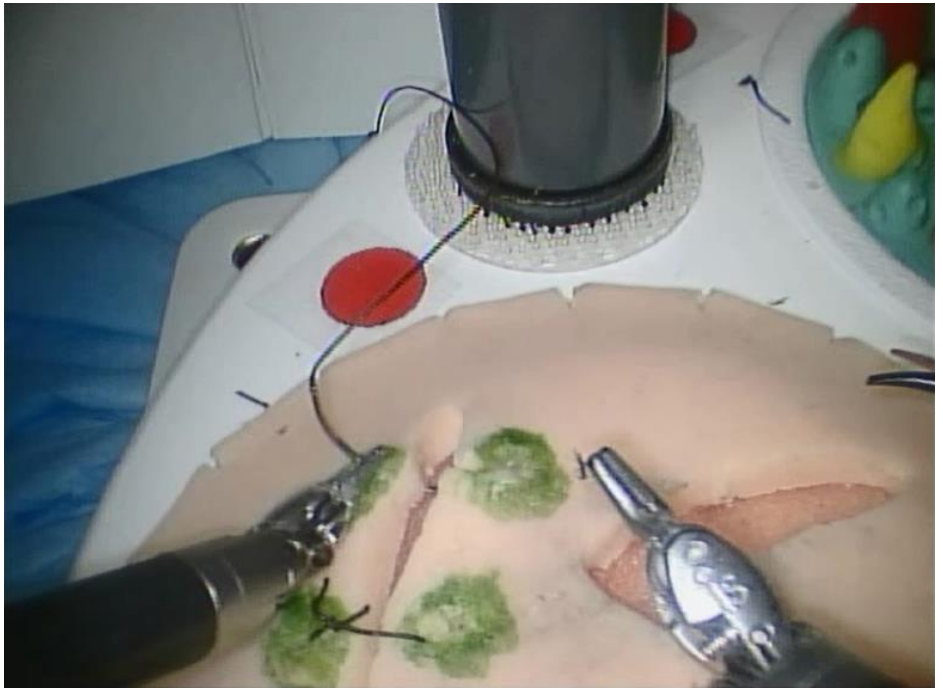
- **Minimum**
  - **Simple stereo** registration and reconstruction for collected Da Vinci video data *(done)*
  - **Planned approach** for modeling components of a procedure *(done)*
  - **IOC software** for computing task models *(in progress)*
  - **Simulation** peg transfer task set up, performed 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

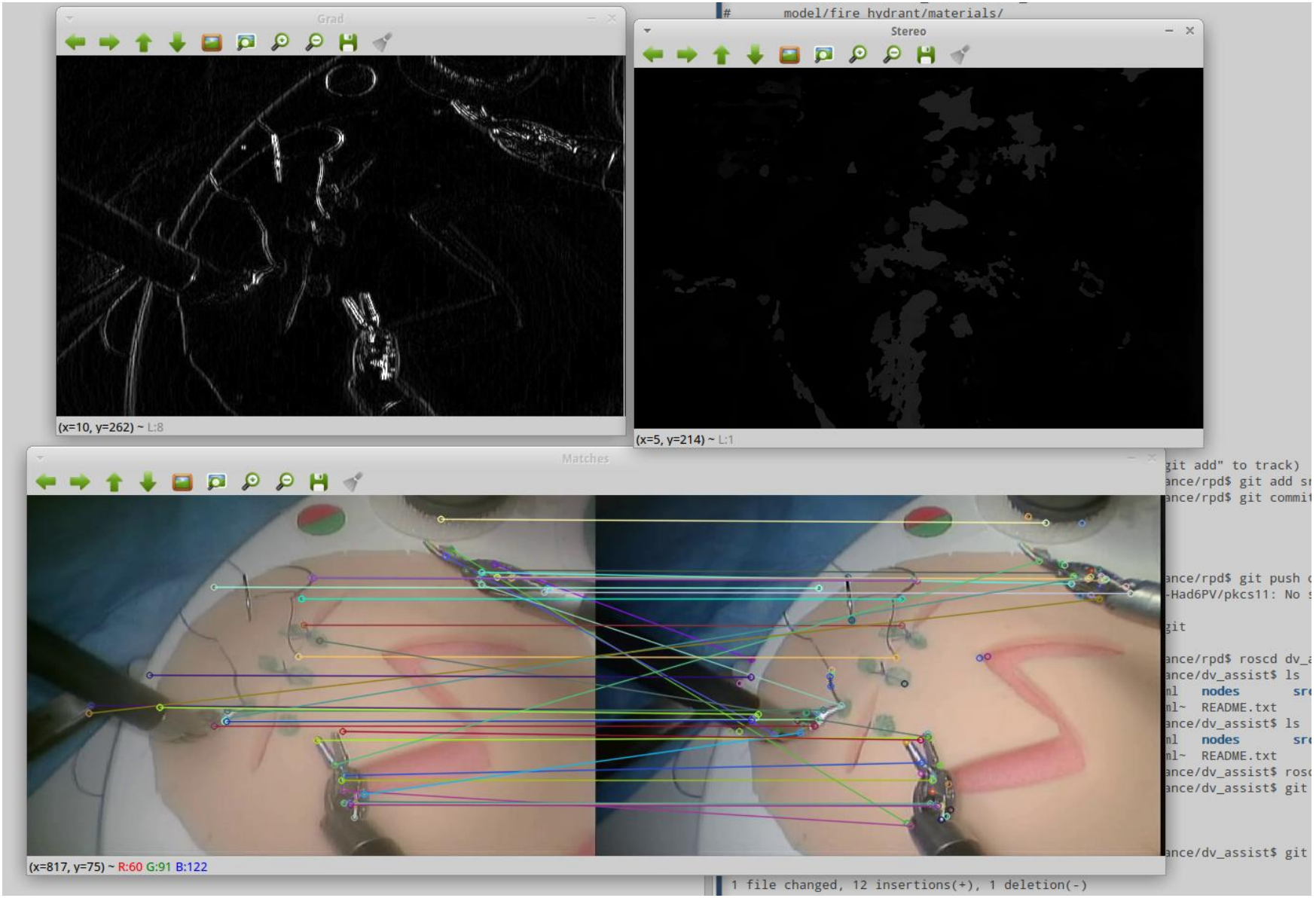
Stereo Video Processing





Goal: develop method to extract objects and useful image features from a scene like this.

Extracting image key points for stereo registration

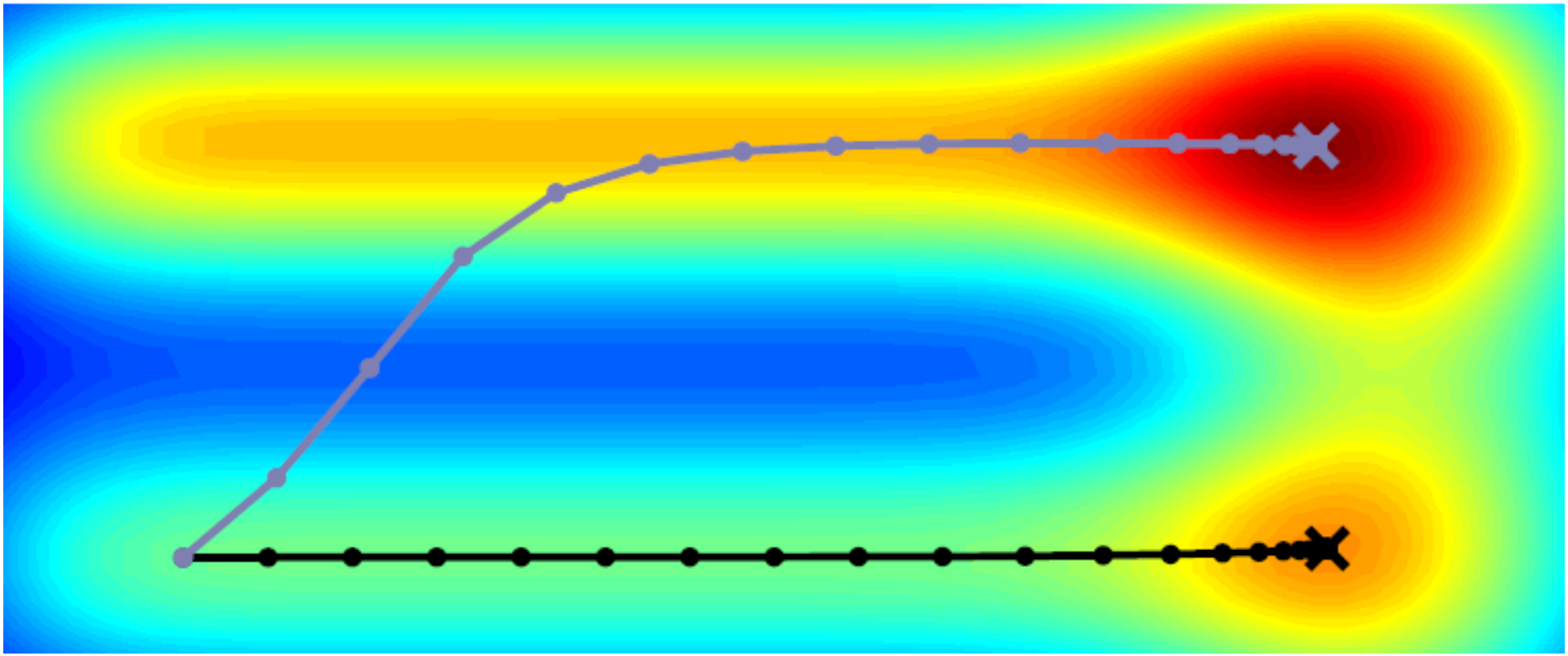


Plan for Learning from Demonstration

- **Modeling task components:**
  - Labels from user demonstrations
  - Gaussian Mixture Regression to determine when algorithm needs to take over, as per previous work
- **Task learning based on:**
  - S. Levine and V. Koltun. Continuous inverse optimal control with locally optimal examples.

- **Focus here instead of Da Vinci data!**

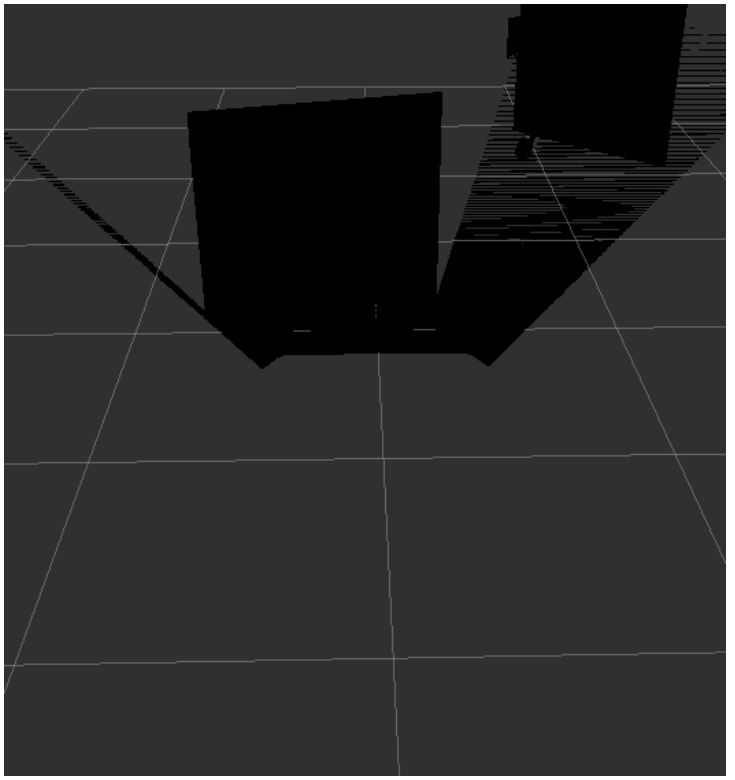
Reward Function from Continuous Locally Optimal Demonstrations



S. Levine and V. Koltun. Continuous inverse optimal control with locally optimal examples. In Proceedings of the 29th International Conference on Machine Learning, ICML 2012, volume 1, pages 41 – 48, 2012.

Simulation Component

- Two Barrett WAM arms using ROS/Orocos integration software
- Gazebo simulation environment
- Simulation provides ground truth on object positions, depth cloud from RGBD sensors

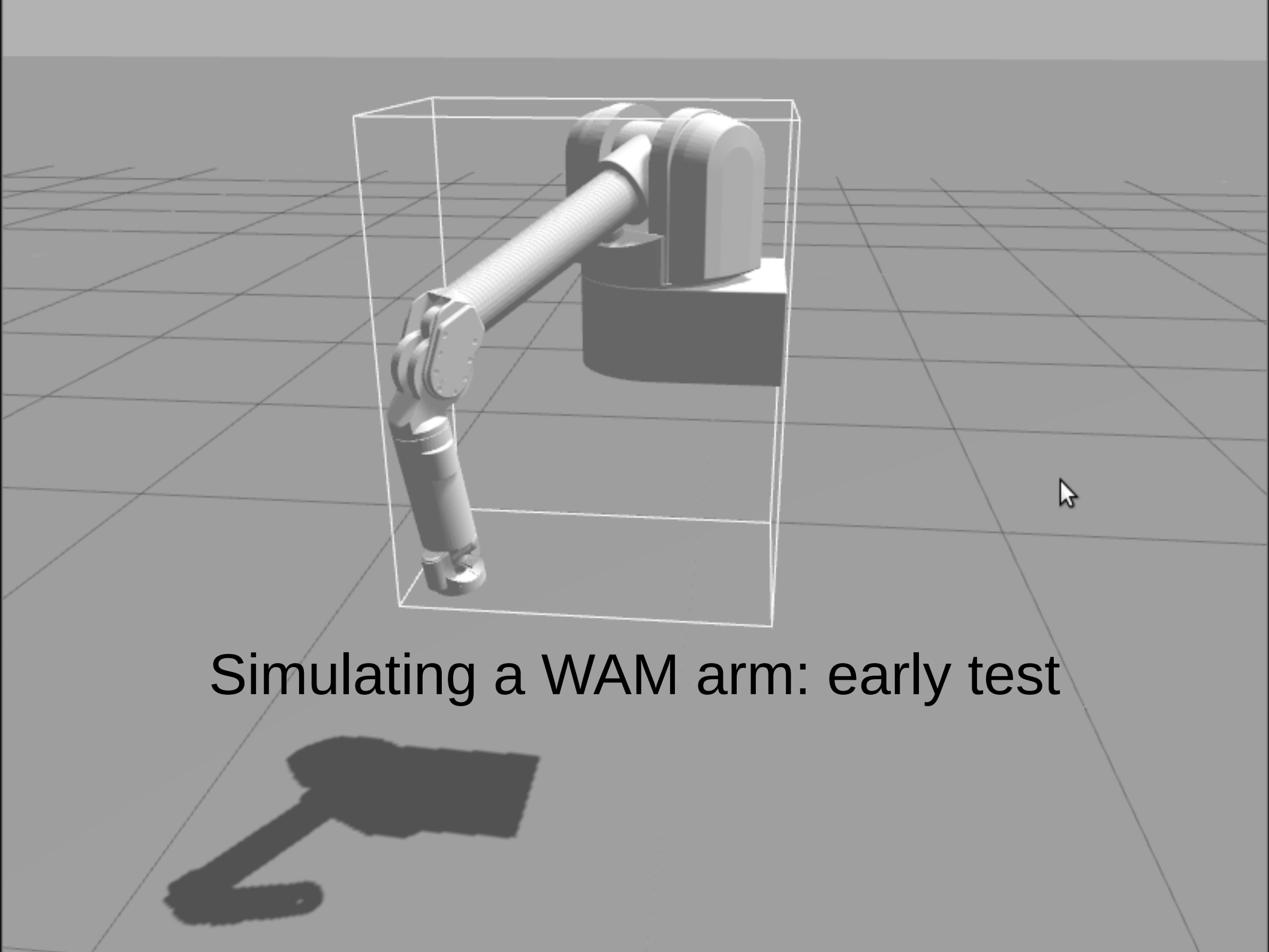


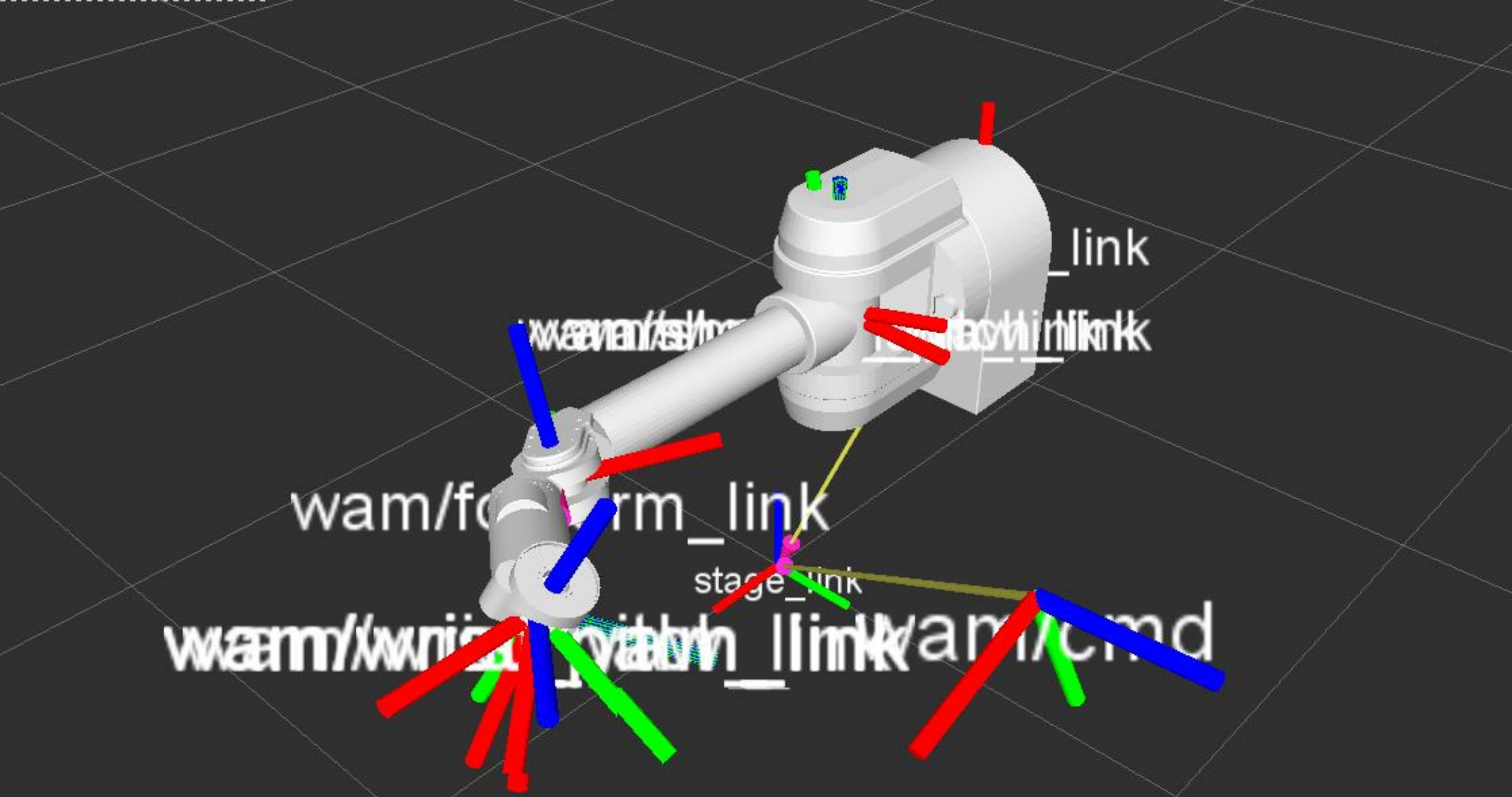
ROS

GAZEBO

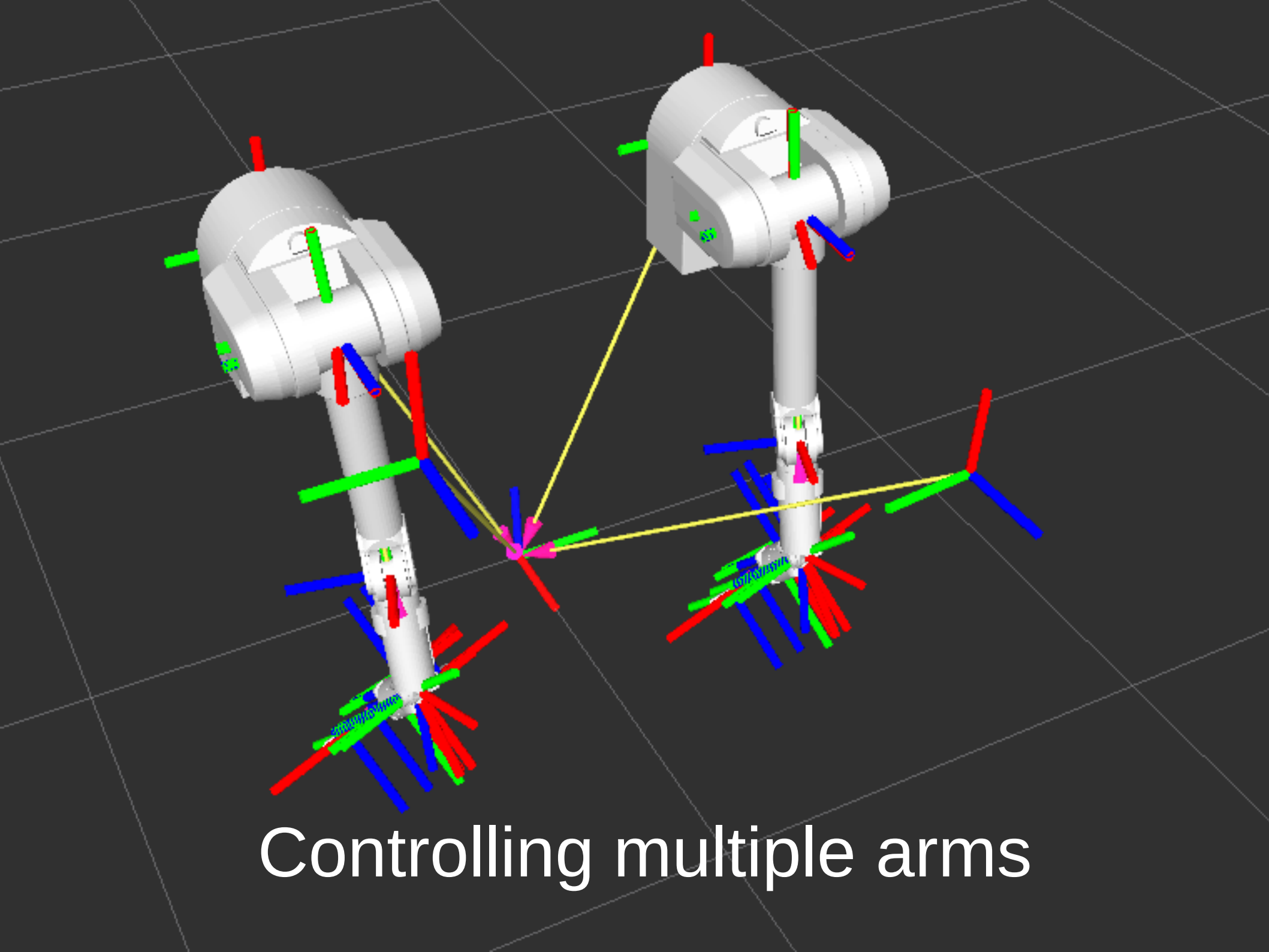
Controlling the Robot

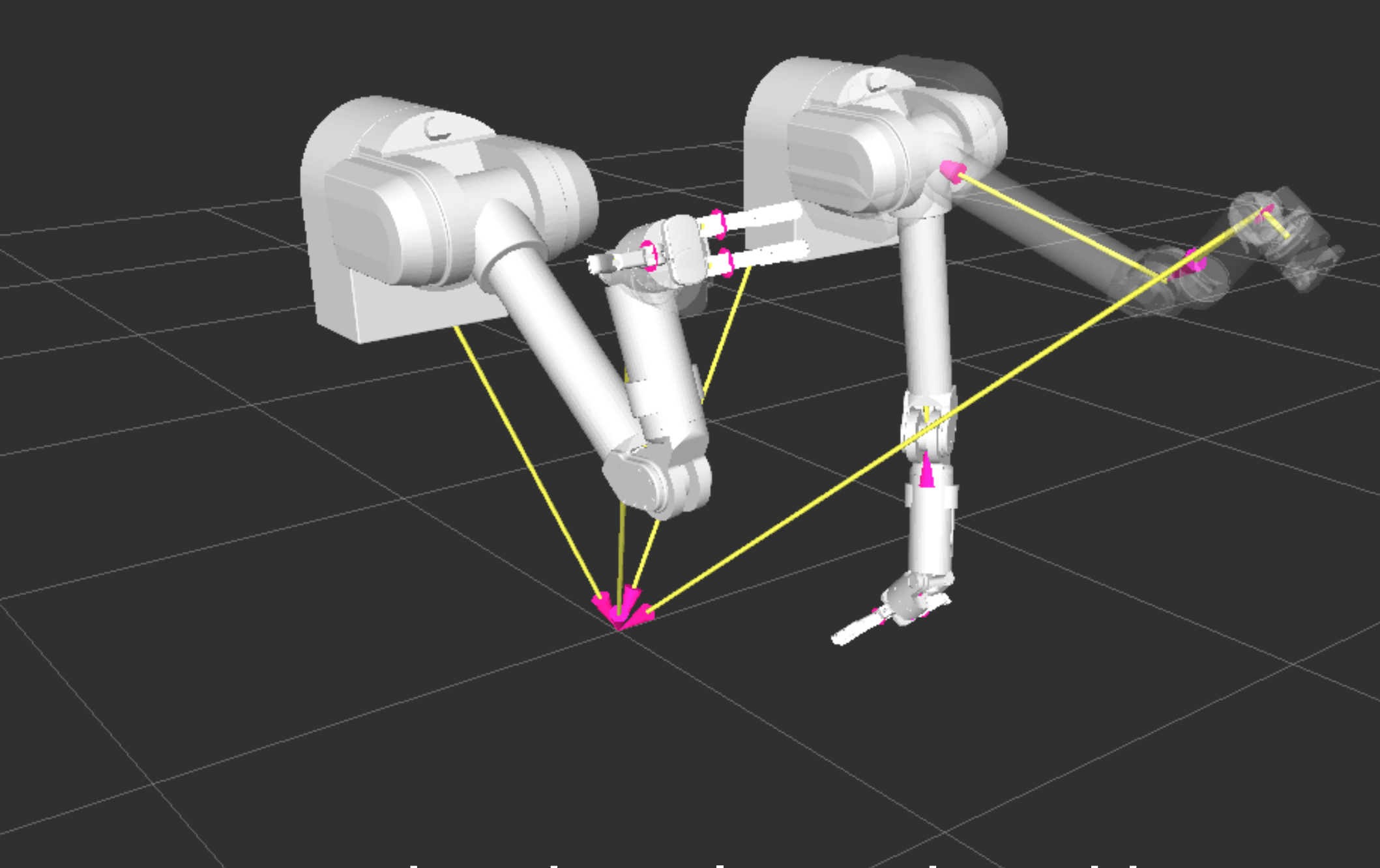
- Settled on 3DConnexion Space Navigator mouse for robot control
  - X, Y, Z
  - roll, pitch, and yaw
- Buttons close the gripper in a preset way, switch current arm being controlled


Simulating a WAM arm: early test

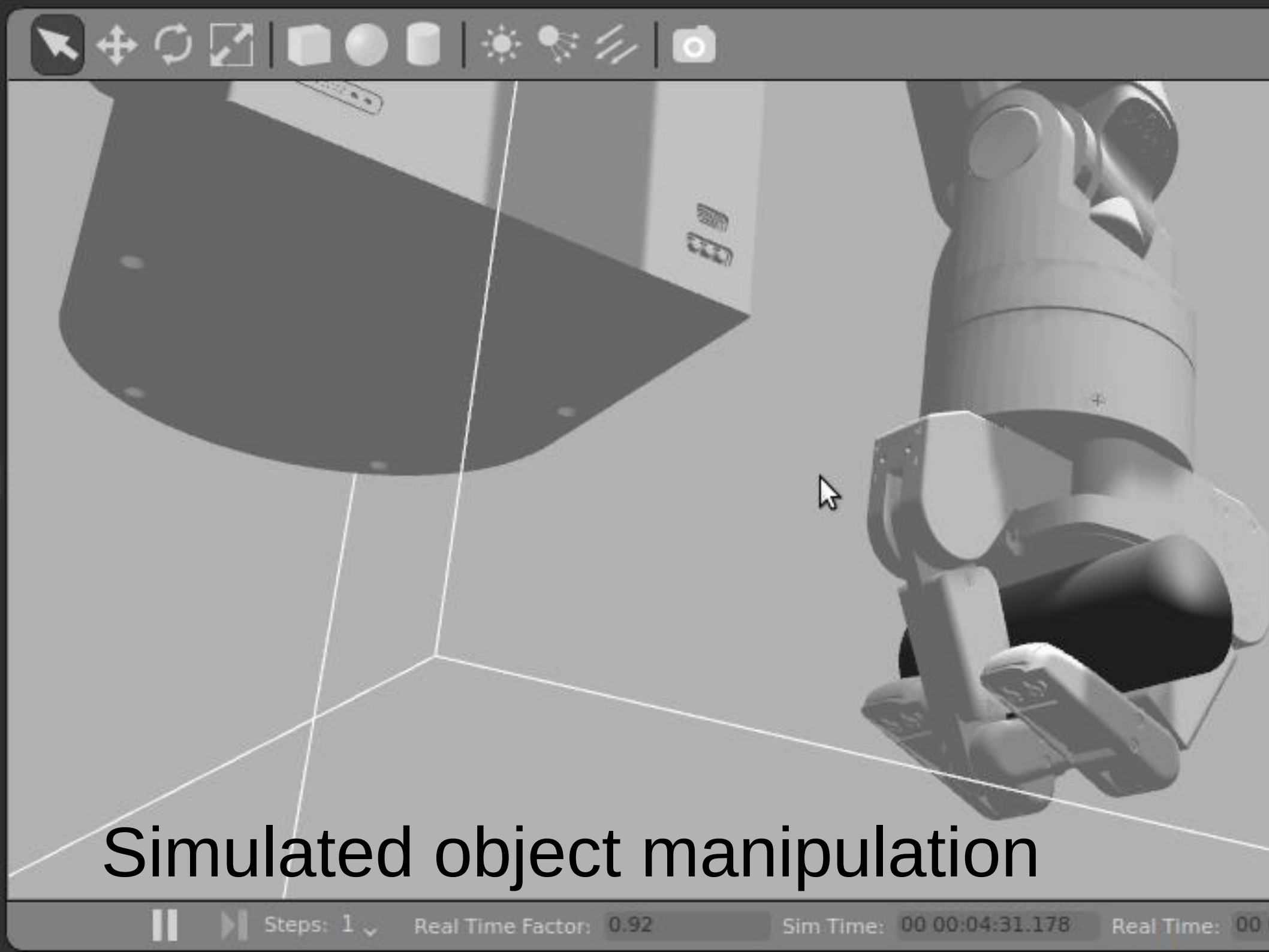


Simulating a WAM arm: TF frames


Controlling multiple arms

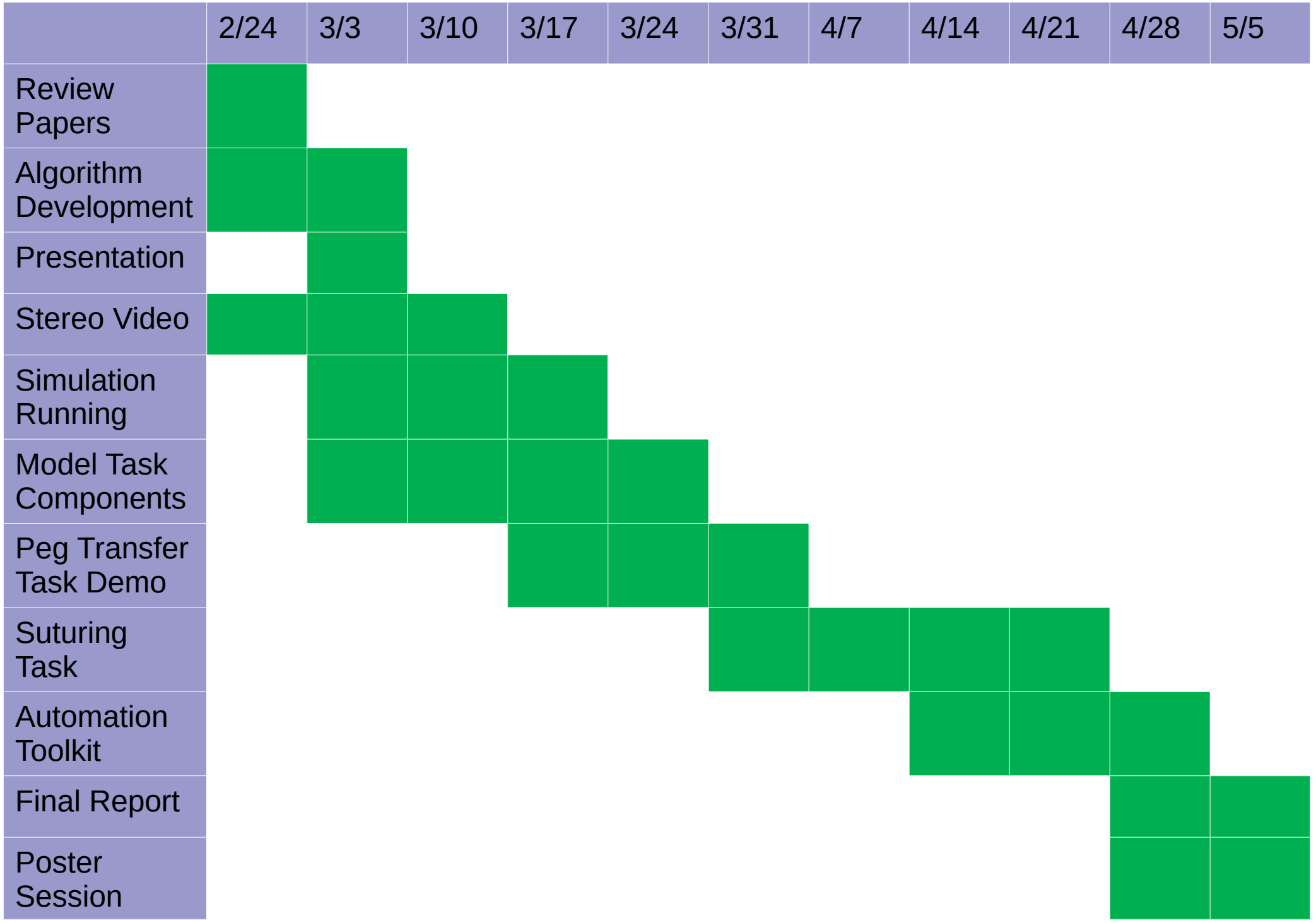


Arms showing planned positions



Simulated object manipulation

Timeline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4/21
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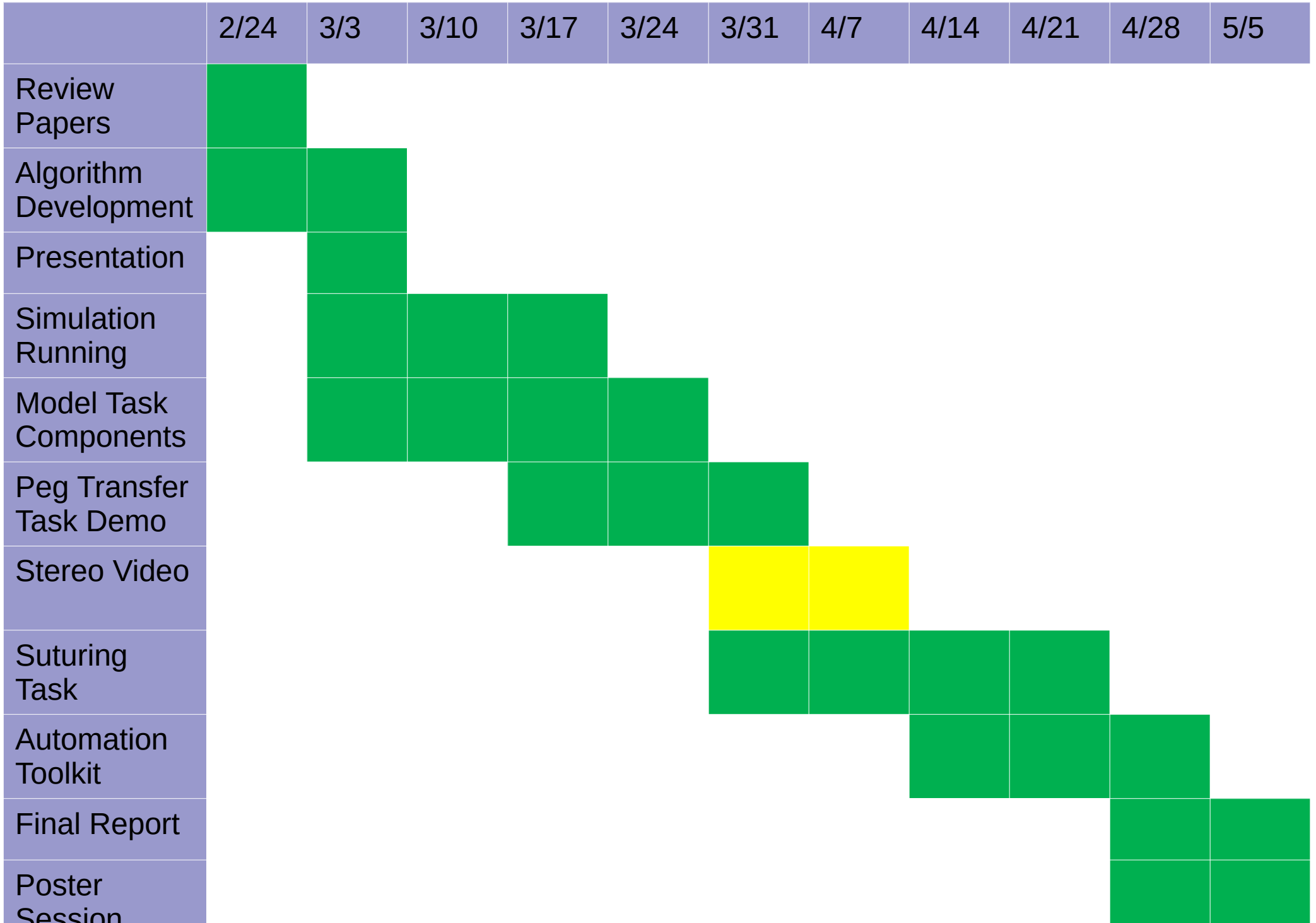
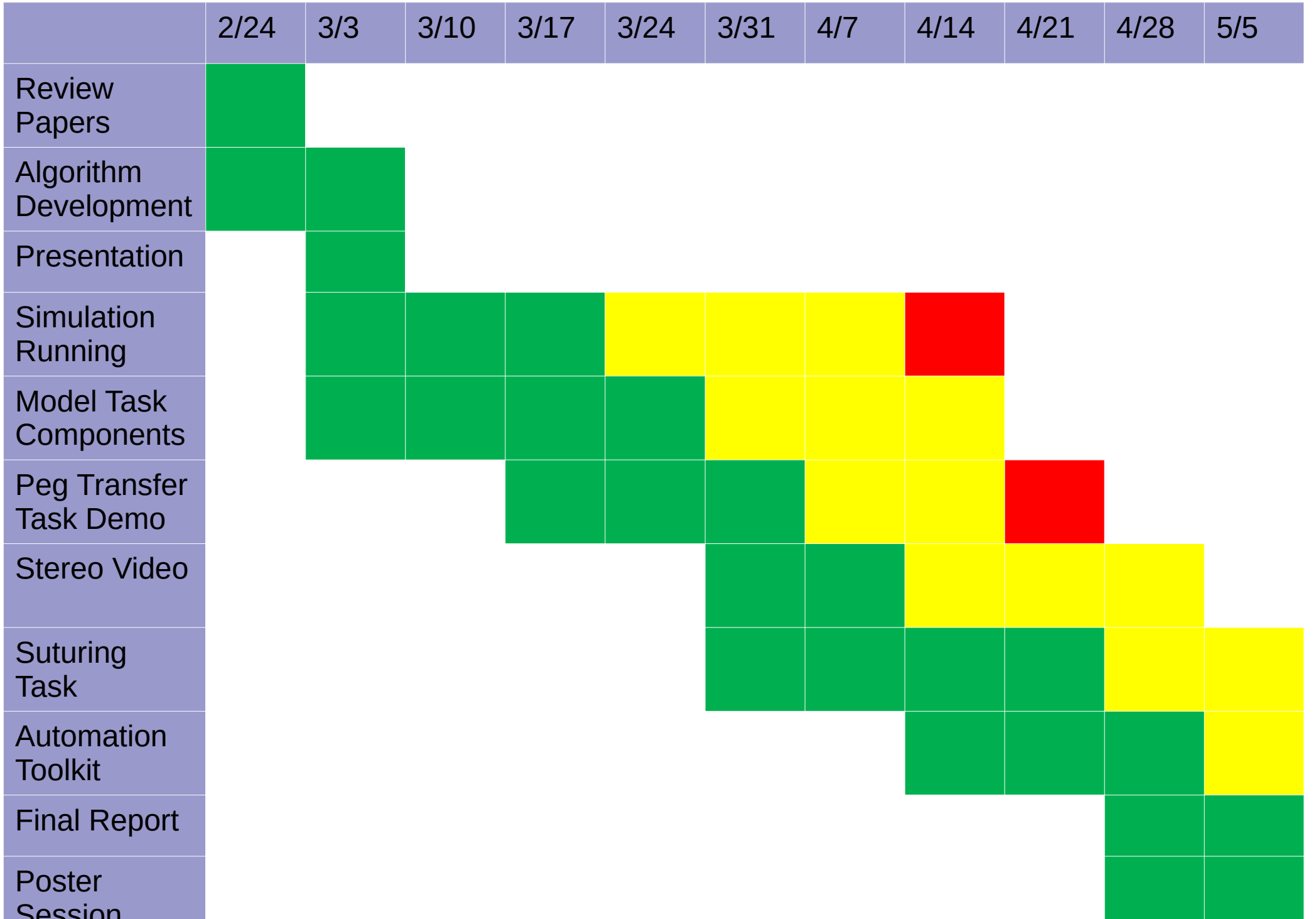
5/5
Review Papers
Algorithm Development
Presentation
Stereo Video
Simulation Running
Model Task Components
Peg Transfer Task Demo
Suturing Task
Automation Toolkit
Final Report
Poster Session

Timeline: Revision 1



Timeline: Revision 2



Questions?