Project 16: Da Vinci Intelligent Surgical Assistance

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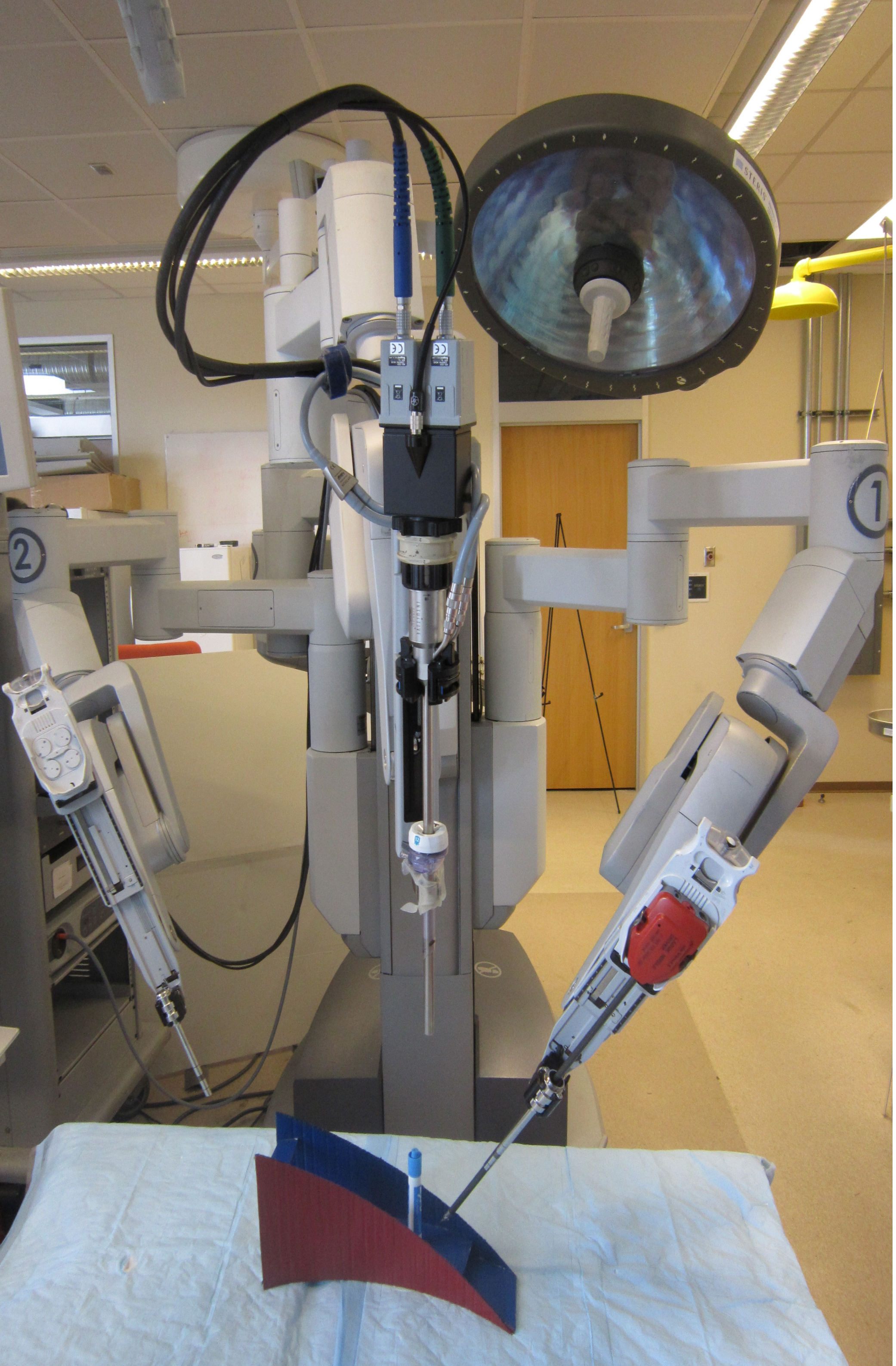
LABORATORY FOR Computational Sensing + Robotics THE JOHNS HOPKINS UNIVERSITY

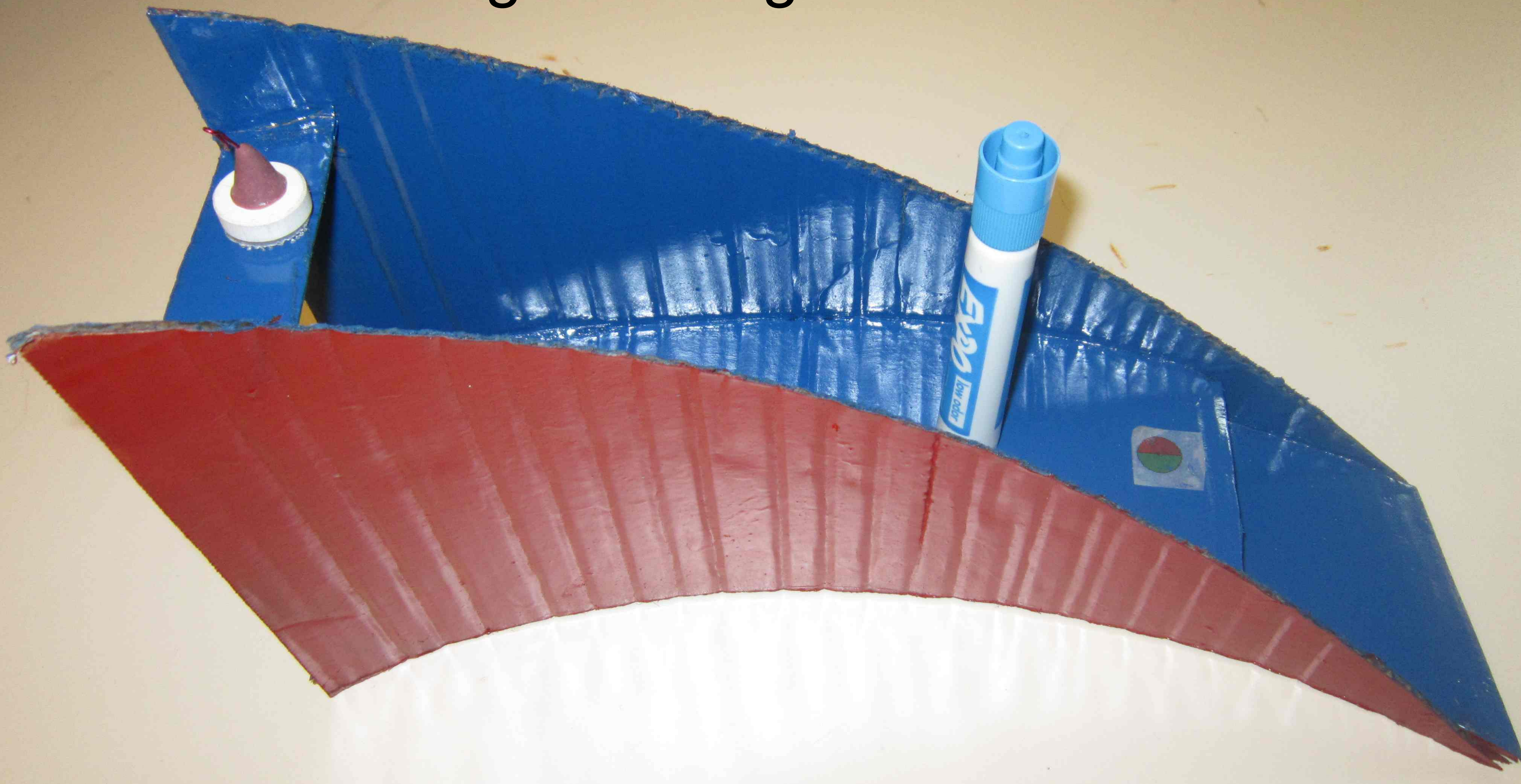
JOHNS HOPKINS WHITING SCHOOL of ENGINEERING



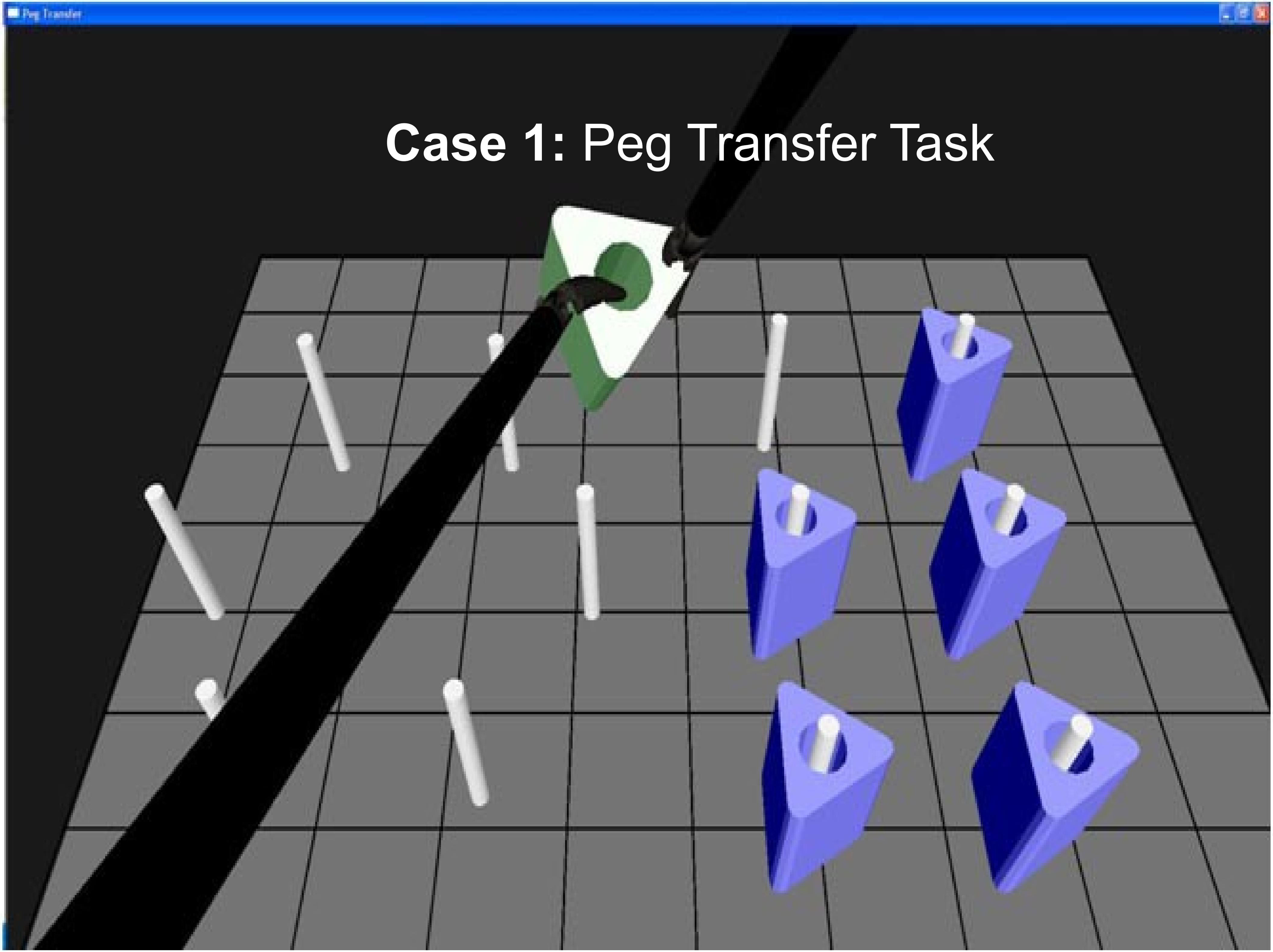
Robotic Tasks

- Grab a needle
- Cut a thread
- Move the camera
- Manipulate small objects or tissue

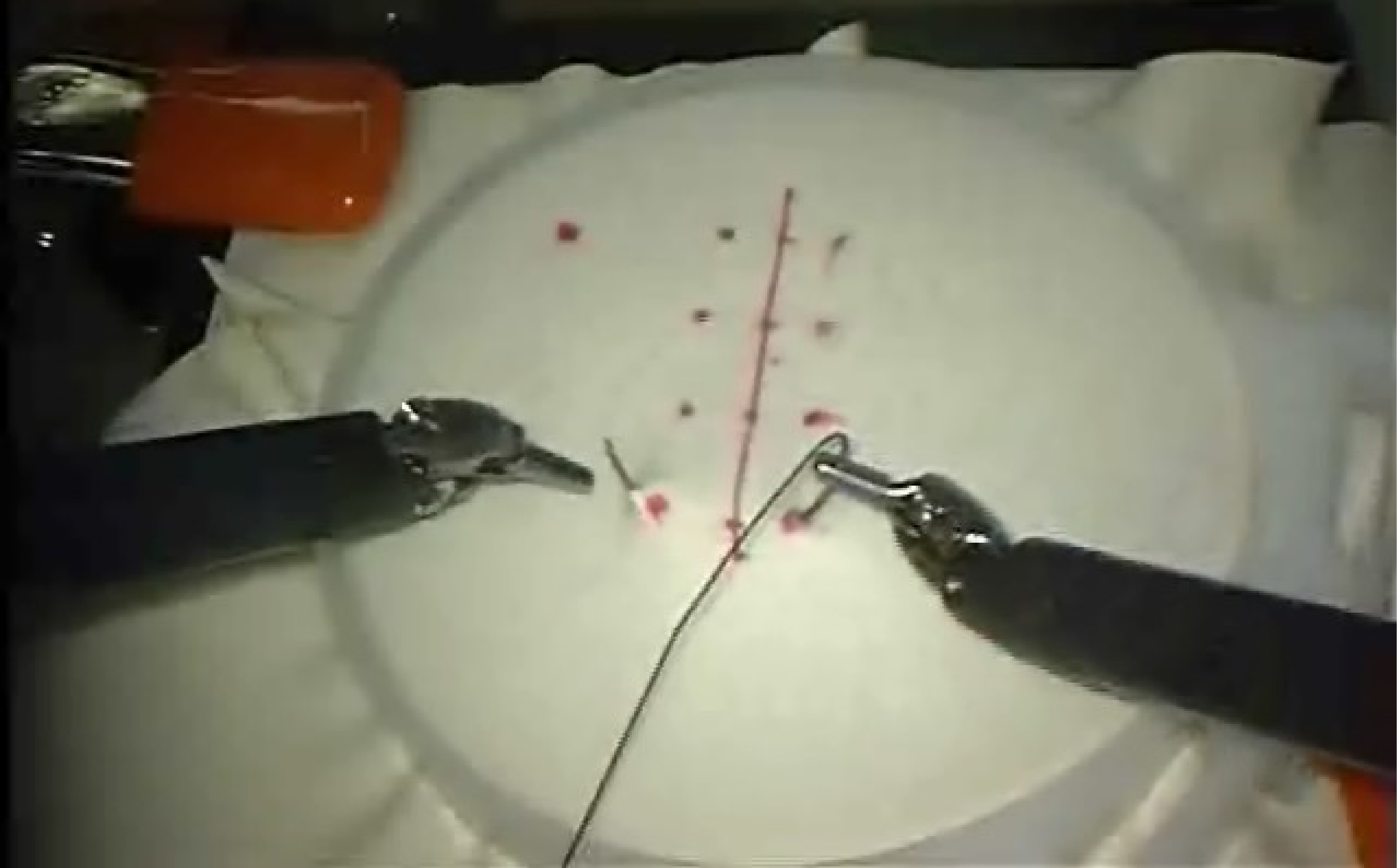
Example: Transfer object from top to bottom, avoiding knocking over the marker.



Why should users have to do this every time?

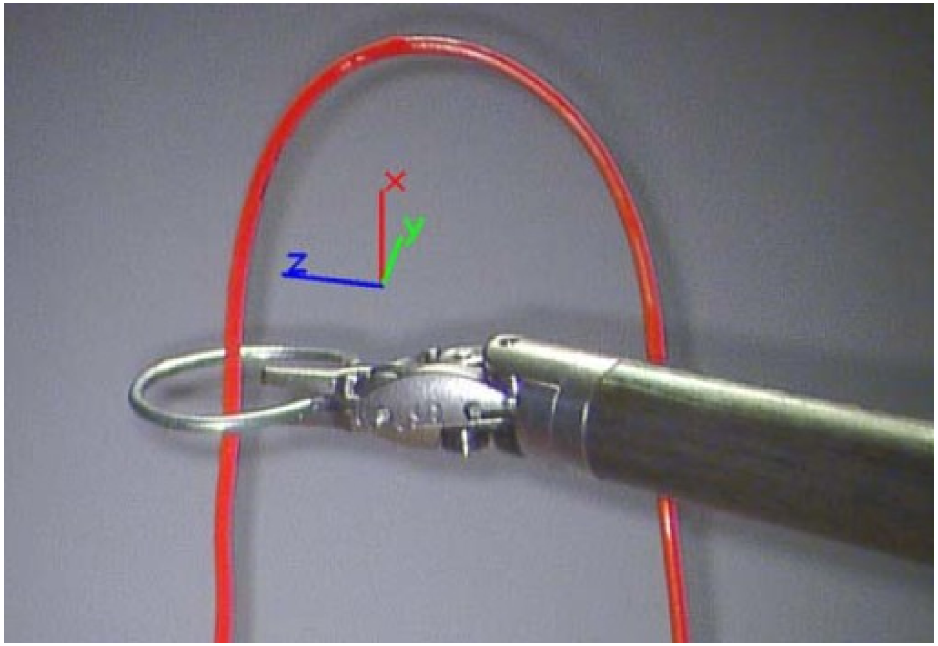

Peg Transfer
Case 1: Peg Transfer Task

Case 2: Grabbing a needle after suture throw



Prior Work

- Language of Surgery project
- Partial automation work by Dr. Nicolas Padoy and Sebastian Bodenstedt
- Learning from Demonstration research with Amir Masoud



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

Technical Approach: Three Key Components

- Inverse Optimal Control to model performance of a specific task within a procedure
- Features extracted from 3D data (stereo video) or object information (simulation)
- Temporal logic describing the relationship between components of a procedure

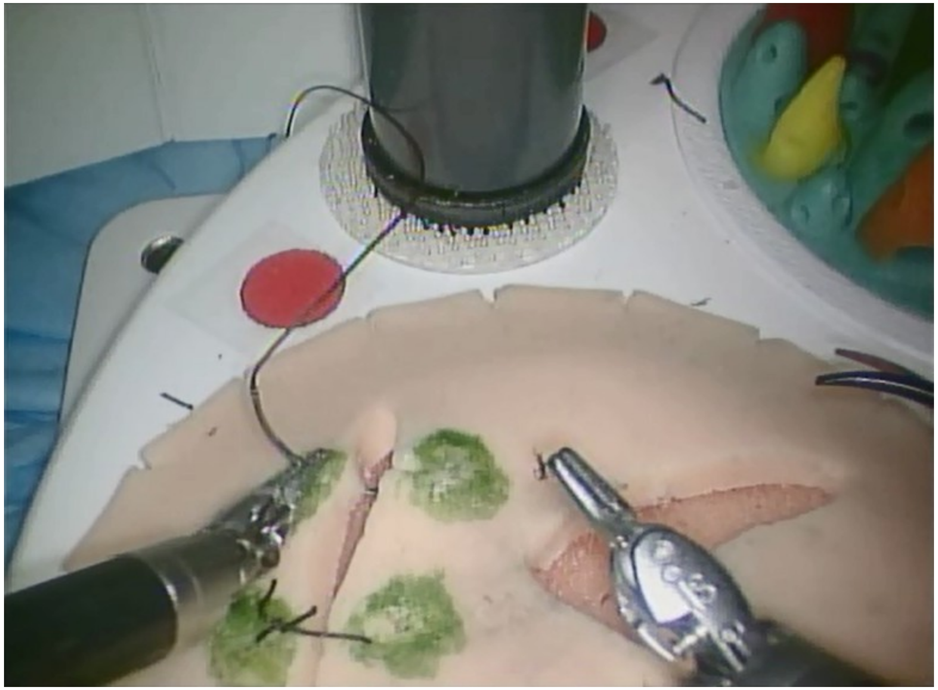
Work will require a simulation for software development and use the ISI BB API to write commands to the Da Vinci for suturing case.

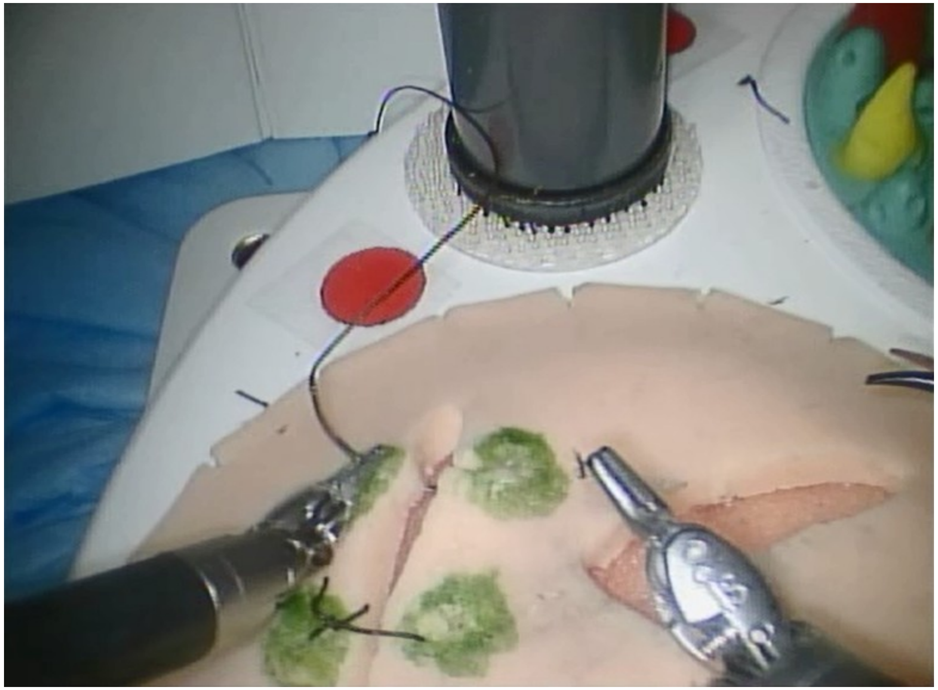
Inverse Optimal Control

Finds a *reward function* relating an observed change in state to changes in observed features of the environment.

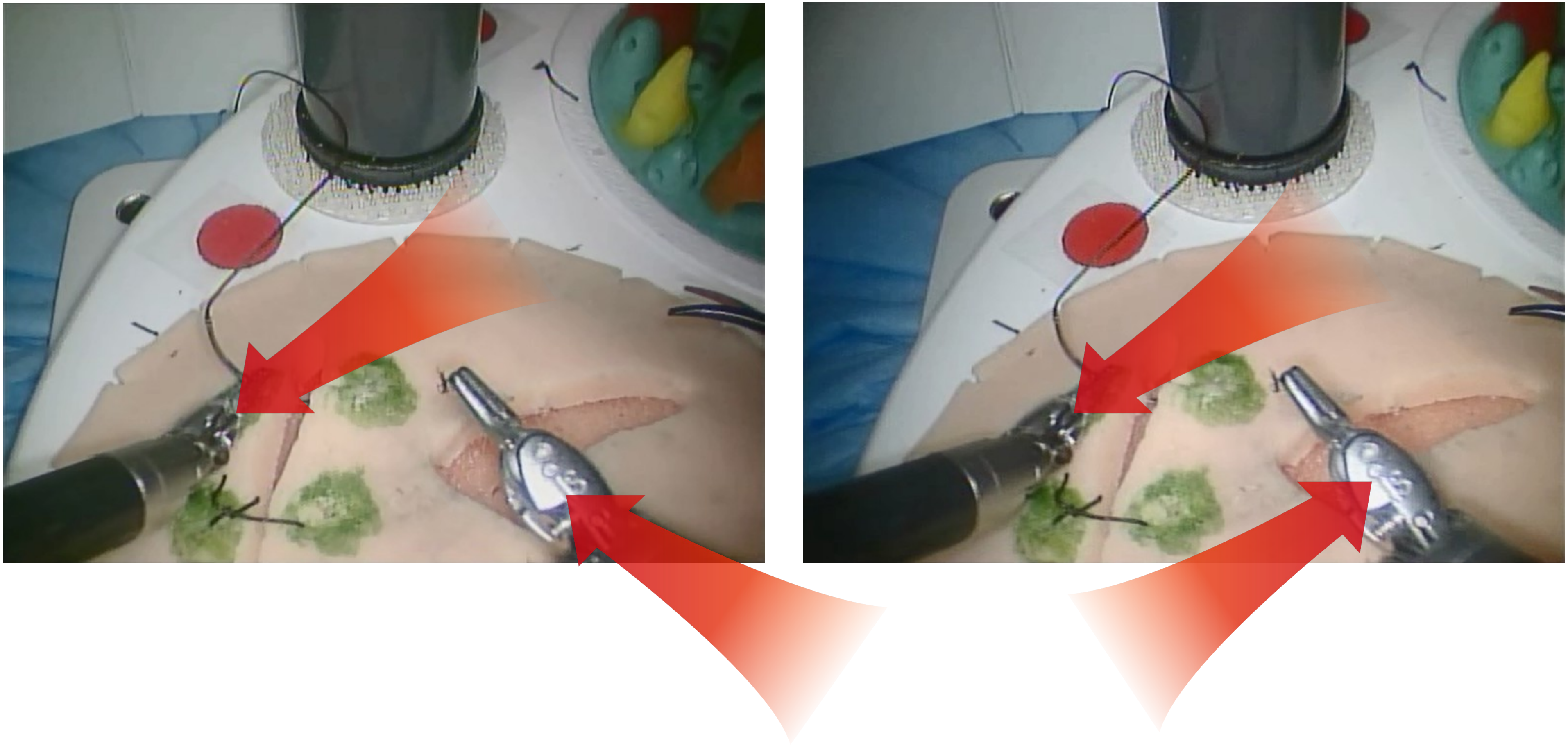
$$P(a_0|s_0) = \frac{1}{Z}\sum_t r(s_t, a_t)$$

Stereo Video Processing



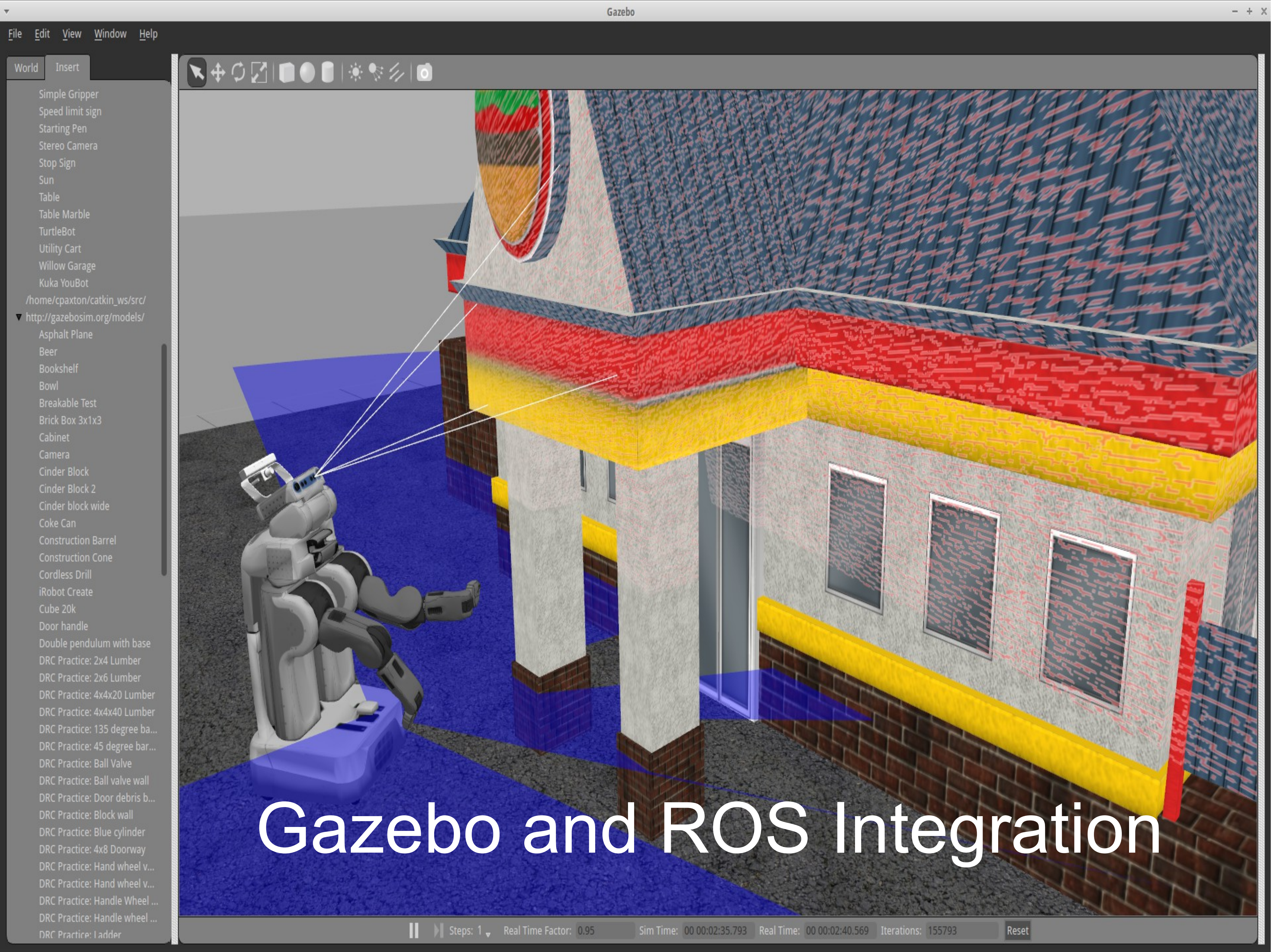


Registration Based on Tooltips



Temporal Relationships

- Develop a task model to determine when a robot should take over control from a human.
- When are certain components of a task complete?


Gazebo
File
Edit
View
Window
Help
World
Insert
Simple Gripper
Speed limit sign
Starting Pen
Stereo Camera
Stop Sign
Sun
Table
Table Marble
TurtleBot
Utility Cart
Willow Garage
Kuka YouBot
/home/cpaxton/catkin_ws/src/
http://gazebosim.org/models/
Asphalt Plane
Beer
Bookshelf
Bowl
Breakable Test
Brick Box 3x1x3
Cabinet
Camera
Cinder Block
Cinder Block 2
Cinder block wide
Coke Can
Construction Barrel
Construction Cone
Cordless Drill
iRobot Create
Cube 20k
Door handle
Double pendulum with base
DRC Practice: 2x4 Lumber
DRC Practice: 2x6 Lumber
DRC Practice: 4x4x20 Lumber
DRC Practice: 4x4x40 Lumber
DRC Practice: 135 degree ba...
DRC Practice: 45 degree bar...
DRC Practice: Ball Valve
DRC Practice: Ball valve wall
DRC Practice: Door debris b...
DRC Practice: Block wall
DRC Practice: Blue cylinder
DRC Practice: 4x8 Doorway
DRC Practice: Hand wheel v...
DRC Practice: Hand wheel v...
DRC Practice: Handle Wheel ...
DRC Practice: Handle wheel ...
DRC Practice: Ladder
Gazebo and ROS Integration
Steps: 1
Real Time Factor: 0.95
Sim Time: 00 00:02:35.793
Real Time: 00 00:02:40.569
Iterations: 155793
Reset

Simulating a WAM Arm in Gazebo

Minimum Deliverables

- **Simple stereo** registration and reconstruction for collected Da Vinci video data
- **Formal approach** for modeling components of a procedure
- **IOC software** for computing task models
- **Simulation** peg transfer task set up, performed by human users

Expected Deliverables

- **Partial automation of peg transfer task**, running in the simulation environment.
- **Tooltip-based stereo registration** to automatically register and extract visual features from collected Da Vinci data

Maximum Deliverables

- **Partial automation of suturing task**
- **Semi-automation toolkit** for use on other problems and on different robots

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

Software Dependencies

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

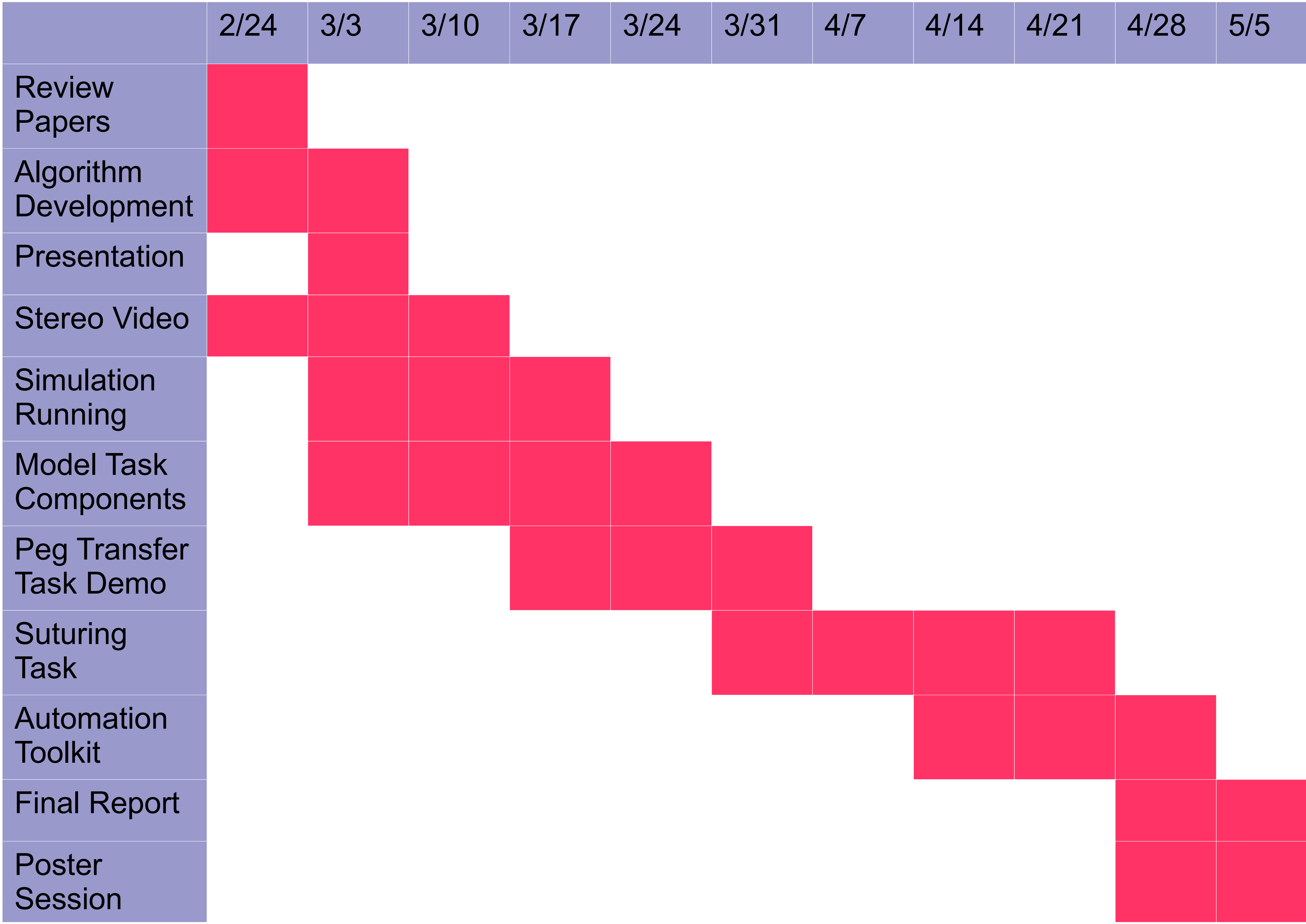
Milestones

- Formal Algorithmic Approach: 3/14/2014
- Tooltip-based Stereo Registration and Reconstruction: 3/7/2014
- Model Task Components: 3/14/2014
- Peg Transfer Task: 4/11/2014
- Suturing Task: 4/25/2014

Management Plan

- Weekly meetings with mentors at 11 am on Monday
- Biweekly meetings with Prof. Hager at 9:30 am on Wednesdays
- Weekly discussions with graduate student mentors on Wednesday at 1 pm

Timeline


2/24
3/3
3/10
3/17
3/24
3/31
4/7
4/14
4/21
4/28
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

References

- 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.
- Conor McGann, Eric Berger, Jonathan Bohren, Sachin Chitta, Brian Gerkey, Stuart Glaser, Bhaskara Marthi, Wim Meeussen, Tony Pratkanis, Eitan Marder-Eppstein, et al. Model-based, hierarchical control of a mobile manipulation platform. In 4th workshop on planning and plan execution for real world systems, ICAPS, 2009.
- Austin Reiter, Peter K Allen, and Tao Zhao. Appearance learning for 3d tracking of robotic surgical tools. The International Journal of Robotics Research, page 0278364913507796, 2013.
- John Schulman, Ankush Gupta, Sibi Venkatesan, Mallory Tayson-Frederick, and Pieter Abbeel. A case study of trajectory transfer through non-rigid registration for a simplified suturing scenario. In Intelligent Robots and Systems (IROS), 2013 IEEE/RSJ International Conference on, pages 4111–4117. IEEE, 2013.
- Brian D Ziebart, Andrew L Maas, J Andrew Bagnell, and Anind K Dey. Maximum entropy inverse reinforcement learning. In AAAI, pages 1433 –1438, 2008.
- Sebastian Bodenstedt, Nicolas Padoy, and Gregory Hager. Learned partial automation for shared control in tele-robotic manipulation. In 2012 AAAI Fall Symposium Series, 2012.
- Kris M Kitani, Brian D Ziebart, James Andrew Bagnell, and Martial Hebert. Activity forecasting. In Computer Vision–ECCV 2012, pages 201–214. Springer, 2012.

Image References

- Slide 2, 3 images from: Amir M. Ghalamzan E., Chris Paxton, Gregory Hager, and Luca Bascetta. Robot learning from demonstration:from imitation to emulation. Submitted to IROS, 2014.
- Slide 5, 9, 10 images from: Language of Surgery data set, public release version. Available online at https://cirl.lcsr.jhu.edu/Research/HMM/
- Slide 6 image from: Sebastian Bodenstedt, Nicolas Padoy, and Gregory Hager. Learned partial automation for shared control in tele-robotic manipulation. In 2012 AAAI Fall Symposium Series, 2012.
- Slide 4 image from: 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
- Slide 12 image from: Conor McGann, Eric Berger, Jonathan Bohren, Sachin Chitta, Brian Gerkey, Stuart Glaser, Bhaskara Marthi, Wim Meeussen, Tony Pratkanis, Eitan Marder-Eppstein, et al. Model-based, hierarchical control of a mobile manipulation platform. In 4th workshop on planning and plan execution for real world systems, ICAPS, 2009.
- Slide 14 image from Jon Bohren
- Slide 18 images from http://opencv.org/ http://ros.org http://ab-initio.mit.edu/wiki/index.php/Main_Page http://gazebosim.org/

Questions?