# Advanced Computer Integrated Surgery Project Report

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Group 22: Visual Feedback for skill acquisition in cataract surgery
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## 1. Introduction:

Feedback during surgical training is important for helping improvement of novice surgeons. Currently, feedback to support technical skill acquisition among trainees in ophthalmology is through qualitative verbal instruction and demonstration. Directed feedback can facilitate deliberate practice and effective skill acquisition. This project aims to develop visual feedback to support technical skill training in cataract surgery during task performance. This work is based on the hypothesis that adequate control of tool forces during the critical step (capsulorhexis) in cataract surgery is essential to safely and effectively perform the surgery.

The aim of the project is to facilitate novice surgeons to develop skill by visual feedback during trials performed on a phantom. Here we propose using a phantom that can be easily replicated and the process can be repeated with good accuracy.  We also propose using visual overlays for assisting surgeons to perform tasks.

## 2. Background:

Cataract is the clouding of the lens in the eye. It is pretty common among older aged adults. Caplusorhexis is the removal of the lens in the eye during cataract surgery using shear and stretch forces. The procedure starts with a small incision near the cornea making way into the lens capsule. The surgeon then uses the same needle to begin a tear in the capsule and then either use the same needle to slowly tear the lens or use a special forceps to do the same (Fig. 1). Though the task does not involve high risks, in occasional cases, the tear if done wrong causes the leakage of the vitreous humor which requires high skill to mend. If training of surgeons if made easier and better, such damages can be avoided.

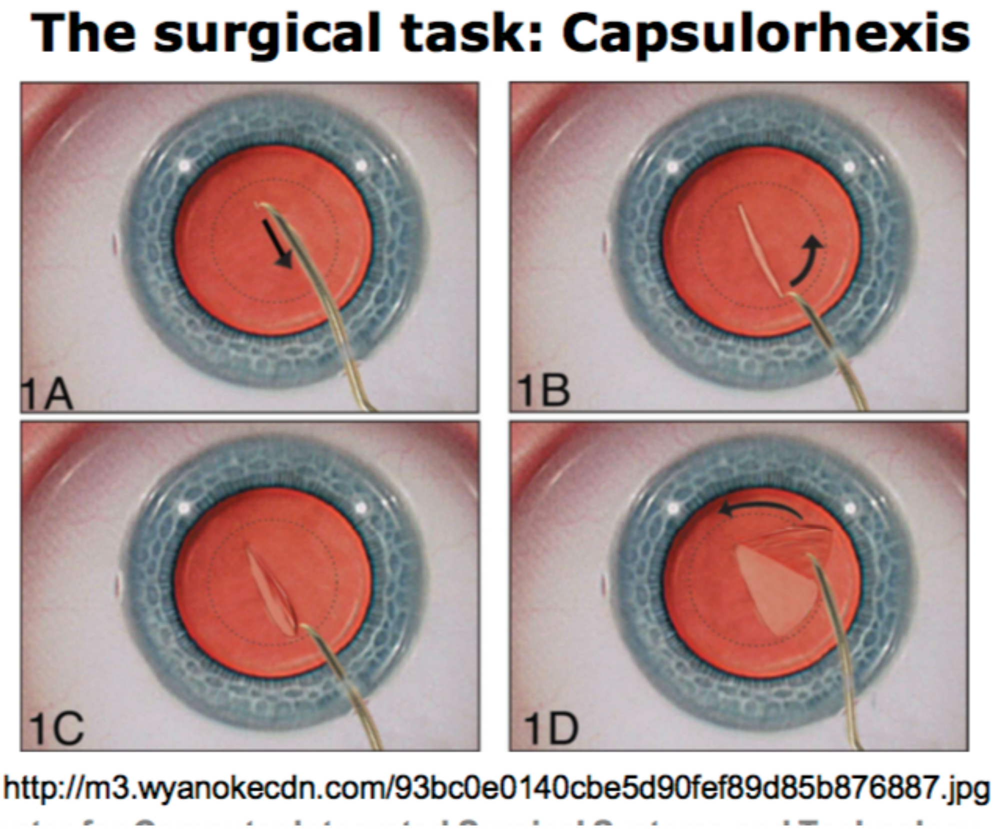


Fig. 1 (Capsulorhexis procedure. (clockwise from top) Notice the removal of the lens during the procedure.

# 3. <u>Technical Approach:</u>

**3.a Phantom to simulate the task.**

The design and choice of the phantom depended on the following factors:

1. Similarity with the task
2. Repeatability
3. Ease of production
4. Sensitivity towards force sensor readings in the DVRK (Da vinci research kit)

Point 4. Was by far the hardest constraint on the choice of the phantom. Several choices were tried which included:

**1.** Using wet tissue paper on gelatin (slightly sticky).

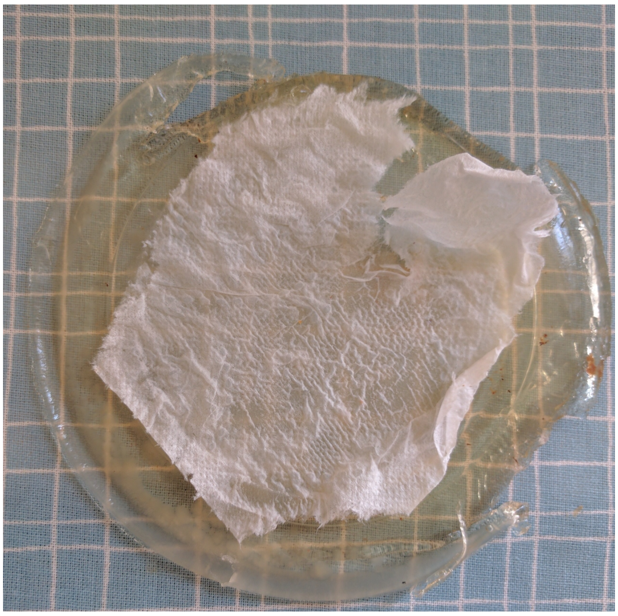

Fig. 2 phantom with wet paper and gelatin

**2.** Steamed side of a tomato with the skin acting as the lens.

**3.** Wax paper on cardboard

Fig. 3 phantom with wax paper glued to cardboard

4. Wax paper with Velcro

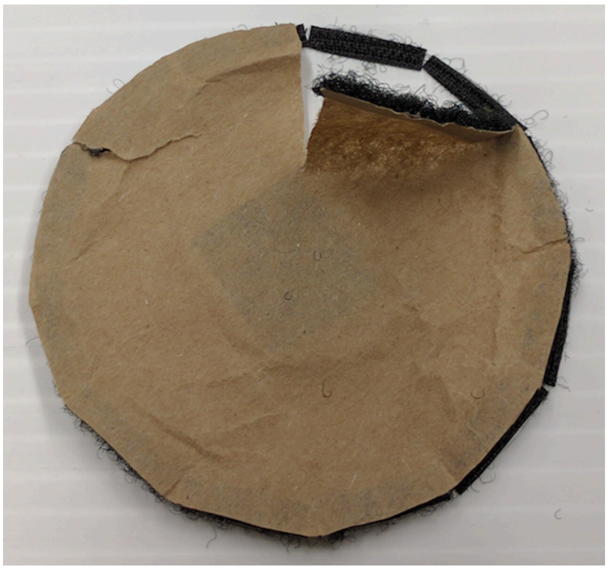

Fig. 4 Phantom with Velcro and wax paper

Choices 1 and 2 simulated the tearing task pretty well. Choice 1 was rejected on account of the fact that the force sensor was not sensitive enough to record the force values. Choice 2. was rejected on account that it was messy to work with (risk of damaging force sensor and other sensitive equipment) and there were issues related to the measured force values.

Among choices 3. And 4., the latter had a better simulation of the task. Also 4. was more repeatable with same results than 3. We also consulted with other ophthalmologist surgeons to confirm the same.

**3.b Da Vinci Camera Calibration and tool tip tracking.**

Calibration of the Da vinci camera was performed using the camera calibration ROS package. Depth is estimated using the stereo camera with the following equation. The tool was tracked using two methods:

- Manually click the tool tip using mouse in the video
- Slightly colour the tool tip and track it using rgb segmentation. The camera matrix estimated from calibration along with the depth map developed by sliding window sum of squared differences (SSD) was used to determine the depth of the tool tip.

The first choice was used to a greater extent due to the illumination constraints and lack of accuracy in the latter case.

Once force values are obtained, they are visually overlayed to be in the frame of the camera. This is performed with the transformation matrix as shown in Fig.5.

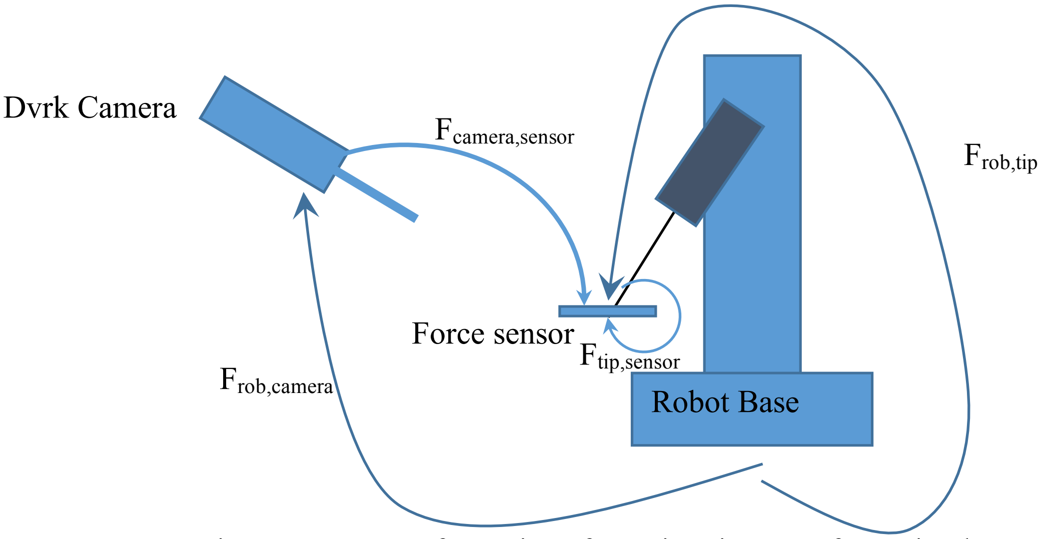


Fig. 5 Frame transformations for estimating transformation between force sensor and camera

$$F_{rob,camera}.F_{camera,sensor} = F_{rob,tip}.F_{tip,sensor}$$
$$F_{camera,sensor} = F^{-1}_{rob,camera}.F_{rob,tip}.F_{tip,sensor}$$

$$F_{rob,tip} \textit{is obtained from the forward kinematics of the robot}$$

`

Arrows are drawn as 2d projection in the image plane in the direction of the force, with the magnitude corresponding to the length of the arrow.

The force values and tool motion video data was recorded and the aim was to record data for many cases and use this, to estimate the force at any instant during the surgery.

### 3.c Ros interface with the force sensor.

The saw ATI force sensor currently used with the DaVinci, does not have a ROS interface. It only has a QT interface. The task involved using a ros bridge (cisst-ros) bridge to bridge the topics from the ATI force sensor and publish it in the ros topic "/atiforce/wrench". The particular package can be found at the cis-website

```
/*--------------ROS Bridge---------------*/
std::string bridgeName = "sawATIForceSensor" + rosNamespace;
std::replace(bridgeName.begin(), bridgeName.end(), '/', '_');
mtsROSBridge * rosBridge = new mtsROSBridge(bridgeName,
                                            rosPeriod, true);

// ATI Force Sensor
rosBridge->AddPublisherFromCommandRead<mtsDoubleVec, geometry_msgs::WrenchStamped>(
            forceSensor->GetName(), "GetFTData", rosNamespace + "/raw_wrench");

// add the bridge after all interfaces have been created
componentManager->AddComponent(rosBridge);

// connect all interfaces for the ROS bridge
componentManager->Connect(rosBridge->GetName(), forceSensor->GetName(),
                          forceSensor->GetName(), "ProvidesATINetFTSensor");

/* --------------------------- */
```

Fig.6 Code Snippet for ros-bridge constructed for sawAtiForce sensor

Other tasks involved time synchronising the force sensor values with the fps of the camera, i.e to the rate of the force sensor is different with the camera. The values were approximated so that they both had the closest possible time stamps.

## 4. <u>Results</u>

The phantom used was chosen after consulting experts. The Fig.8 shows the final phantom which was chosen for the task. This particular phantom was chosen since it simulates the capsulorhexis task to a good amount and can be easily repeated.

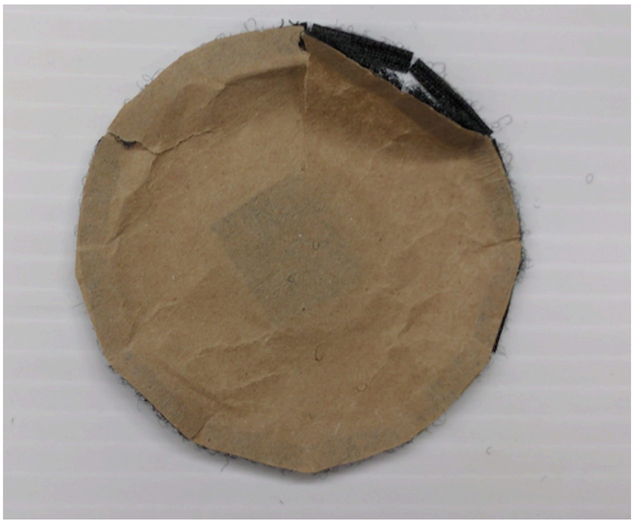

Fig.7 Chosen phantom made using Velcro and wax paper

Force values obtained was visually overlayed to help users have a visual feedback experience of the forces applied by them. Fig.8 show the overlayed forces in the procedure.

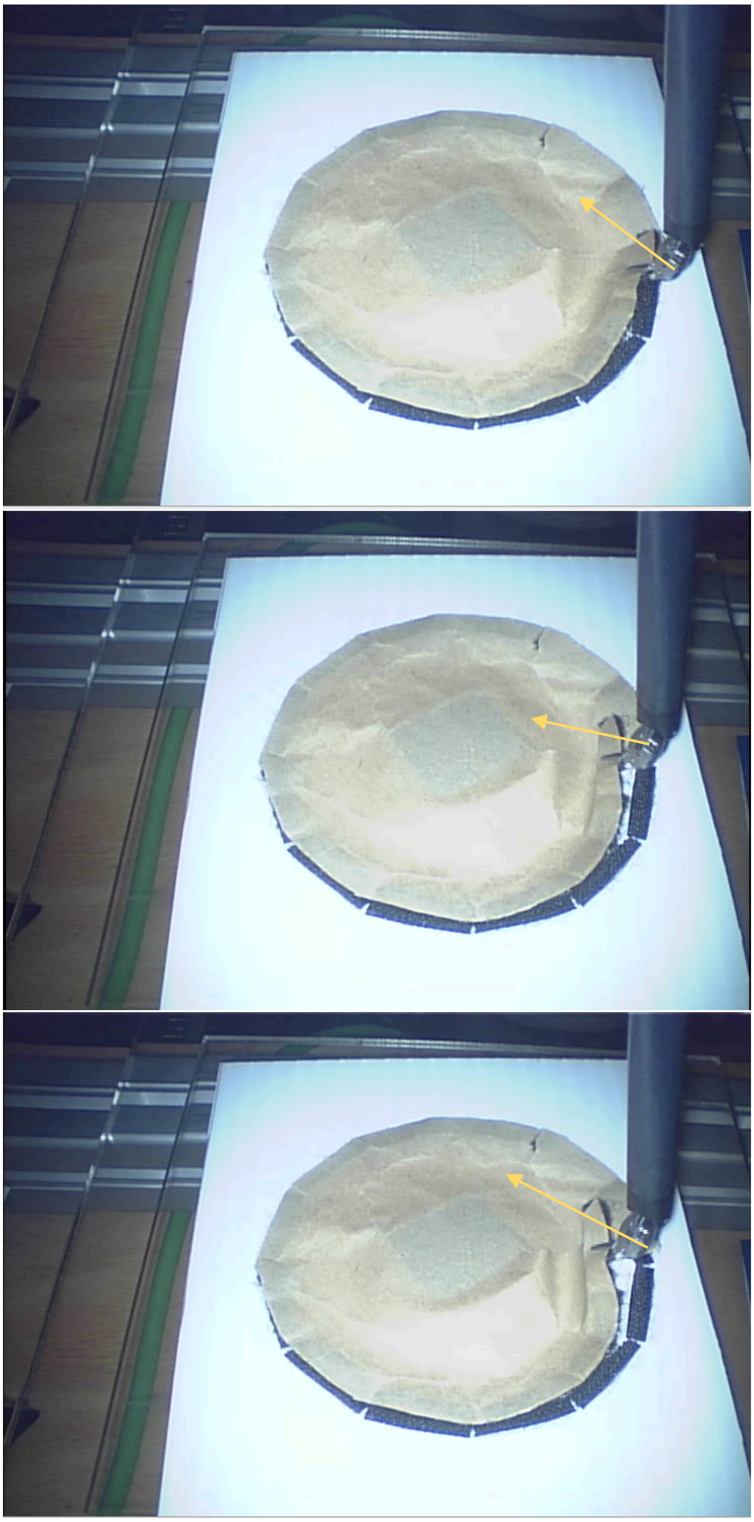

Fig. 8 Images of the Overlayed Force vector.

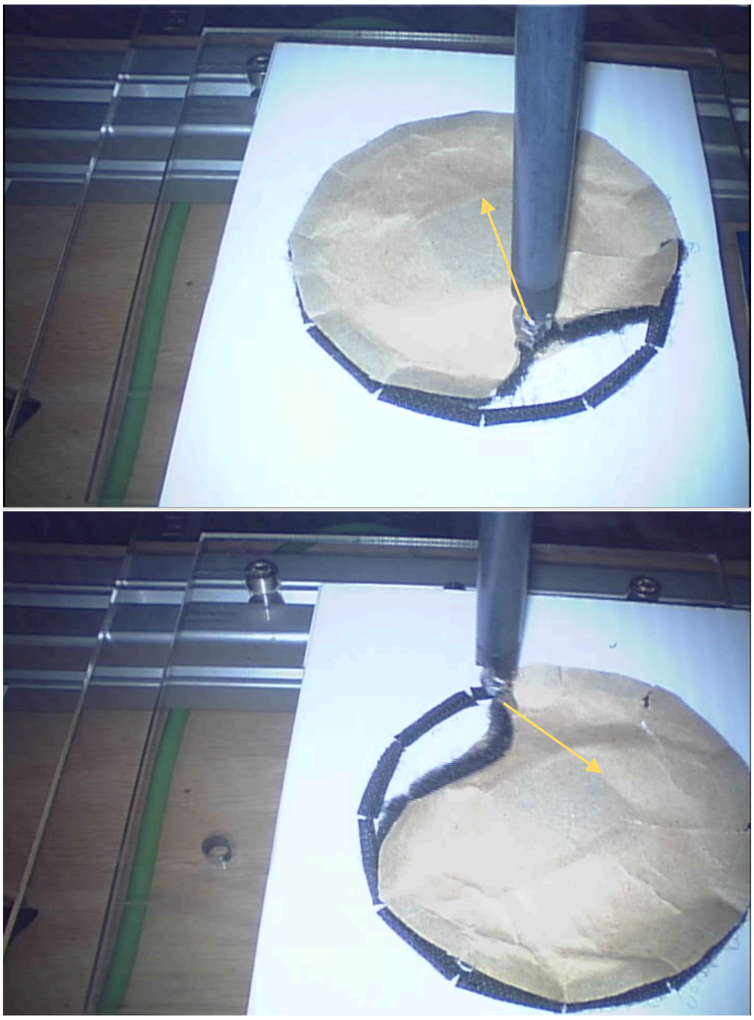

Fig. 8 Images of the Overlayed Force vector.

The logged force and video data was proposed to be used for estimating the force vectors using regression techniques to provide force at any point of the procedure.

The setup was ready for gathering data. But due to hardware constraints, I was not able to collect sufficient data for force estimation and comparison of tool force pattern between experts and novices.

## 5. Significance:

General simulation tools seldom have sufficient data to help in the surgery and to analyse the surgery. Though, we were not able to complete all the deliverables, the setup nonetheless provides a visualization of the force patterns. This is important because, it helps the surgeons analyse the patterns and forces exerted by them during the surgery. Given more time and better hardware, the project could be completed including the maximum deliverables.

## 6. Management Summary:

The minimum deliverables for the project was completed. Setup and codes for visual overlay on tool video was achieved. The setup was ready for data collection. However due to hardware constraints adequate data was not recorded. This affected the expected and the maximum deliverables.

**Minimum:**

- ~~Simple phantom to simulate the task~~
- ~~Video of tool motion with da vinci research kit~~
- ~~Visual overlay of tool forces~~

**Expected:**

- Compare tool force pattern between experts and novices (could not complete)

**Maximum:**

- Data of errors in this estimation (could not complete)

## 7. Division of Labor:

Because I did not have a student partner, I worked alone under the guidance and support of my mentors.

## 8. Future Plan:

The task has to be performed on a robotic system with much better force sensors and what would be better would be if we were able to measure the tool force data directly instead of reading the forces on the phantom. Future work here would be to setup this system on a better robot. Also, data can be gathered which can be used to extrapolate the force values. For future work, we could also combine force torque values for the visual overlay instead of just using force values.

Also, good would be to design a haptic feedback for the procedure in addition to visual feedback which would help the surgeon perceive the tool motion and force better.

## 9. Lessons Learned:

Time synchronisation in ROS is not upto the mark with discrepencies in time stamps which forces manual time synchronisation of data. Any mechanical system developed has to be repeatable with good results. Appropriate time has to be allotted for data collection and hardware used should be continuously monitored and ensure to be working. Another important learning was the importance of communication with mentors and seeking their advice.

## 10. Acknowledgements:

I would like to thank my mentors, Dr.Swaroop Vedulla and Austin Reiter for valuable advice during the course of the project. I would also like to thank Dr. Shameema Sikder for letting me use the simulator system at the Wilmer Eye Institute and for providing valuable feedback with the phantom. I would also like to thank Preetham Chalasani for helping me out with the force sensor.

## 11. References:

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# 600.446/646 – CIS II – Mentors Report

Dear CIS II Mentor,

First, thank you for mentoring a CIS II project this year. This course provides a great educational experience for the students, and also can produce useful research results. Its success depends greatly on the project mentors, and I hope that your experience this year has been productive both for you and for the students.

As part of our grading process this year, I am encouraging project mentors to provide some input. You all should have been granted access to the course web site and to the individual project(s) that you are mentoring. Go to

https://ciis.lcsr.jhu.edu/dokuwiki/doku.php?id=courses%3A446%3A2017%3Aprojects

You will be asked to log in by clicking the login link in the upper right. You can then follow the link to your specific project. Contact either me (rht@jhu.edu) or Alexis Cheng (acheng22@jhu.edu) if you have problems.

We would really appreciate it if you can answer a few questions. The students are expected to have the form below filled out by one of their mentors as part of their **final project report**.

Finally, note that the annual final exam / poster session will be Thursday, May 18 from 2 PM until about 5 PM. It will start with a poster teaser session in Hackerman B17 and will then move to the Hackerman B08 labs and the Mock OR for posters and demos. I very much hope that you can attend. Also, the project reports are due on the day of the poster session, but the students have been told that you need an opportunity to review the reports before then. We encourage you to have a final meeting before May 18 with your students to review their final reports and to provide them with your feedback on how they performed.

Russ Taylor

PS: An electronic copy of this word file may be found on the CIS 2 Wiki page at

https://ciis.lcsr.jhu.edu/dokuwiki/doku.php?id=courses:446

Our contact information is below:

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Alexis Cheng: acheng22@jhu.edu; cell (443) 826-8229

## Questionnaire – Project # _22___

7/10 Overall project and progress

- Were you satisfied with the overall technical progress made in the course of the semester?
  I think the progress was satisfactory up to the minimum expected deliverables. Making more headway with the data collection would have made the deliverable more realistic and interesting.
- Was the total accomplishment appropriate for the number and level (undergrad/graduate) of students on the project?
  Yes
- Will the results be useful to you in the future?
  Yes, we intend to continue this project through to completion.
- Do you see a prospect for patents or publication to result?
  Maybe, it is likely but unclear at this time.

8/10 Report (which the students should have shared with you)

- Does the project report accurately reflect the scope and accomplishment of the project?
  Yes
- Were you given an adequate opportunity to review the report?
  Yes
- Does the report and its appendices, together with the web site, provide sufficient information that subsequent groups can make effective use of the project results.
  Yes
- In particular, are any project designs or code adequately documented.
  Yes, the code is on Github and the project website for this course.

8/10 Web site

- Does the web site reflect the scope and accomplishment of the project?
  Yes
- Do you wish the web site to remain password protected after May 30? If so, for how long?
  Yes, at least until May 30, 2018

8/10 Management

- Were the students fully engaged in the project?
  Yes
- How often did they meet with you? Was this enough?
  Once in about 1 to 2 weeks. A more frequent schedule could have led to additional progress.
- Were the "deliverables" and "dependencies" realistic?
  Yes.

- Was the plan realistic?  Were unmet dependencies approached in an effective manner?
  Yes, with respect to the simulation phantom and programming targets. Perhaps not in terms of scheduling robot time given the choice of robot.

Other comments or suggestions

- Do you have any other comments or suggestions, either about the specific project or about the overall structure of the course for next year.