Visual Feedback for Skill Acquisition in Cataract surgery

As part of the course

Advanced Computer Integrated Surgery (600.646)

At

Johns Hopkins University

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1. Summary

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.

2. Background and significance

Cataract is the clouding of lens in the eye which in turn affects vision. It is pretty common among older aged adults.

The procedure of Capsulorhexis was discovered by howard gimbel to remove the lens during a cataract surgery by shear and stretch forces. The procedure begins with making a small incision near the cornea making way into the lens capsule. The surgeon then uses the same bent 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. [1] (refer Figure 1.)

The task generally does not involve high risk. However, sometimes, the tear results in damage of the capsule causing leakage of the vitreous humor. This is called a run-away tear. The skill required to mend this damage is very high. Also the skill level required for this procedure in general is high.

[1] https://en.wikipedia.org/wiki/Capsulorhexis

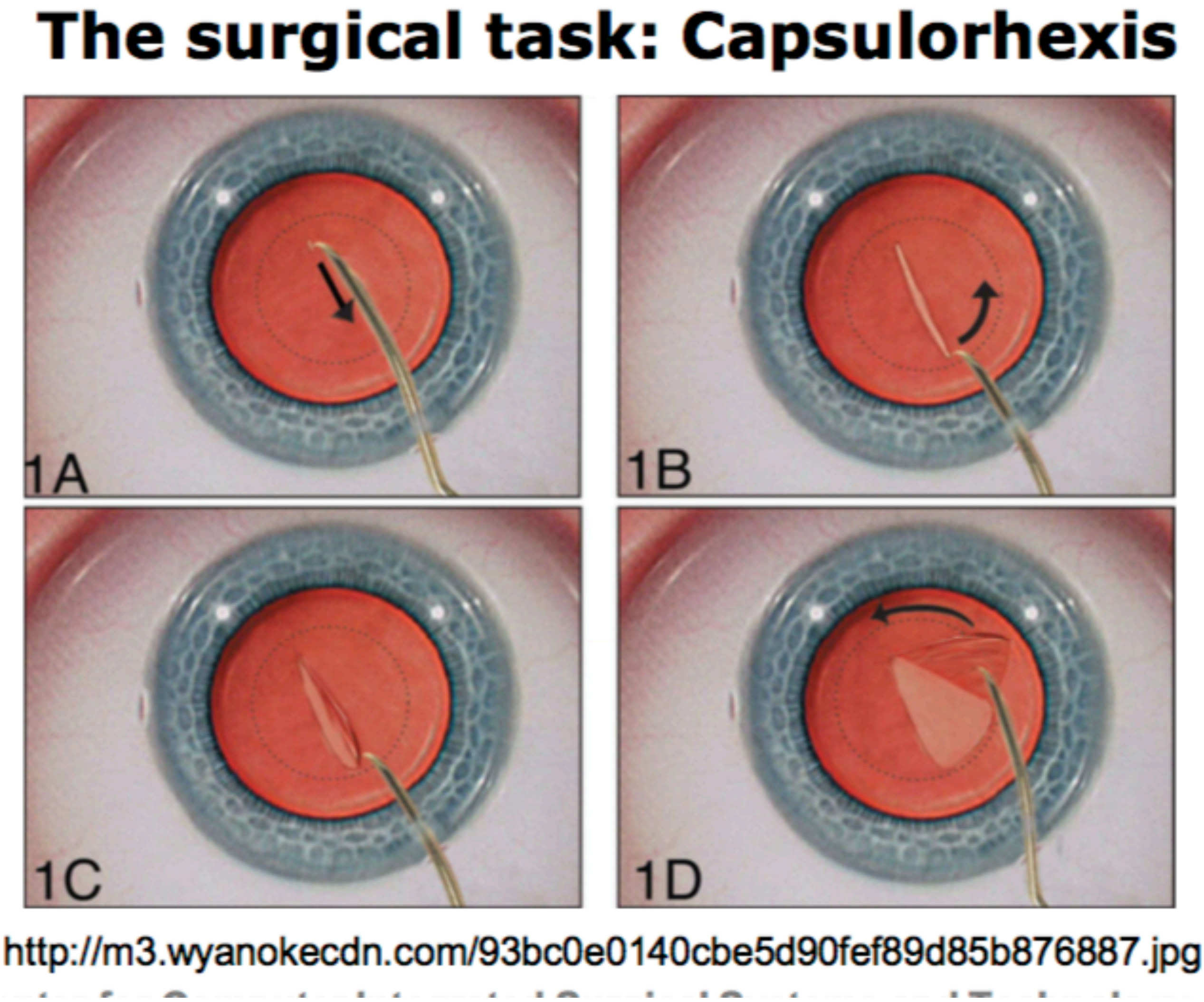


Figure 1. Capsulorhexis

Currently, for procedures in ophthalmology, training is done mostly through verbal instruction and demonstration. Instead, if directed feedback is used, it can facilitate effective skill acquisition. This project aims to develop visual feedback to support technical skill training in cataract surgery during task performance. This is explored in this project via visual overlays of tool force vector to guide the surgeon while performing the task.

3. Technical Approach

3.1 Design

Design of phantom: In order to perform simulations for data collection, a phantom similar to the human eye is needed.

Da-vinci Research Kit: "open-source mechatronics" system, consisting of electronics, firmware, and software that is being used to control research systems based on the first-generation da Vinci system. [2]. For data collection, understanding the dvrk ROS package is cruicial.

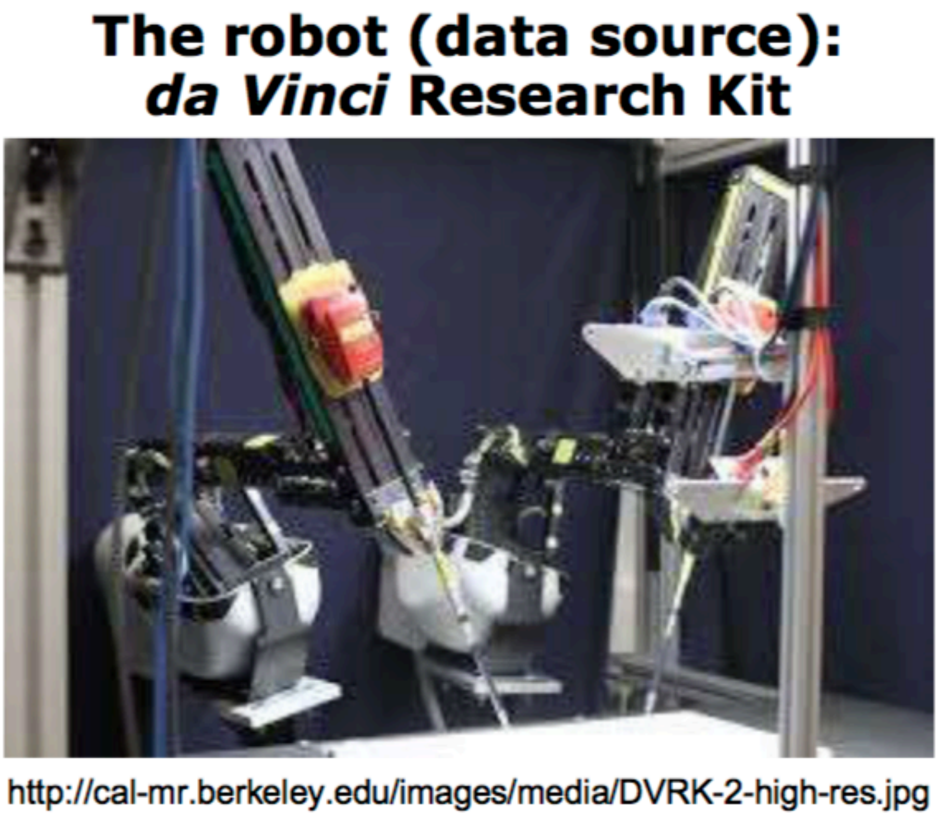


Figure 2. Da Vinci Research Kit

3.2 Brief procedure

Once we have the phantom, we perform the capsulorhexis procedure on it using the da-vinci research kit. The procedure is performed multiple times to obtain video of operations and hence tool-force data at every point of the operation. To do this, we setup a ros node using the da-vinci ros package and pull the relevant data. This data obtained is then stored properly indexed for better access.

[2] https://github.com/jhu-dvrk/sawIntuitiveResearchKit/wiki

Once data is obtained, regression can be used to determine the tool force vector at any point during surgery. The obtained tool force vector is then overlayed on top of the operation image to provide visual guidance for the surgeon performing the task.

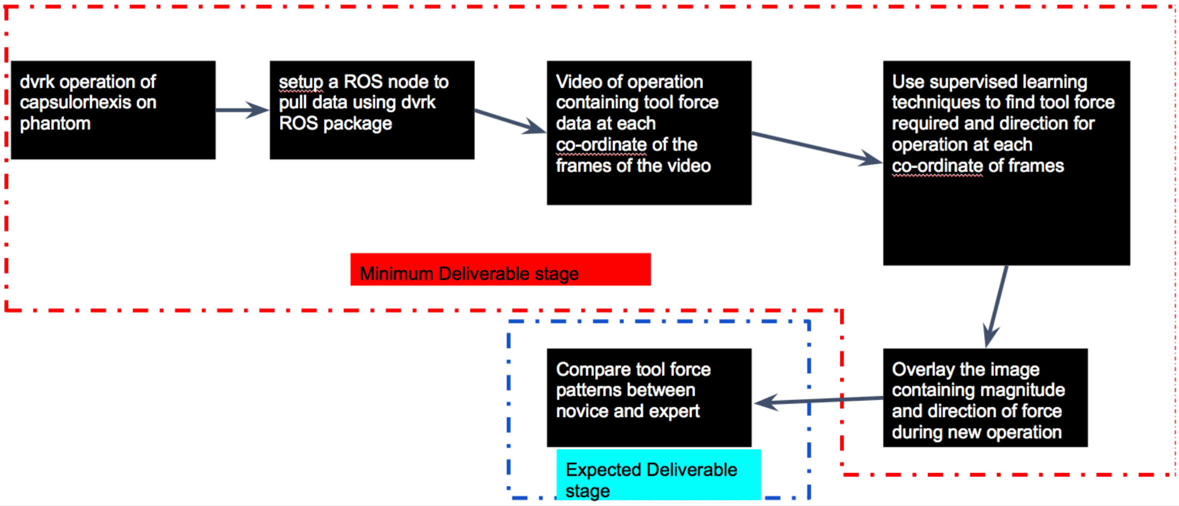


Figure 3. Brief Work flow

Once we collect data from experts and novices, we can compare their respective tool-force data using relevant measures which could be something like average of the force-vector magnitudes for the whole procedure, accuracy of the procedure, average changes in tool force direction, etc.

4. Evaluation

The first course of action will be to ensure the phantom designed is appropriate or not. This can be done possibly by checking dimensions and tool force required to operate on the phantom and comparing it with a human eye. Though this is not accurate, the project aims at establishing a procedure which can be easily extended to real human eyes if tool force data is provided.

Then, we check if the ros node designed can obtain data accurately from the da vinci. This can be done by checking for some values which are known before hand, like probably lengths, or we can instruct the dvrk to move one of its arms to some distance and compare the error in its movement with the calculated one.

Once the forces are determined and overlayed, we can check the errors of the forces estimated from existing tool-force data.

5. Deliverables

Minimum

- Simple phantom to simulate the task

A phantom that decently resembles a human eye so that the procedure can be performed to collect tool force data using the da-vinci research kit

- Video of tool motion with da vinci research kit

This is a video containing the tool motion of the da vinci research kit. Using this and the existing tool force data, we can estimate the tool-force vector at each point of the procedure

- Visual overlay of tool forces

The tool force vector estimated is then overlayed onto the operation image to facilitate the surgeon to perform the procedure

Expected

- Tool force pattern between experts and novices

This will give a clear cut comparison between experts and novices. This also facilitates skills acquisition by providing a clear comparison measure.

Maximum

- Data of errors in tool force estimation:

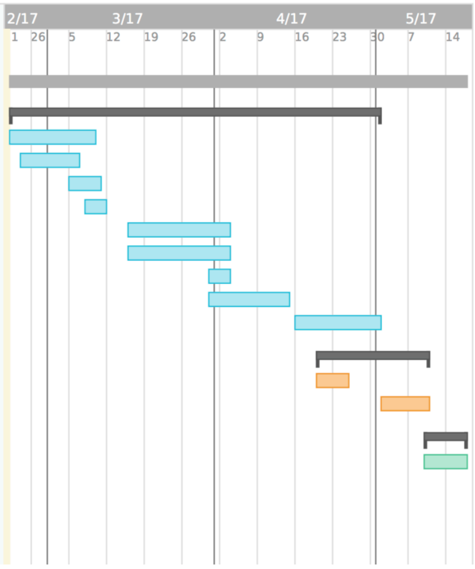
A report tabulating the errors in the too-force vector estimation method used in the project versus actual tool force.

6. Dependencies

Dependencies	**State (resolved/pending/in progress)**
Phantom for simulation of the task	In progress
Setup of Da Vinci research Kit ROS package	Pending
Access to Da Vinci Research KIT	Pending
Software setup (misc. i.e script for supervised learning, ROS node for pulling data from dvrk, visual overlay system, relevant OpenCV packages)	Pending
Mentors	Resolved

7. Timeline:

CIS 2	start	end
Minimum deliverables	**02/22/17**	**05/01/17**
Simple phantom to simulate the task	02/22	03/09
Understand DVRK software	02/24	03/06
Understand how to use DVRK	03/05	03/10
Setup ROS node to pull data from dvrk	03/08	03/11
Operate on the phantom using the dvrk to collect data	03/16	04/03
Video of tool motion with dvrk	03/16	04/03
Extract Tool-force vector at each co-ordinate in each frame of video	03/31	04/03
Estimate tool-force vector for any point of the procedure	03/31	04/14
Visual overlay of tool force vectors	04/16	05/01
Expected Deliverables	**04/20/17**	**05/10/17**
Obtain video data of operation via experts and novices	04/20	04/25
Compare the tool-force patterns between experts and novices	05/02	05/10
Maximum Deliverable	**05/10/17**	**05/17/17**
Compute errors in tool-forces between estimated and actual	05/10	05/17



8. Reading List

[1] Lam, Chee Kiang, et al. "Virtual phacoemulsification surgical simulation using visual guidance and performance parameters as a feasible proficiency assessment tool." *BMC ophthalmology* 16.1 (2016): 88.

[2] Reiley, Carol E., et al. "Effects of visual force feedback on robot-assisted surgical task performance." *The Journal of thoracic and cardiovascular surgery* 135.1 (2008): 196-202.

[3] Kazanzides, Peter, et al. "An open-source research kit for the da Vinci® Surgical System." *Robotics and Automation (ICRA), 2014 IEEE International Conference on*. IEEE, 2014.

[4] Gerovich, Oleg, Panadda Marayong, and Allison M. Okamura. "The effect of visual and haptic feedback on computer-assisted needle insertion." *Computer Aided Surgery* 9.6 (2004): 243-249.

More to come….