JOHNS HOPKINS UNIVERSITY

Data Collection System for Smart Endoscope Project

Final Report

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Technical Summary

Introduction

In the past 30 years, endoscopic techniques has gradually become the mainstay for many procedures. Especially in sinus surgeries, advances in imaging technology, increased understanding of the anatomy and the pathophysiology of chronic sinusitis, and image-guided surgery have allowed surgeons to perform more complex procedures with increased safety.

However, during traditional functional endoscopic sinus surgery (FESS), the surgeon uses one hand to manipulate the endoscope and the other hand to manipulate the surgical instruments. This situation limits the surgeon's dexterity during the procedure, where in order to conduct two-hand operations, an assistant surgeon needs to manipulate the camera (this requires an excellent communication between both sides).

Therefore, recently many efforts have been made to automate the manipulation of endoscopes. However, none of them yielded ideal clinical outcomes. The biggest challenge is to make the manipulation as intuitive, and as effortless as possible for surgeons. This requires predicting and controlling the endoscope based on other sensor information. Therefore, to thoroughly understand the hidden rules and signals behind the manipulation of endoscopes, I built an intra-operative data collection system, which captures data of different aspects of the surgery. Analyzing those data together with preoperative CT and statistical data, we are hoping to finally make the endoscopic manipulator 'smart'.

Method

Overview

Based on literature and surgeon feedback, I built an intra-operative data collection system, which captures the movement of the endoscope, the endoscope video, the movement of a suction tool, and the movement of the patient's head, as well as the gaze information of the surgeon. A detailed summary of data is presented in Table. 1. Figure 1 shows the data flow diagram of the system.

DATA NAME	DATA TYPE	DATA RATE	ACCURACY	HARDWARE	SOFTWARE
Head Pose	Pose	20HZ	0.8mm/0.7°	Head Fixture, 6 DOF Reference, Aurora	sawNDItracker
Suction/Pointer Pose	Pose	20HZ	0.8mm/0.7°	Suction Tool, 6 DOF Cable Tool, Aurora	sawNDItracker
Endoscope Pose	Pose	20HZ	0.8mm/0.7°	Endoscope Adapter, 6 DOF Reference, Aurora	sawNDItracker
Fiducial Position	Pose	20Hz	0.8mm/0.7°	Standard Probe, 6 DOF Probe, Aurora	sawNDItracker
Endoscope Video	RGB Video	30HZ	N/A	PointGrey Camera	Point Grey Driver
Gaze	Gaze	30HZ	N/A	GazePoint	GazePoint API
Comment: all data is logged using rosbag. Gaze information is collected on a Windows computer and then transmitted to and logged on Linux.					

Table. 1: A detail summary about the data collected by the system and how they are collected.

There are mainly three components of this project: Hardware, Software, and Experimental Design. I contributed to the majority of Hardware and Experimental Design, and partially to Software.

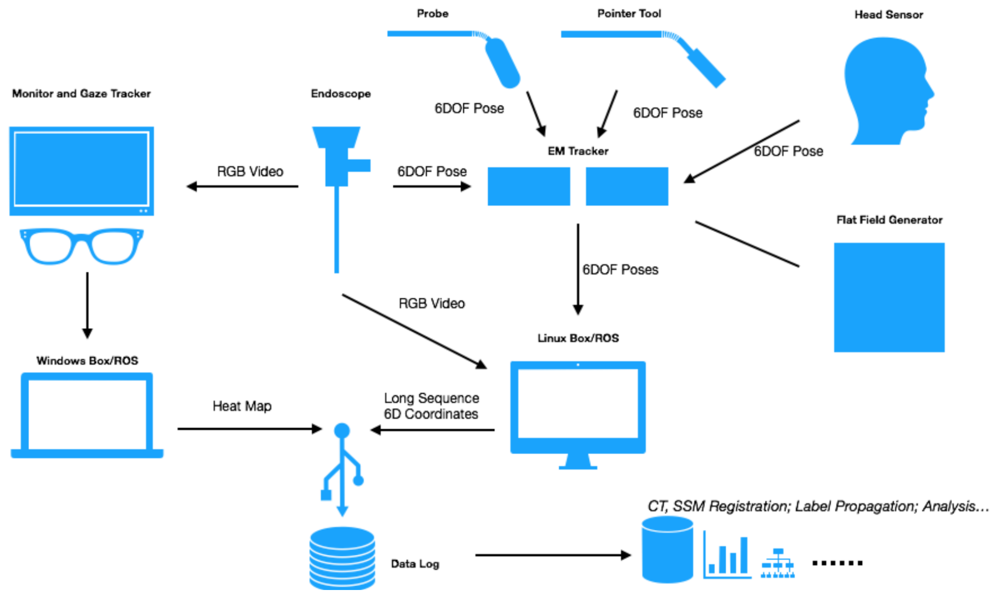
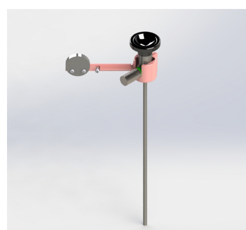


Figure. 1: A flow diagram shows how data is transmitted within the physical system.

(a) Suction Tool Phantom



(b) Endoscope Sensor Adapter

(c) Head Reference Adapter

Figure. 2: Final Design for Each Tool Adapter

Hardware

First off, we selected and acquired Aurora EM Tracking System and GazePoint GP3 Eye Tracker based on their specs and requirement of our purposes. Then, in order to attach sensor to surgical tools, I designed and manufactured custom tool adapters, which include the adapter for the endoscope, the adapter for the head reference, and a suction tool phantom. There are number of factors that were taken into account during the designing: ergonomics, metal interference, manufacturability, and reusability. Figure 2 shows the final design for each adapter. Finally, after acquiring all needed hardware components, I also integrated them into a mobile platform, which would make it easier to do experiments at different facilities. Table 2 shows a summary of all the hardware items used in this project as well as their cost and vendors.

Software

On the software side, we decided to use ROS as the operating system in order to acquire time stamped data logging. I mainly contributed by acquiring all necessary drivers and packages. After that, I integrated all of them onto ROS, and wrote a master package that launch all the nodes with

PART NAME	QUANTITY	UNIT COST	VENDOR
Suction/Pointer Tool	1	$30	WSE Manufacturing
Endoscope Adapter	1	$30	WSE Manufacturing
Head Fixture	1	$30	WSE Manufacturing
Aurora 6DOF Reference, 25mm Disc, Standard	2	$400	DNI
Aurora 6DOF Cable Tool, 2.5 x 12mm	1	$225	DNI
Aurora 6DOF Probe, Straight Tip, Standard	1	$1,075	DNI
Aurora Window 50-60 Field Generator with Detachable Cable	1	$5,415	DNI
Aurora V3 System Control Unit Kit	1	$4,412	DNI
Aurora 4-port Sensor Interface Unit V3 Kit - 4P FW3.000	1	$2,499	DNI
Flir Grasshopper3 GS3-U3-41C6C-C Camera	1	$1,450	FLIR
GazePoint GP3 Eye Tracker 150HZ	1	$1,995	GazePoint
Windows Computer	1	$500	Dell
Linux Computer	1	$1,300	Dell
Comment: Surgical tools are not included. Manufacturing materials and tools are not included.			

Table. 2: A detail summary about the hardware used in this project.

one launch file. Table 3 shows a summary of the software packages used in this project as well as their authors and source code.

Experimental Design

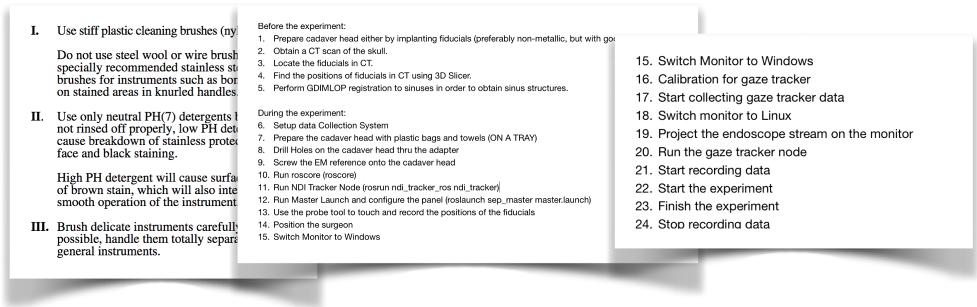
In terms of the experimental design, I created a detailed work-flow including the preparation of the cadaver head, the setup of the system, the post-processing of the cadaver head, and the clean up of the surgical tools. Figure 3 shows a part of the documentation.

Results

The hardware and software are fully implemented and tested. As a result we now have a functional system that is able to collect time stamped data for the normal duration of a sinus surgery. The work-flow is completed and submitted for revision.

PACKAGE	OS/SYSTEM	DEVELOPER	SOURCE
NDI Tracker	Ubuntu 16.04/ROS	Anton Deguet	https://github.com/jhu-saw/sawNDITracker/tree/devel
Point Grey Driver	Ubuntu 16.04/ROS	Chad Rockey	https://github.com/ros-drivers/pointgrey_camera_driver
Experiment Controller	Ubuntu 16.04/ROS	Rui	https://github.com/RuiYinRay?tab=repositories
Gaze Point	Windows/SDK	GazePoint	Offline
GP ROS Wrapper	Ubuntu 16.04/ROS	Rui/Cong	https://github.com/RuiYinRay?tab=repositories
Comment: FYI			

Table. 3: A detail summary about the software used in this project.



I. Use stiff plastic cleaning brushes (ny

Do not use steel wool or wire brush
specially recommended stainless st
brushes for instruments such as bor
on stained areas in knurled handles.

II. Use only neutral PH(7) detergents b
not rinsed off properly, low PH det
cause breakdown of stainless prote
face and black staining.

High PH detergent will cause surfa
of brown stain, which will also inte
smooth operation of the instrument

III. Brush delicate instruments carefully
possible, handle them totally separa
general instruments.

Before the experiment:

1. Prepare cadaver head either by implanting fiducials (preferably non-metallic, but with go
2. Obtain a CT scan of the skull.
3. Locate the fiducials in CT.
4. Find the positions of fiducials in CT using 3D Slicer.
5. Perform GDIMLOP registration to sinuses in order to obtain sinus structures.

During the experiment:

6. Setup data Collection System
7. Prepare the cadaver head with plastic bags and towels (ON A TRAY)
8. Drill Holes on the cadaver head thru the adapter
9. Screw the EM reference onto the cadaver head
10. Run roscore (roscore)
11. Run NDI Tracker Node (rosrun ndi_tracker_ros ndi_tracker)
12. Run Master Launch and configure the panel (roslaunch sep_master master.launch)
13. Use the probe tool to touch and record the positions of the fiducials
14. Position the surgeon
15. Switch Monitor to Windows

15. Switch Monitor to Windows
16. Calibration for gaze tracker
17. Start collecting gaze tracker data
18. Switch monitor to Linux
19. Project the endoscope stream on the monitor
20. Run the gaze tracker node
21. Start recording data
22. Start the experiment
23. Finish the experiment
24. Stop recording data

Figure. 3: Some parts of the workflow and the cleanup manual.

Future Work

There are mainly four tasks that need to be addressed at this point.

1. An evaluation and practice run need to take place until the troubleshoot for the cadaver experiment is complete.
2. The post-processing software needs to be developed according to the results from the test.
3. Some calibration and registration algorithms need to be implemented.
4. The user manual of the system needs to be completed.

This project will be a part of my Master Thesis. After step one is finished, we will start collecting data with experts surgeons over the summer. Then I will carry on the work into next year with an aim to produce a functioning prototype control model.

Management Summary

Credits and Acknowledgment

First, this project is funded by Galen Research Budget from Galen Robotics Inc,. I would like to first thank them and Dr. Taylor for trusting me and sponsoring this project. Second, since I am the sole member of the group, most the the described work was done by me. However, this project won't be possible without necessary instruction and support from my mentors, as well as the help from Cong Gao for setting up the gaze tracker. Last but not least, I would like to thank Anton Deguet, Dr. Simon Leonard, and Dr. Iulian Iordachita for their generous help and guidance.

Deliverables

The following list details what has been done v.s. the plan.

1. System Hardware Integration: Done (Expected)
2. Collection Software Integration: Done (Expected)
3. Workflow Design: Done (Expected)

4. User Manual: In Progress 80% (Maximum)
5. Post-processing Software: In Progress 20% (Maximum)

In conclusion, I accomplished the expected deliverables, and completed half of the maximum deliverables. Overall, it's an acceptable outcome for the course and good progress considering the challenges encountered during the process. The main reason for the 'under-performance' is the underestimation of the workload and my imbalanced distribution of time.

Lessons Learned

- Spreading myself too thin is not a good idea in graduate school.
- Sometimes, a surgeon's feedback is worth 10 hours of engineering.
- Planning for the unknowns is critical for the success of a project.
- Doing physical experiments is not easy.
- Even the minutest detail can be significant if ignored.
- I can't stay up for 48 hours straight.
- Dr. Ishii is very very busy.

Technical Appendices

All current documentation has been archived to Wiki page. Click here to browse.

Reference

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