Towards A Smart Endoscope: Data Collection System for Sinus Surgery

Computer Integrated Surgery II

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Abstract

In the past 30 years, 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 throughly understand the hidden rules and signals behind the manipulation of endoscopes, 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. Analyzing those data together with preoperative CT and statistical data, we are hoping to finally make the endoscopic manipulator 'smart'. A detailed summary of data is presented in Table. 1.

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: This table summarizes all data that is to be collected by the system.

Gaze Information

A gaze tracker allows us to capture where the surgeon is looking at at specific time during a surgery. Together with a video to CT registration algorithm, we will be able to know which anatomy structure that the surgeon is looking at, and study how that relates to the movement of the endoscope.

In our system, we used a GazePoint GP3 Eye Tracker(hardware), as well as GazePoint Analysis(software), to track the gaze information. Using the software, fixation path and heat map can be generated both online and offline, making it possible for both analysis and application. However, the software is only provided on Windows, therefore a separate PC is needed. The data is then transmitted to the Linux PC and received thru an internet cable to be synced and logged. Figure 2 and 3 show the fixation path and heat map generated from tests.

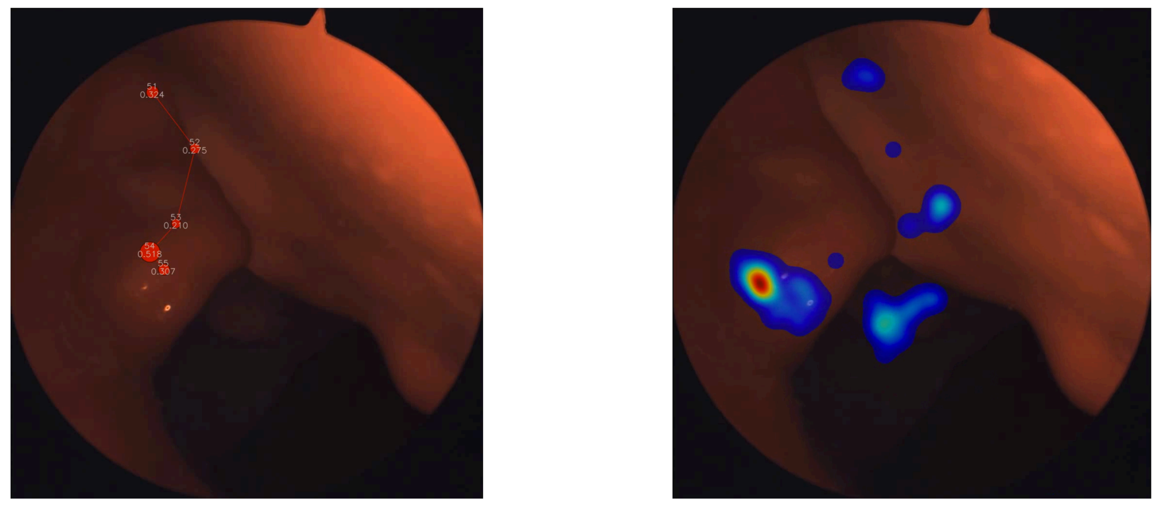

Figure. 1 & 2: Figure 1 on the left shows the fixation path and Figure 2 on the right shows the heat map, both generated by the GazePoint software.

Endoscope Video

A FLIR Grasshopper®3 High Performance USB 3.0 Camera is used to capture the endoscope view. Flycap and its driver package are used to stream the video to the monitor and also to be logged together with gaze tracking data. An additional endoscope adapter/lens is used to adapt the endoscope.

The video can be recorded at up to 2048 x 2048 resolution and 60 fps. However, due to limited bandwidth and space limit, the experiment will be run at lower setting.

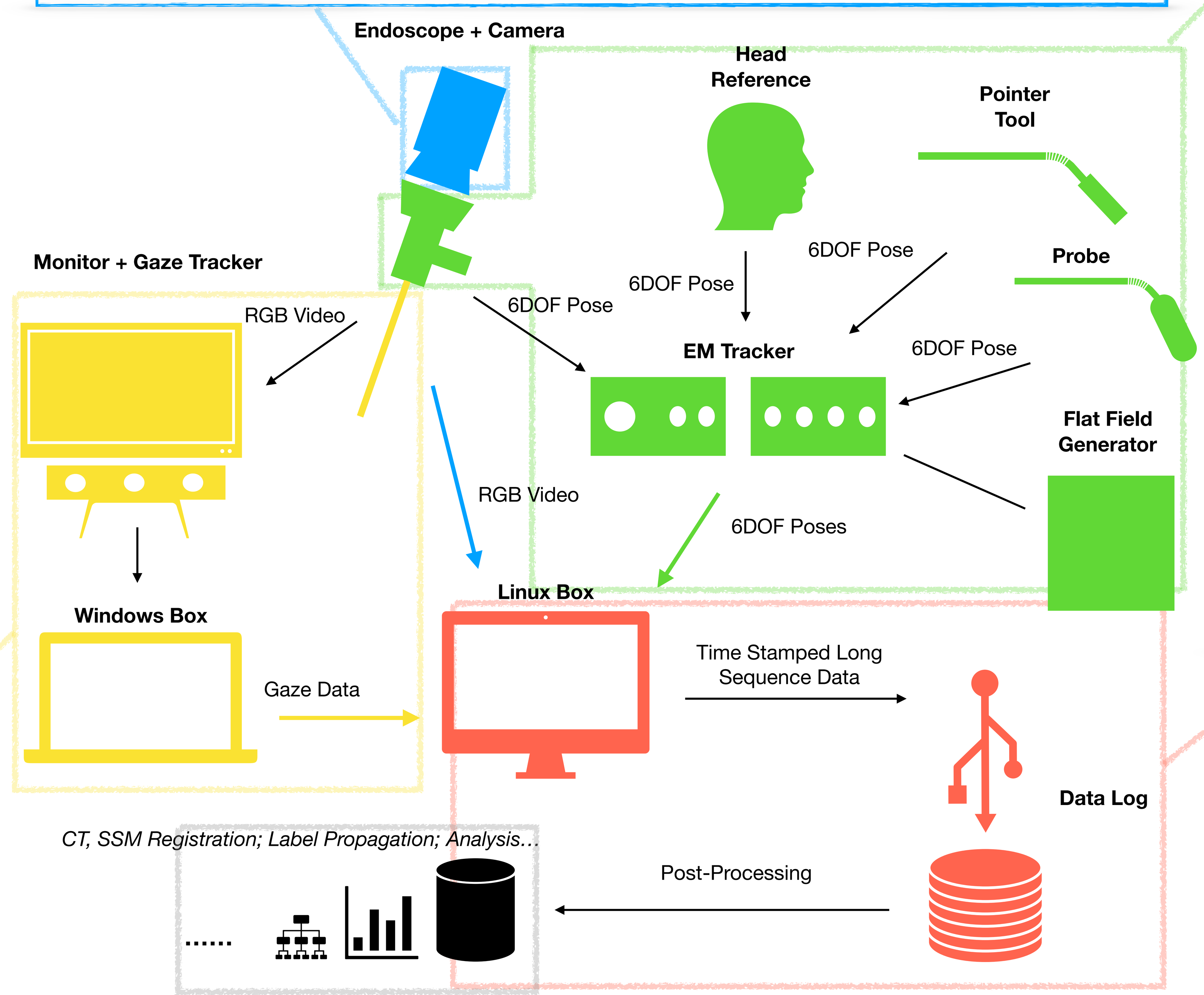

Figure. 3: This diagram shows the data flow between each physical composition of the system.

Future Work

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

First, an evaluation and practice run need to take place until the troubleshoot for the cadaver experiment is complete.

Second, the post-processing software needs to be developed according to the results from the test.

Third, some calibration and registration algorithms need to be implemented.

Forth, the user manual of the system needs to be completed.

After step one is finished, we will start collecting data with experts surgeons over the summer.

Instrument Traces

An Aurora EM Tracking System is used for the tracking of instrument traces. Utilizing the flat field generator model, the system has a work volume of 420x600x600(mm). The system can measure at 40 HZ with an accuracy of 0.8mm/0.7°. Due to limited bandwidth and space limit, the experiment will be run at lower setting.

In order to attach sensor to surgical tools, custom tool adapters were designed and manufactured, 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 4, 5, and 6 show the final design for each adapter.

During the experiment, we also need to perform several pivot calibration in order to register the tracker frame to the CT frame. This is done by utilizing the pointer probe that comes with the Aurora system.

Figure. 4, 5 & 6: Pictures of the final design of (from left to right): the suction tool, the head reference adapter, the endoscope adapter.

Workflow and Integration

After we've completed all the components, there are still some planning and integration work that needs to be done before this system can be implemented.

To acquire time stamped data logging, we decided to use ROS as the operating system. Therefore, the corresponding ROS wrappers are either found, acquired or self composed. In the end, all nodes are written into one single launch file, except for the sawNDItracker. Then rosbag is used to time stamp and log all data.

At the same time, we also designed a detailed workflow 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 7 shows a part of the documentation.

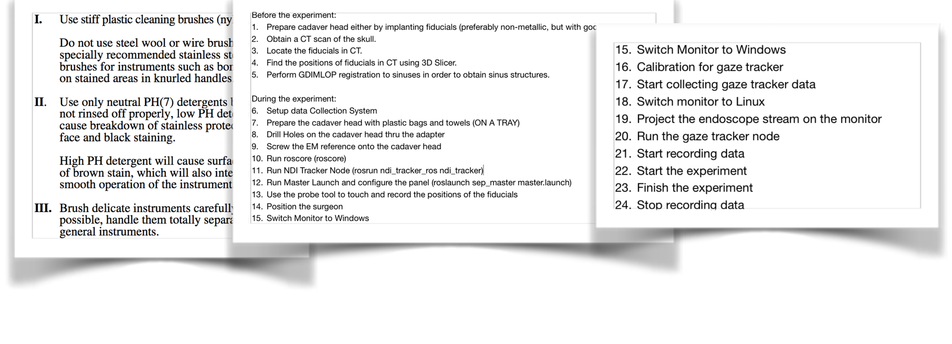

Figure. 7: This figure shows some parts of the workflow and the cleanup manual.

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