Rohit Joshi

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CIS II

Seminar Paper Critical Review – Automated Objective Surgical Skill Assessment in the Operating Room from Unstructured Tool Motion in Septoplasty

Project Overview:

Septoplasty is an extremely common procedure, with 260,000 cases in the US in 2006 (Ahmidi). However, it is typically conducted in a “black box” with only the operating surgeon who is conducting the surgery able to see what exactly is being done. This presents a problem during training and evaluation, as the evaluating surgeon cannot see what the trainee surgeon is doing before or after the surgery. We aim to use septoplasty tool motion data to construct visualizations of patients’ septums using registration algorithms, thereby allowing a visual model of the septum that can be paired with other data to give feedback to the trainee surgeon post-operatively.

Paper Selection:

The paper “Automated Objective Surgical Skill Assessment in the Operation Room from Unstructured Tool Motion Data” was chosen because it aims to address the same problem of allowing objective evaluation and feedback for septoplasty from a different angle. It also highlights the various ways septoplasty tool motion data can be manipulated, which is important because we need to isolate the on-plane movement of the tool to construct our model.

Problem and Key Results:

Current methods for evaluating surgery include generic motion metrics and other statistics methods such as hidden Markov Models and descriptive curve coding. However, generic motion metrics such as time and number of movements don’t lend themselves well to septoplasty due to its unstructured tool motion in its most important part, mucosal flap elevation. In addition, statistical methods such as HMM and DCC have not been used for procedures like septoplasty in the past so it is unclear whether they would work. Even if they would, they only classify and do not provide enough useful feedback for trainee surgeons. Hence in this paper, the authors developed a novel stroke-based classification which was able to correctly classify surgeons into "expert" and "novice" categories with 91% correctness and offer valuable feedback to surgeons on their movement patterns. It also found that DCC was an accurate metric due to its encoding of the raw data into higher level features, but that HMM and generic motion metrics were inaccurate in their classification.

Background:

Septoplasty is a core surgical procedure that all head and neck surgeons learn and training programs must ensure that residents are competent to perform this surgery before they graduate. The most important and difficult part of this surgery is the mucosal flap elevation, where the skin of the septum has to be elevated away from the underlying bone and cartilage using a tool called the cottle elevator. During this portion, surgeons make repeated "strokes" where they lift a portion of the skin using the cottle and then repeat the process until all the skin is lifted. This makes the procedure difficult to evaluate as the motion is unstructured and varies from patient to patient depending on a variety of external factors, such as septum and nose size, as well as the amount of deviation of the septum. In addition, there is no visual way to give feedback to the operating surgeon because the nasal passageway is only large enough for one person to see.

Experiment and Methods:

In this experiment, the authors first converted the motion data to the septal coordinate system from the world coordinate system and subtracted any movement from the patient's head (accessible from the head sensor). Then they approached the problem in four different ways. First, they extracted and tested some basic signal-based features, including velocity distribution, acceleration distribution, and frequency spectrum profile. Then, they used statistical methods such as HMMs trained on feature combinations in septal and world frames as well as DCC's tested with a dictionary of common strings for each skill class. Lastly, they developed and tested their new stroke based model by encoding the data into several strokes, which consisted of local minimum and maximums from the septal plane. From these strokes, they extracted several features which they both developed into a "search graph" that gave a visual model and input into a kernel SVM to classify.

Assessment:

This paper was extremely useful in describing the importance of the overall problem and why the current methods do not work. In addition, it gave an extensive description of the experimental workflow and described in depth the stroke based features that it extracted. I also liked that they used many stroke based features in total, which were useful in creating robustness in the model and allowing the trainee surgeon who would potentially use this to gain insights on multiple levels. An area of improvement I saw was that they could have gone more in depth on their analysis of the 14 multi-surgeon cases, as these could have caused significant deviations in the data. In addition, I would have liked for there to be head sensors in all of the patients, not only a subset of them. Lastly, I believe that while the feedback the final solution was able to generate was useful, without a visual feedback it might be hard for trainee surgeons to fully understand how to fix their process. Thus, I believe our project combined with the output of this project would provide an excellent combination of feedback for trainee surgeons in the future.

References:

Ahmidi, N., Poddar, P., Jones, J.D. et al. (2015) Automated objective surgical skill assessment in the operating room from unstructured tool motion in septoplasty. International Journal of Computer Assisted Radiology and Surgery (2015) 10: 981. https://doi.org/10.1007/s11548-015-1194-1