3D Infrared Imaging Applications for Cranioplasty Procedures

Johns Hopkins Applied Physics Laboratory

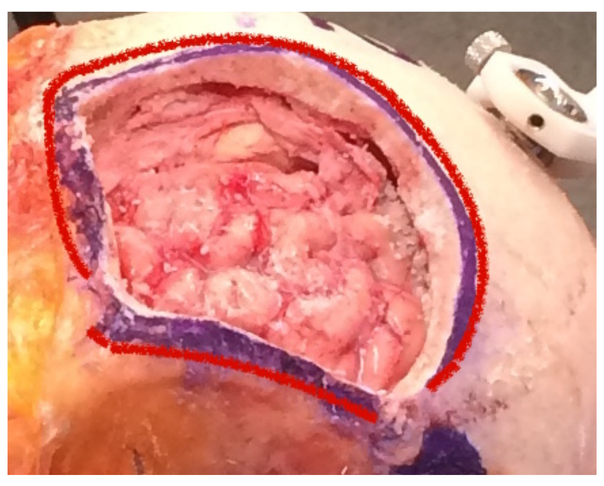
Computer Integrated Surgery II
Spring, 2015

Johns Hopkins School *of* Medicine

Alex Mathews and **Joshua You**
Under the auspices of **Dr. Mehran Armand**, **Dr. Chad Gordon**, **Dr. Ryan Murphy**, and **Cpt. Gerald Grant**

Introduction

Using an **iPad mounted, 3D Infrared Sensor**, we have developed a quick and accurate method of modeling a defect on a skull as a 3D mesh. With this triangle mesh, we are able to **extract precise features of the defect** (edge shapes, wall angles, etc.), which will enable surgeons to efficiently create accurate Customized Cranial Implants.




Left: Image from a Cranioplasty Mock Operation, showing a real defect.
Right: Image of the structure sensor attached to an iPad.

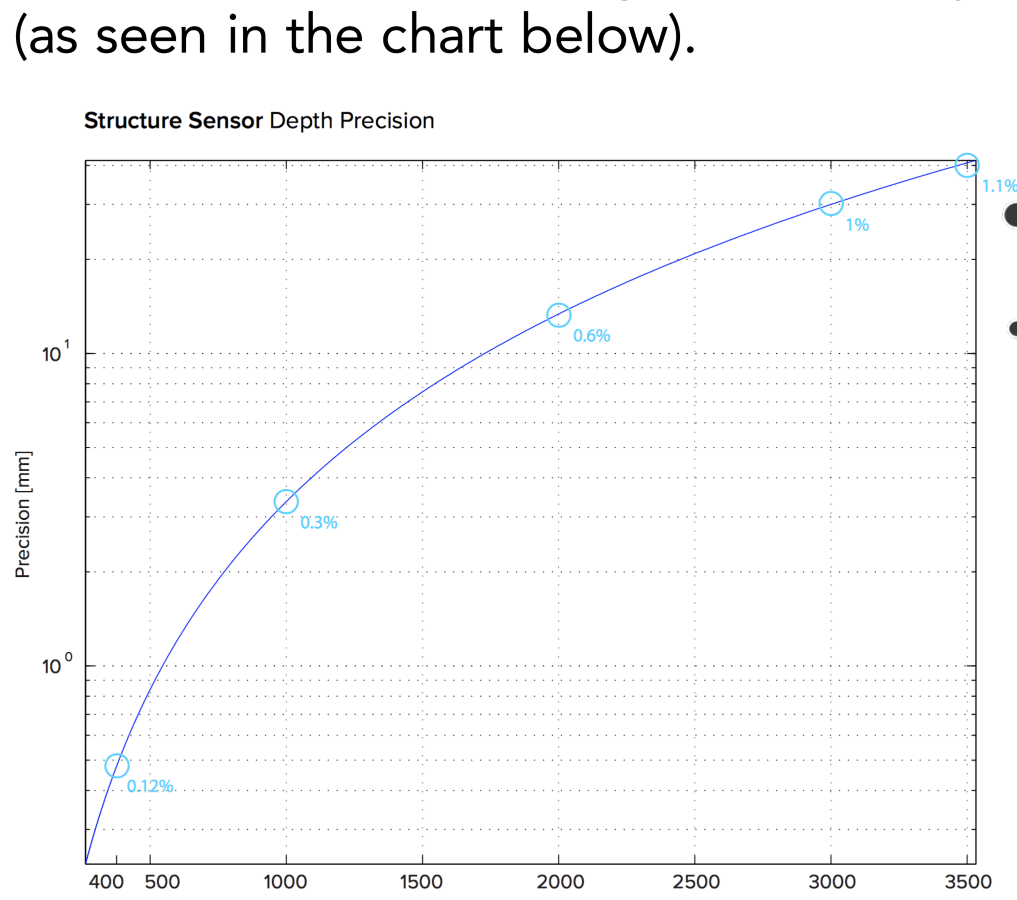
3D Infrared Optical Imaging has the potential to revolutionize the surgical environment with its safety and ease of use. If properly implemented, these scanners can add a **new level of precision** to the cranioplasty procedure while simultaneously **reducing operation time.**

The Problem

The Cranioplasty Reconstructive Surgery is currently a trial and error process, with no effective means of intraoperative implant modification. While implants can be designed preoperatively, **no current systems exist to account for the exact features of the cranial defect**. Current procedures are slow, imprecise, and rely solely on the skills of the reconstructive surgeons.

The Solution

Our solution was to implement the **Structure Sensor** (developed by Occipital) and its associated software to precisely obtain 3D surface models during the operations. The Structure Sensor offers unparalleled portability and ease of use, while maintaining the accuracy of high end scanners (as seen in the chart below).



STRUCTURE
SKANECT

Precision information showing millimeter depth accuracy when scanning within .5 meters.

This project focuses on adding layers of software to adapt scanning technology for the cranioplasty procedure. This includes:

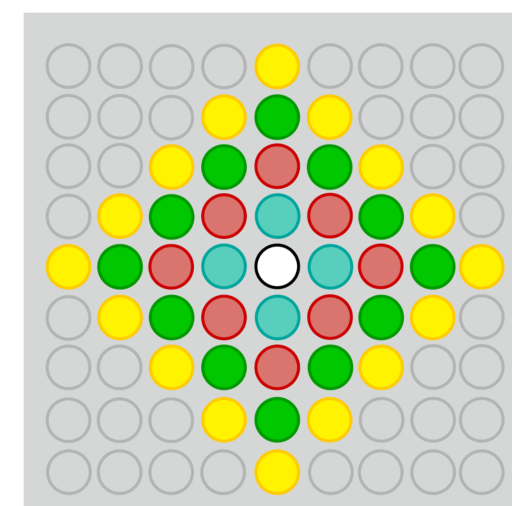
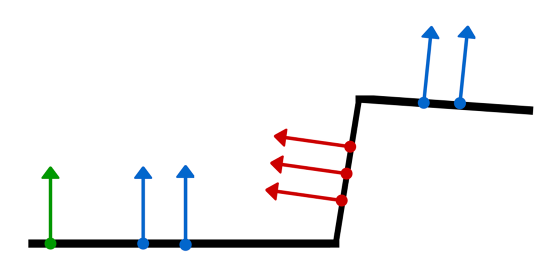
- **Gross Registration** via Color Dot Segmentation
- **CT Registration**
- Defect **Wall Identification**

With this software the scanner can be used to quickly create a point cloud describing the defect in CT coordinates.

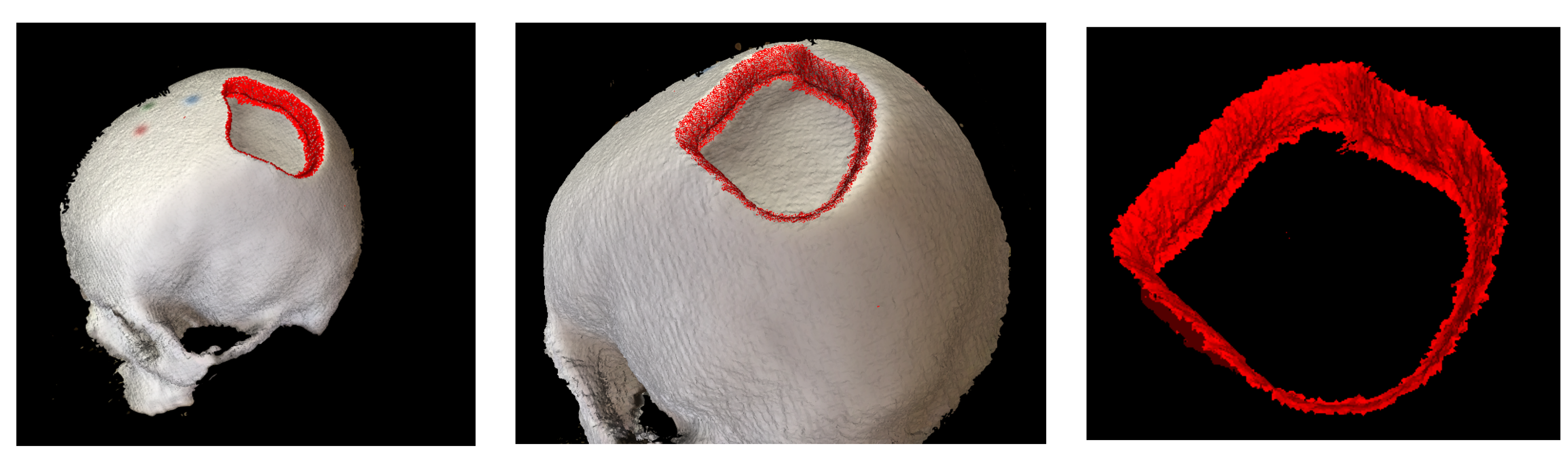
Outcomes and Results

The **Color Dot Based Registration** was achieved by using 3 different colors of stickers, segmenting their location from the scan using HSB values, and using Horn's method to calculate a transformation between two scans. This method and the **CT Registration** both achieved RMS values of **below 1mm** in initial testing.

To identify the wall of the defect, a new algorithm was created, which we have named the **Neighbor Based Scoring Algorithm.** This algorithm works by considering vectors in the surrounding region to refine calculations of a point's normal vector. This method yielded promising results of detecting points with normal vectors perpendicular to the centroid, shown below.

Top: Image demonstrating the selection of neighbors for refined selection
Bottom: •-Centroid •-Ignored •-Selected



Images of a surface model generated from the 3D scanner. Red indicates areas determined to be defect walls by the Neighbor Based Scoring Algorithm.

Future Work

The results of this project were quite promising, therefore work will continue over the next 3 months, with two major subprojects:

1. **IRB Approved Study** – use of the scanner in a surgical environment to verify scanner accuracy, confirm its ease of use, and validate 3D Scan to CT Scan Registration
2. **Application Development** – create 3D Slicer Modules for streamlined defect identification and registration, as well as communication with CNC milling machines.

Lessons Learned

This project was a great first experience with the power of 3D IR Imaging. We learned the importance of proper planning for software design, and had great experiences in the Mock Operating Room.

Credits

Alex Mathews – Scanner Use, Image Registration
Joshua You – Neighbor Based Scoring Algorithm

Publications

As of this presentation, no papers have been published; however, a paper will be written regarding a general form of the Neighbor Based Scoring Algorithm.

Support by and Acknowledgments

This project would not have been possible without the mentorship and guidance provided by Dr. Armand, Dr. Murphy, Dr. Gordon, and Dr. Taylor.