Control Architecture of Cranial Implant Laser Cutting System

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Introduction
• Cranioplasty is a procedure to repair cranial defects using custom cranial implants (CCIs).
• The goal is to develop a portable 5 DOF laser cutting system that assists surgeons in resizing CCIs in single-stage cranioplasty.
• Currently, CCIs are resized manually. This system aims to automate the current procedure. Benefits include decreasing surgery time and labor cost, and improving accuracy of implant modifications.

• Area of research
  • Biomedical engineering
  • Surgical instrumentation

The Problem
• CCIs are made in oversized profiles, and require numerous iterations of manual modification to become suitable for patients.
• This process can take up to 80 minutes depending on the size of the implant and the complexity of the modification.
• Modification is based on the surgeon’s visual analysis, and therefore is prone to errors in precision and accuracy.

The Solution
• CNC laser system consisted of 35W CO₂ laser, mirrors, and linear stage; constitutes 3 transitional axis
• Rotary table; constitutes 2 rotational axis

Outcomes and Results

Future Work
• Implant registration
• Cutting path to G-Code conversion algorithm
• FreeCAD cranioplasty module

Lessons Learned
• We acquired experience in tool path generation, FreeCAD, LinuxCNC, hardware abstraction layer, system configuration, and software/hardware debugging.

Credits
• Joshua focused on implementing algorithms for cutting motion and tool path generation, and developing GUI
• Jerry focused on assembling hardware, aligning laser components, path to G-Code conversion
• Both contributed to configuring and debugging the system

Publications

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• We would like to thank the LCSR Robotorium and Wyman Park for providing access to the machine shops

Software Design for the laser cutting system