Surgical Simulator for Endoscopic Carpal Tunnel Surgery

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Background

Motivation
- Simulators reduce cost and increase repeatability as training tool
- No current simulators incorporate haptics and realistic visuals for a low cost
  - Hybrid models only used for laparoscopic surgeries
- This simulator would serve as a model for more complex surgeries

Surgical Background
- Relieves symptoms of carpal tunnel syndrome, such as pain and numbness
- Deployable blade cuts transverse carpal ligament to relieve pressure on the median nerve (Figure 1)
- Surgeons use combination of haptics and visual feedback during procedure

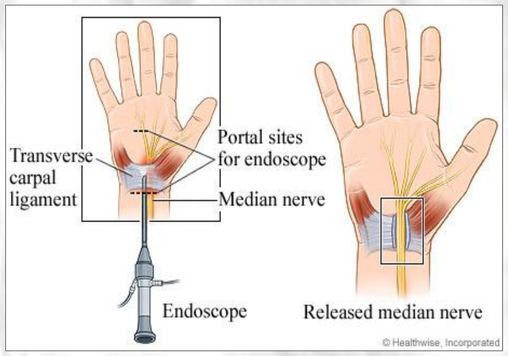

Figure 1. Carpal Tunnel Release procedure.
http://www.health.com/health/library/mdp/0,,zm2464,00.html

Current System
- Camera view moves through virtual environment
  - Up and down arrow keys, space bar to deploy blade
  - Series of 147 endoscope photos
- Only one degree of freedom (z axis)
- No haptic feedback or exposure to surgical instruments

Client Specifications

Haptics
- Life-like feel/appearance
  - More restrictive carpal tunnel
    - approx. 1 cm diameter
  - Corrugations
    - 1 mm height by 1 mm width
- Feel endoscope when palpating palm
- Resistance felt when ligament is “cut”
- Mechanism must use current surgical instruments
- Must withstand repeated simulations

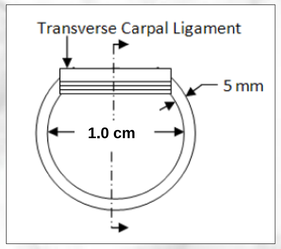

Figure 2. Carpal tunnel dimensions

Visualization
- Interface with anatomical images
  - z-axis and rotation about z
- 1 mm precision of movement
- External devices must not interfere with surgical procedure
- Improve aesthetics of LED circuit

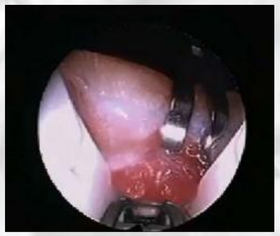

Figure 3. Endoscopic camera view as seen in the virtual simulation.
Photo from Dr. Benjamin Mandel

Problem Statement: to design a simulator as a training tool for endoscopic carpal tunnel release surgery that interfaces a realistic hand model and force feedback mechanism with a virtual representation of the wrist.

Final Prototype

Hand Model
- Silicone tube suspended in gel
- Corrugated ligament
- Pre-made carpal incision
- Resistance similar to human tissue

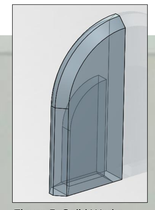

Figure 5. Solid Works Drawing of Blade Cap.

Blade Cap (Haptics)
- Photopolymer resin (Accura 60)
- 0.250 inches tall
- Provides haptic feedback when ligament is “cut”
- Does not interfere with current blade mechanism

Figure 4. Final prototype.

LED Circuit
- Covered circuit similar to regular endoscope attachment
- Wii remote infrared camera tracks position of 2 LEDs
  - Translation in x-y-z, rotation about z
- Middle LED acts as trigger signal
  - Controlled by switch in endoscope shell
- Wii remote connects to Java program via Bluetooth

Testing

Objective: Determine optimal range of accurate LED detection by Wii remote.

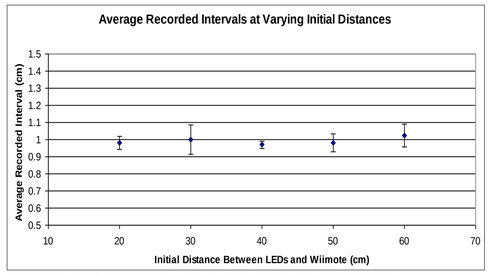

Figure 7. Average and standard deviation of interval measurements.

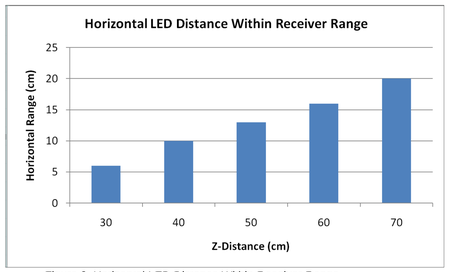

Figure 8. Horizontal LED Distance Within Receiver Range

Results: No significant difference in accuracy exists between the range of 20-60 cm.

Future Work

- Develop carpal tunnel with adjustable diameter
  - Tighten fabric band around tunnel when blade is deployed
- Further improve aesthetics of LED circuit
- Create complete training tool
  - Video, instructions
- Perform additional testing with more surgeons
  - Quantifiable results on haptics
- Increase resistance offered by blade cap

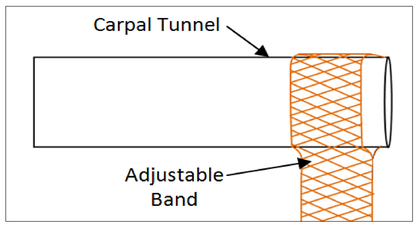

Figure 9. Sketch of band around tunnel.

Virtual Visualization
- Java program translates pixel coordinates to 3D position
  - Based on trigonometric relationship
- Change in z-position corresponds to linear progression of recorded endoscope photos
- Accommodates linear motion in z, rotation about z

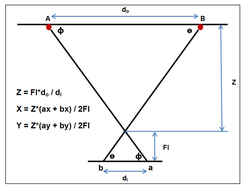

Figure 6. Trigonometric relationship of pixel coordinates.

Table 1. Cost analysis

Item	Cost ($)
LED circuit attachment	32.50
Endoscope (donated)	500.00
Hand model	300.00
Wii remote	40.00
Platform	45.00
TOTAL	**927.50**

References

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