Medtronic Navigation - Snapshot Registration

Jack Napoli | Kyle Paris | Charlie Gau | Alex Zinman | Sarah Bian | Ryan Garrett

Paul M. Rady Mechanical Engineering
UNIVERSITY OF COLORADO BOULDER

Medtronic

Goal

Increase safety and efficiency of surgeries by creating an integrated hardware and software system that enables surgeons to locate patients in 3D space using two cameras, with the simple click of a button

Background

- Medtronic creates technology to aid surgeons via 3D visualization of CT scan information
- Registration - locating of patient in 3D space pre-surgery, enabling digital aid
- Current methods display surgical tool placement with ~2mm of accuracy, and takes one minute to complete

Software Requirements

- <1mm Total Registration Error
- Low Operation Time (~10 sec)
- Decreased Operator Error

Hardware Requirements

- Lightweight (Under 5 lbs)
- Ergonomic Design
- FDA Compliant

Software

① Camera Calibration

- Determine lens characteristics
- Calculate relative position between cameras
- Quantify input image quality

② Initial Guess

- Educated guess of head location with respect to left camera
- Required for high-accuracy scan
- Relate 2D pixels to 3D points

③ Sticker Detection

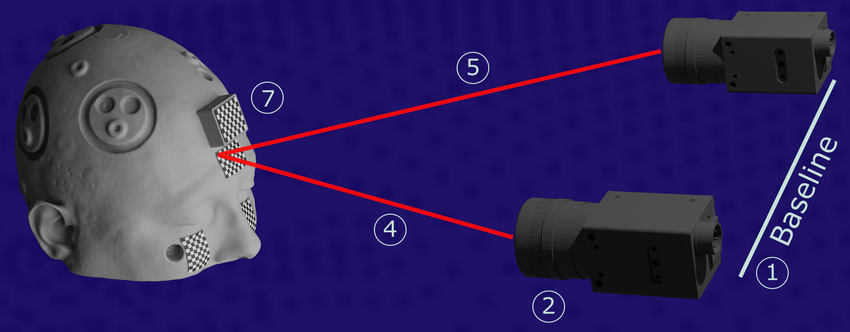
- High accuracy required to ensure proper projection in steps 4 and 5
- Known points that can easily be solved for correspondence

④ 2D to 3D Projection

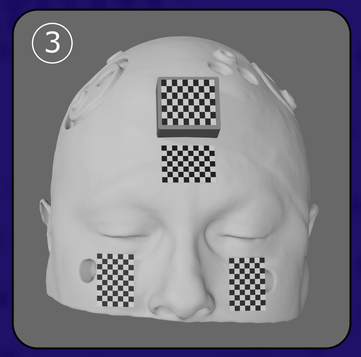
- Find 3D points associated to detected sticker points
- Based on initial guess of head

⑤ 3D to 2D Projection

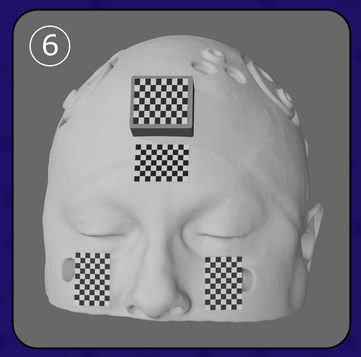
- Use known relation between left and right camera
- Project sticker points into the right image plane



Left Camera View



Right Camera View



⑧

⑥ Optimization

- Adjust head location guess found in Step 2
- Align detected corners and projected corners

⑦ EM Frame Detection

- Relate reference frame to left camera location
- Based on checkerboard pattern on EM frame

⑧ Matrix Calculation

- Calculate transformation matrix between CT scan and EM frame
- Based on relationship between left camera, patient head, and EM frame

Software Results

Simulated Data

Simulation in Blender application with known camera and head locations

Tests Run	100
Accuracy	0.2mm
Time	10 sec

Standardized Test

Medtronic standardized test where exact location of EM reference frame is known based on CT scan of 3D print

Tests Run	25
Accuracy	0.6mm
Time	10 sec

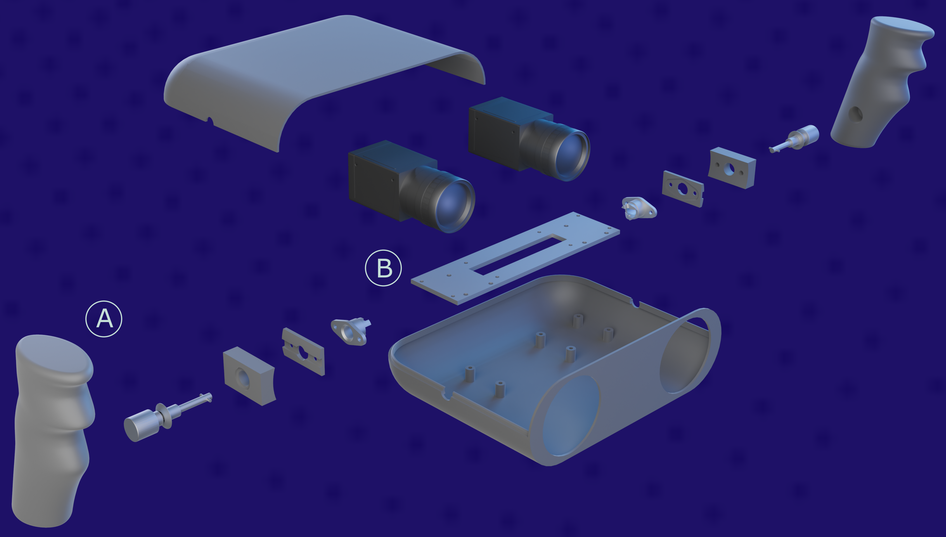
Hardware

Ⓐ Handles

- Reduce wrist strain at various angles
- Support full weight of housing and components
- Increase stability during registration process to aid accuracy

Ⓑ Steel Plate

- Minimize camera movement after calibration
- 304 Stainless Steel
- Final weight: 0.25 lbs



Ergonomics

- Designed with anthropometric data in mind
- Analyzed hand dimensions of surgeons of various ethnicities and genders
- Weight distribution optimized to reduce wrist strain

Hardware Results

Final Weight	2.11 lbs
Ergonomics Review	✓
Drop Test	✓
Cleaning Test	✓

Future Work

- Medtronic can continue to test and validate the accuracy of this product by performing cadaver testing
- Surgeons can be consulted to review ergonomics and time efficiency
- After internal trials, the device can be submitted for FDA approval
- Future areas of research may involve replacing cameras with IR emitters and receivers, further simplifying production

Thank you again to supporters of our project, including CU Boulder faculty, Medtronic's Ear Nose and Throat division, and industry connections

- The Medtronic Navigation Team