3D Reconstruction of Infants' Cranial Shape using Mobile Devices

Computer Integrated Surgery II
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Introduction

What we did:

- Develop a software pipeline to reconstruct an accurate 3D model of a baby's head, using depth information from a sensor and mobile application

General problem:

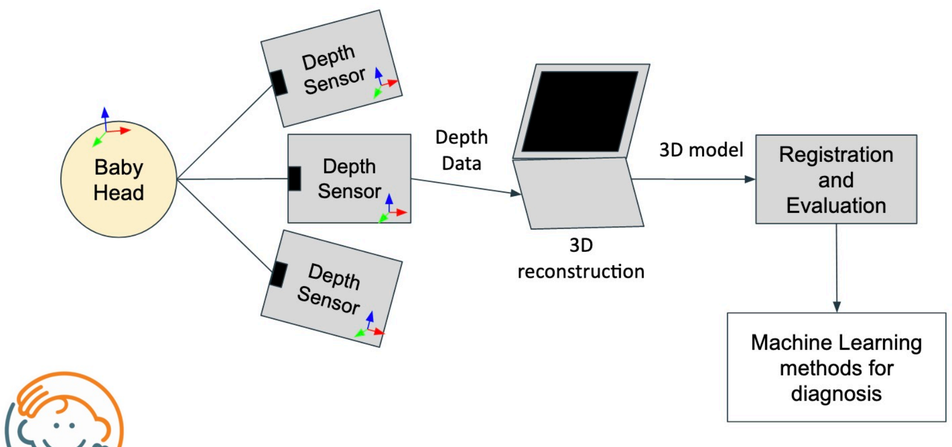
- Pediatricians need a more effective, accurate, and efficient method for evaluating and diagnosing children with skull deformities
- 3D reconstructions can provide accurate and automatically-generated quantitative metrics for diagnosing deformities

The Problem

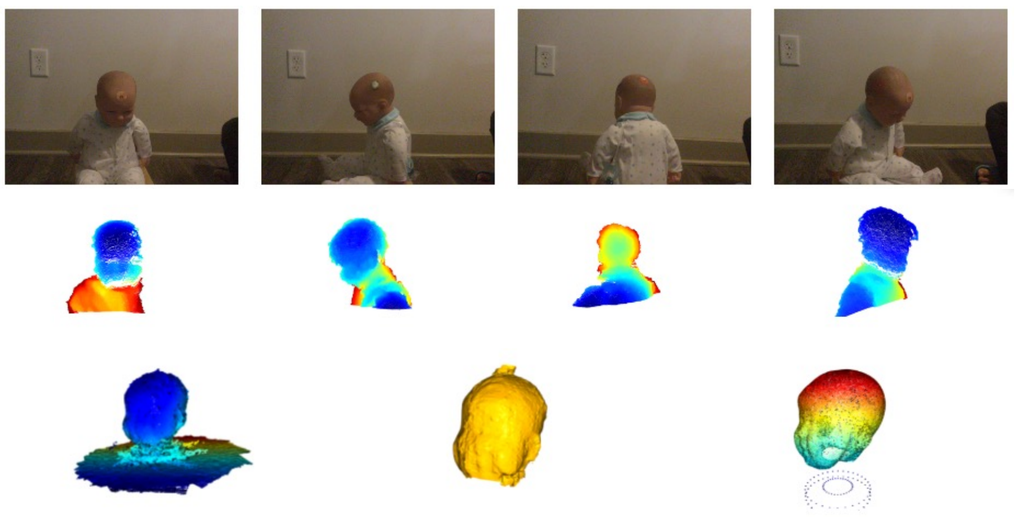
- Before 6 months of age, infant skulls are easily deformed. Deformational plagiocephaly (DPB) is a pediatric epidemic, affecting 20-30% of newborns in the US. Early detection of DPB and other skull-related deformities can prevent trauma and potential surgery.
- Pediatricians use simple measuring tape for forehead circumference. Methods using computer vision with 2D photos from above a baby's head have also been developed but are limited.
- 3D models hold more information like volume, allowing for better detection of cranial deformities.

The Solution

- We created a software pipeline that can take in depth images and output a 3D reconstruction of the images.
- To gather the depth data, PediaMetrix Inc. provided us with an iPad with a depth sensor by Occipital. The data was uploaded to an Amazon bucket for download.
- We preprocessed the depth maps and converted them into point clouds using the Open3D package. From here, we used the ICP registration algorithm from Open3D to register the consecutive images together.
- From these registrations, we register all point clouds back into a single coordinate frame to produce a point cloud reconstruction.
- Using Open3D functions, we down-sampled and converted the point cloud into a mesh using the Surface Poisson Reconstruction method.



Our workflow described in gray.



Top Row: Captured RGB images of baby doll

Middle Row: Depth maps of baby doll

Bottom Row: (Left) Registered point clouds in a single coordinate frame. (Middle) Mesh generated from the registered point clouds. (Right) Ground truth point cloud.

Outcomes and Results

- Average surface distance: 4.5097 millimeters
- Distinct shape of baby was achieved in reconstruction, but error built up in consecutive ICP, resulting in the appearance of two misaligned faces
  - Average surface distance small, indicating a generally well-aligned cranial shape

Future Work

- We will not be continuing the work but have provided PediaMetrix Inc. with code and documentation in their GitHub repository
- Implementing loop closure detection
- Taking videos instead of a series of photos
- Vision-based approaches to registration that can penalize large transformations

Lessons Learned

- More literature review and sticking to a plan of approach before starting implementation may have saved us some time.
- Quality of data collection and preprocessing is crucial to creating an effective ICP pipeline

Credits

- David and Tara worked on all parts of the project together in frequent meetings over Zoom.

Support by and Acknowledgements

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- Thank you to our mentors for supporting us and providing helpful advice, encouragement, and tutelage throughout the project.