Facial-landmark guided augmented reality (AR) system for real-time neuroimaging optode or electrode placement guidance

Fan-Yu Yen[1], Yu-An Lin[1], and Qianqian Fang[1]

1. Department of Bioengineering, Northeastern University, 360 Huntington Ave, Boston, MA, United States

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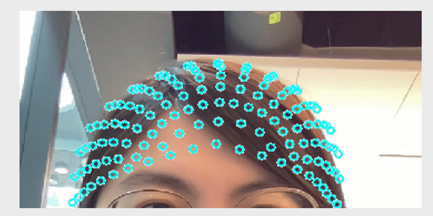
Current challenge

- FNIRS/EEG optode & electrode placement is time-consuming, requiring manual measurements
- Standard caps do not consider subject specific head shapes
- Lack of real-time guidance tools

Our solution

AR Guide Placement System

- Uses a simple camera for real-time tracking
- Supports age-specific atlases for accuracy
- Renders head 10-20 landmarks in real-time



Demo

① Preprocessing

3D Head Library → 10-20 Anchor Points → Facial Landmarks → Face-to-head Mapping → Optode/Electrode Placement Map

3D Head Model Library

- Liverpool-York Head Model (LYHM)[1]
- Comprises 1,519 subjects
- Contains textured 3D head surfaces
- Covers a wide age range (2-90 years)
- Covers diverse head sizes, shapes, and gender representations (Male: 750, Female: 768, Others: 1)

Anchor Points

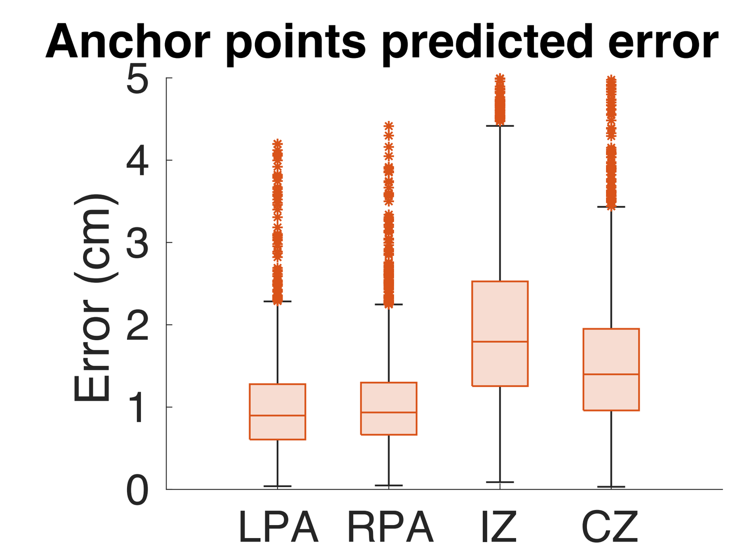
- Manually labeled left-preauricular-point (LPA) and RPA
- LPA, RPA, nasion (NZ), and inion (IZ) are assumed to be coplanar to compute IZ and vertex (CZ)
- Excluded 645 subjects due to incomplete head models, improper head positioning, and unavailable facial texture

Facial Landmarks

- Applied a deep-learning based facial recognition API -- MediaPipe[2]
- Created 468 facial landmarks per view; 20 are selected for next step
- Repeated face-recognition for multiple views

Linear Matrix Fitting

- Determined an optimal linear mapping to transform facial landmarks to the anchor points



To test robustness, we

- Used 80% of the data for fitting and 20% for testing
- LPA/RPA error: 1.06 cm
- IZ/CZ error: 1.77 cm

Reference 10-20 landmarks

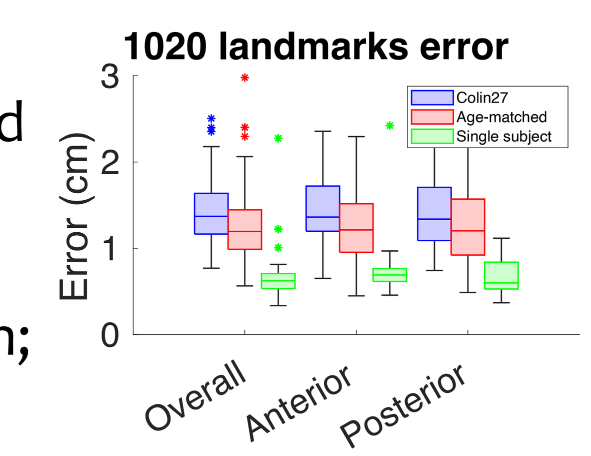
- Computed 10-20/10-10 landmarks on all valid LYHM head models based on manually selected anchor points and head surfaces as the ground-truth.

Pre-computed Atlas Model

- Computed 10-20 points on various atlases
- Includes two types of atlas model
  - Average Brain model (Colin27)
  - Age-specific model (Neurodevelopment database)

10-20 points validation

- Register the atlas 10-20 points based on predicted anchor points
- Colin27 error: 1.37 cm; age specific error: 1.20 cm; single subject: 1.62 cm



② Experimental workflow

01 Capture Video Streams → 02 Facial Landmark Generation → 03 Anchor Point Prediction → 04 Computing 10-20 Landmarks → 05 GUI Real-time Rendering

Capture Image

Capture a single frame image of the subject's face using a camera.

Facial landmark generation

Utilize the previously captured image to generate facial landmarks with the aid of MediaPipe[2].

Anchor points prediction

Generate anchor points using the fitted linear matrix.

Optode/electrode placement

Register atlas derived 10-20 points based on subject's predicted anchor points.

GUI real-time rendering

Overlay the placement map on the camera for real-time visualization.

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Conclusion

We have successfully demonstrated

- Implementation of real-time overlay of placement map
- 10-20 prediction error if using Colin27: **1.37 cm**; if using age-specific model: **1.20 cm**
- When using a subject's own head surface, the error reduces to **0.62 cm**

Future improvements

- Plan to incorporate deep learning techniques to generate head surface from a single view image, aiming to increase placement accuracy

Reference

1. H. Dai, N. Pears, W. Smith, and C. Duncan, "Statistical modeling of craniofacial shape and texture," International Journal of Computer Vision, vol. 128, p. 547–571, Feb 2020.
2. Y. Kartynnik, A. Ablavatski, I. Grishchenko, and M. Grundmann, "Real-time facial surface geometry from monocular video on mobile gpus," Jul 2019. arXiv:1907.06724