

A Hand-Held Device to Quantify Facial Asymmetry Through Computer Vision

BE 4355 Senior Design

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Executive Summary

This project aims to develop an asymmetry index (AsI) to establish a score range and to reduce subjectivity in neurological assessments, using a portable, self-contained system that quantifies facial asymmetry and droop via 3D facial landmark analysis. The accumulation of scores from the various quantification codes, with its consistency from previous methods would help in obtaining the normal population values that would then be used to provide a range in our AsI. Upper vs lower facial weakness can indicate different neurological involvement (central vs peripheral patterns). Subtle asymmetry is easy to miss and varies between examiners. Our system outputs Upper AsI, Lower AsI, and Overall AsI to standardize facial droop quantification for screening and monitoring.

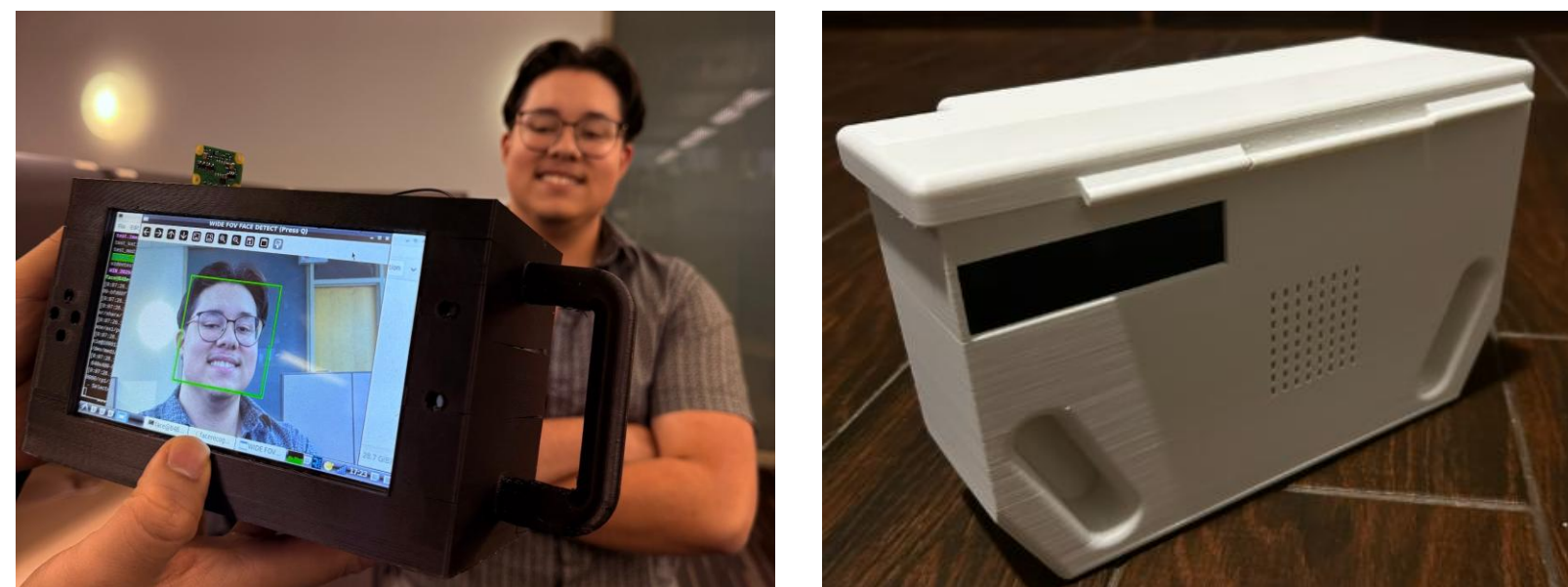


Figure 1. First and most recent iteration of the prototype

Background

Facial drooping is one of the earliest signs in stroke patients and those at risk of stroke for the first time; however, it can be difficult to detect even the subtle changes. Landmark analysis through computer vision can lead to insights into the possible severity or depth of asymmetry within our faces. Several different methods and equations for determining these parameters have been presented in previous studies and will be used for this study.

Our goal is to design a way to address the subjectivity and non-sensitivity of manual facial symmetry assessments in patients recovering from neurological injuries as well as patients showing symptoms before stroke, that allows objective, portable quantification of facial movement symmetry to guide therapy and monitor recovery overtime.

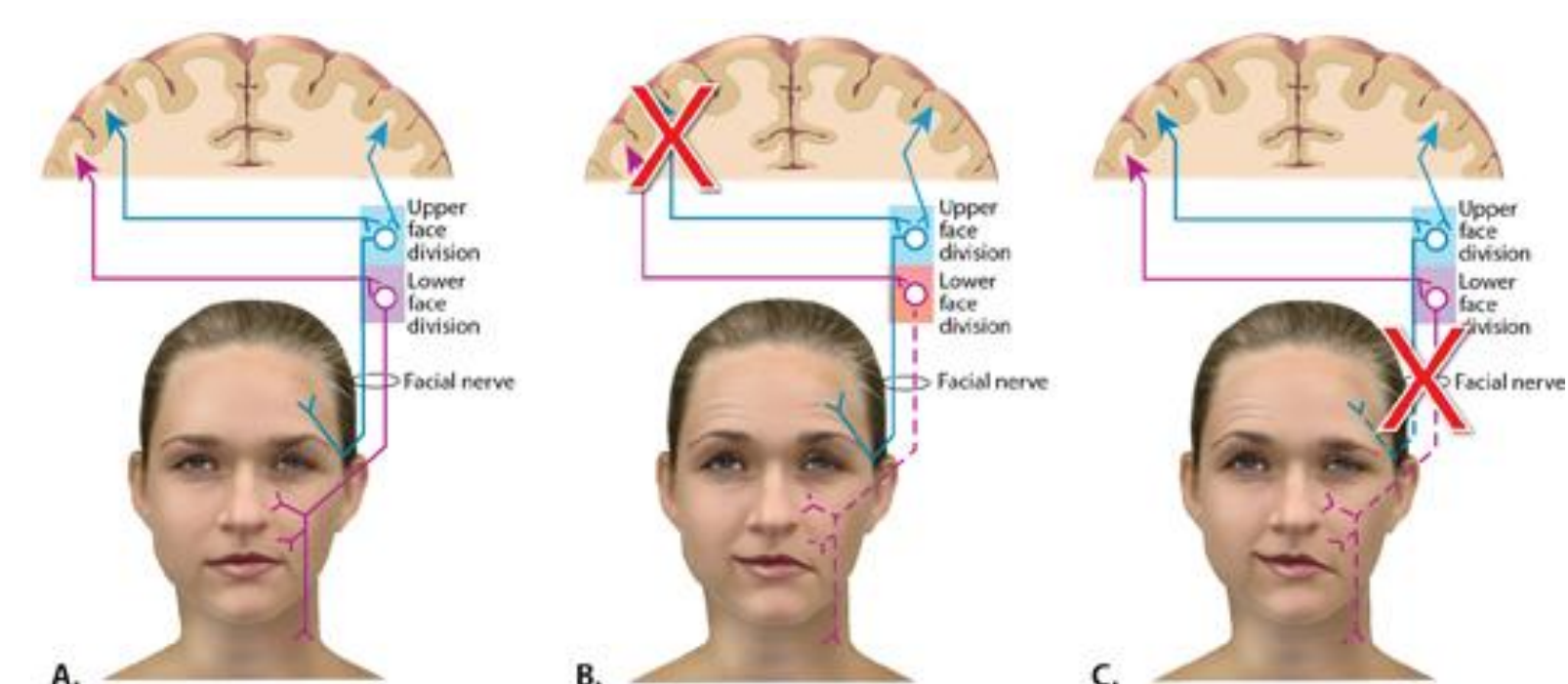


Figure 2. Clinical relevance of facial asymmetry: upper vs lower facial weakness reflects different neural pathways/lesion locations (Mullen)

Experimental Setup

Functional Requirements

- Objective, accurate, consistent measurements through quantitative asymmetry scoring
- Real-time scoring for neural assessment checks through display
- Clinical workflow integration with USB transfer of results
- Consistent and robust across skin tones and lighting through high-resolution camera

Physical Requirements

- Weight ~ 3kg ; capable of being held up
- Last a day without charging
- Safe to use with medical-grade materials
- Secure mount in its compact material

Constraints:

- Housing: Compact and secure; not too boxy
- Software: library compatibility and adaptations of Python language between PC and RPi 5
- Cost: \$1000 (Total Project Cost: \$503.54; Remaining: \$496.46)

Integration Status/Process: The Raspberry Pi 5 platform is fully assembled and validated for camera capture and display. On-device integration of our facial asymmetry (AsI) algorithm is in progress, with current testing performed on a development machine while optimizing performance and deployment on the Pi. Landmark detection identifies the key facial feature points. The primary objective is landmark filtering - refining and selecting the important landmarks, improving robustness and consistency across subjects and lighting conditions.

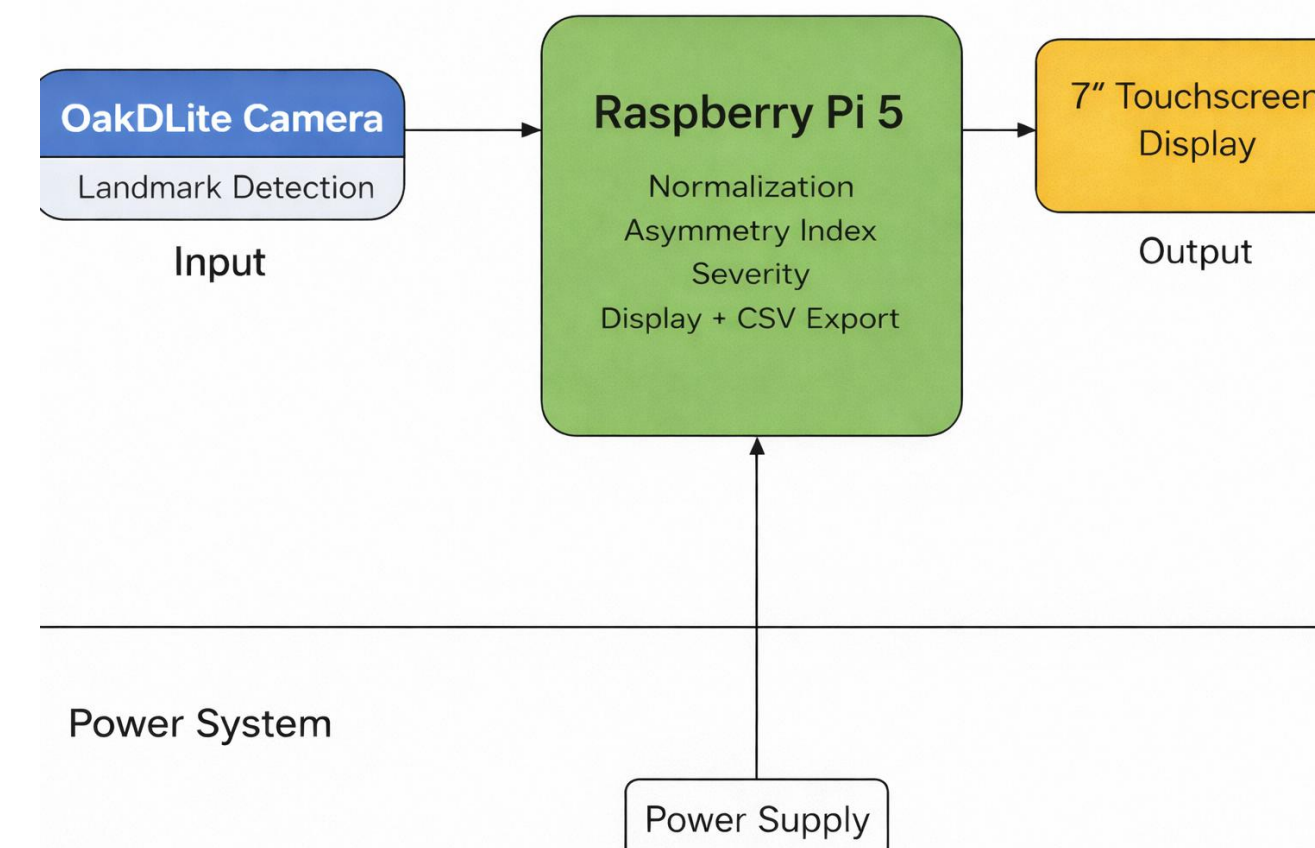


Figure 3. Flow Diagram of Process

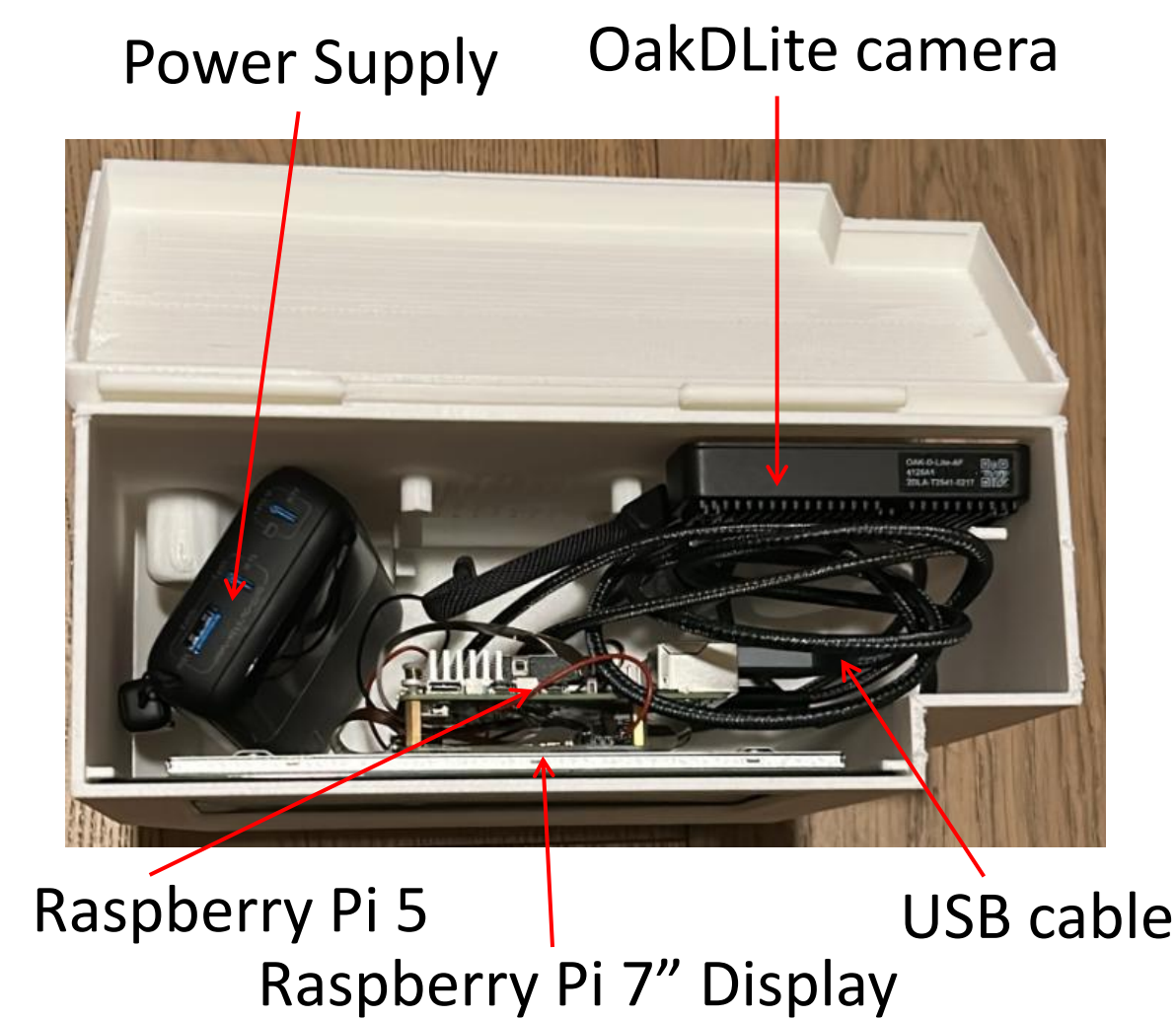


Figure 4. Fabrication of all materials

Experimental Test Plan

Figure 5. Abbreviated facial landmarks

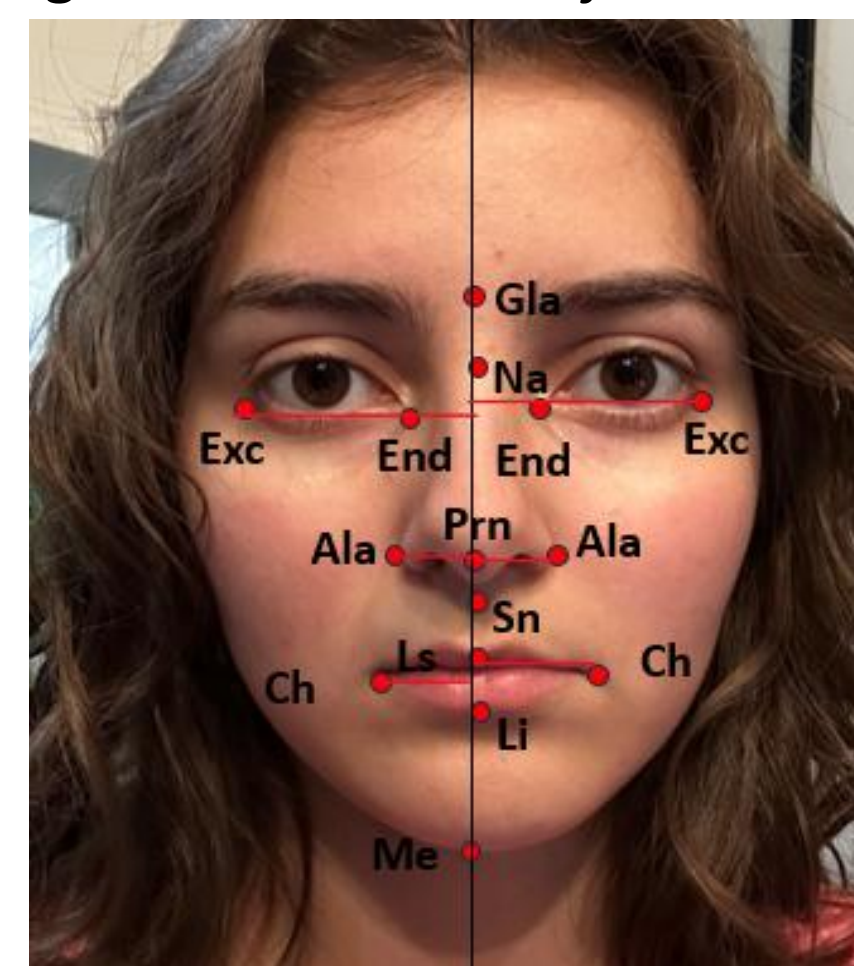


Figure 6. Mathematical formula of the Asymmetry Index (Vrochidou)

Facial Landmarks

Glabella (Gla), Exocanthion (Exc), Endocanthion (End), Alar curvature (Ala), Pronasale (Prn), Subnasale (Sn), Cheilion (Ch), Labial superius (Li), Menton (Me)

Figure 5 Shows how each landmark is paired and referenced to a defined midline. These coordinates are stored and processed into the mathematical formula in Figure 6, to compute distances and symmetry measurements. Using Python libraries, such as OpenCV, MediaPipe, and NumPy, distances from the midline to corresponding left (dLi) and right (dRi) landmarks are calculated (e.g., exocanthion left, exocanthion right, etc.). These values are then applied to the Asymmetry Index (AsI) to objectively quantify facial asymmetry.

$$AsI_{Overall} = \frac{1}{l} \sum_{i=1}^l \left| \frac{d_{R_i} - d_{L_i}}{d_{R_i} + d_{L_i}} \right|$$

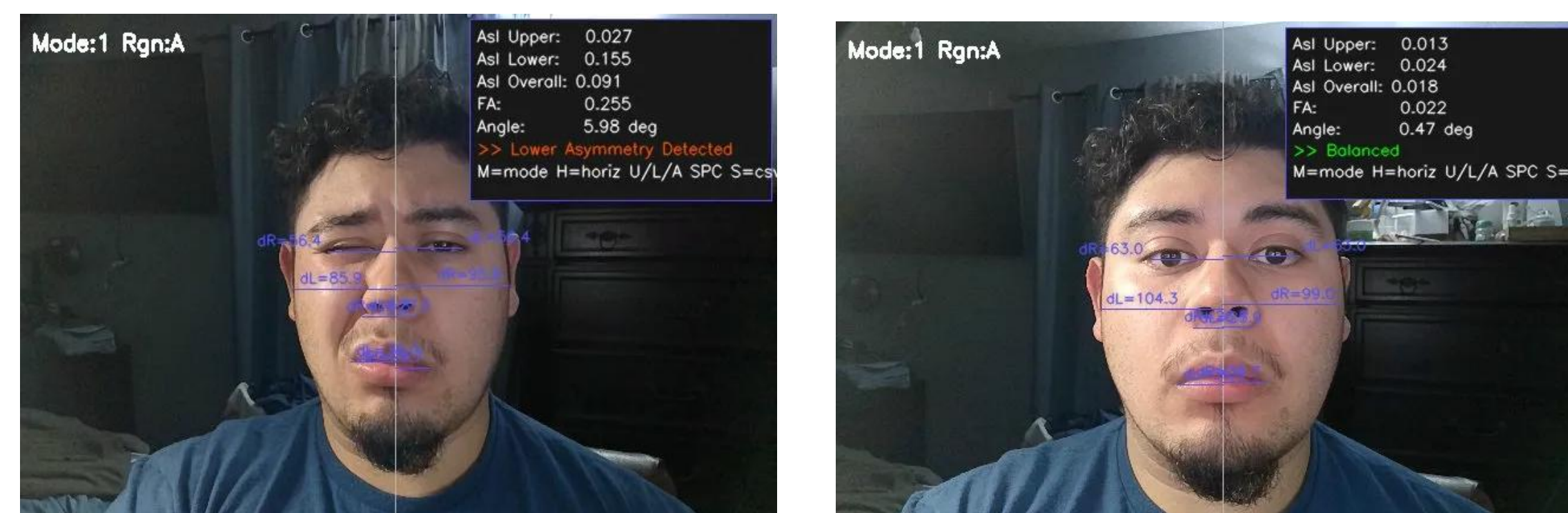


Figure 7. Example of Live Test Runs of Facial Asymmetry

Experimental Results

BEFORE	AFTER	ASI SCORING (code)
		Results Face #1 AsI (Upper): 0.006 AsI (Lower): 0.333 AsI (All): 0.170 FA: 0.65 Angle: 8.25 deg Verdict: Lower Asymmetry Detected
Face 1 AsI = 0.170	Face 1 AsI = 0.042	Face 1: Lower Asymmetry
		Results Face #2 AsI (Upper): 0.020 AsI (Lower): 0.065 AsI (All): 0.042 FA: 0.09 Angle: 0.75 deg Verdict: Balanced
Face 2 AsI = 0.020	Face 2 AsI = 0.019	Face 2: Balanced

Conclusions

The above figures show face 1 and 2, depicting a before and after stroke neurological assessments. The results in the third column are calculated from the code to detect asymmetry and give verdict on the location of the asymmetry. By identifying key landmarks as shown in Figure 5 and calculating metrics in Figure 6, our current algorithm can detect subtle changes in facial structure. These slight variations are easily captured, allowing for more objective evaluation than subjective observation. Building upon this foundation for moving forward, future improvements will focus on increasing the algorithm's sensitivity and refining the landmark detection accuracy.

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