The Incorporation of Hammermen of Edinburgh Scholarship Report – 2024

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Over the summer of 2024, I began a research project under the supervision of Professor Yuhang Chen from Heriot-Watt University, in collaboration with Professor Grainne Gorman and Dr. Renae Stefanetti from the Wellcome Centre for Mitochondrial Research at Newcastle University. This project focused on developing a biomechanics-based algorithm for facial feature tracking to assess the progression of mitochondrial disease (MD) through simple eye and mouth movement tests. The Hammermen Award Scholarship helped fund two trips to Newcastle University, allowing me to collaborate with my research team, and, most importantly, to present my research work in front of hundreds of public members and patients.

Since the fourth year of my mechanical engineering program, I have developed a passion for research. This scholarship has allowed me to immerse myself in biomechanics research and develop my personal, research, and interdisciplinary communication skills. It has also helped me refine my interest in biomechanics.

Project Scope

The aim of this project is to develop an algorithm for more accurate eye tracking while also implementing tracking methods for other facial features, such as mouth and cheek movement. The goal is to create a more accessible and scalable tool for assessing MD, often involving progressive changes in human mitochondria which would lead to muscle weakness and neurological conditions. This was achieved using Google's Mediapipe library, a machine learning tool previously used for motion capture, to conduct real-time assessments of facial movements.

MD is a neurodegenerative muscular disease that weakens muscles, particularly those in the face and eyes, resulting in slow and weak eye and mouth movements. As a rare disease, MD does not receive sufficient attention, and there are no specialised MD test centres in Scotland—the nearest one is in Newcastle. Therefore, this research aims to develop a remote assessment tool that can analyse patient videos captured via smartphone or other standard cameras.

Using the mediapipe library, the algorithm was able to efficiently and reliably map three-dimensional facial features using 468 different points, as shown in Figure 1. This allowed us to obtain several measurements at the eyes, mouth, and other points of the face. This 3D mapping feature has been tested against a 3D facial scan obtained from a hand-held high-precision 3D scanner, showing a high accuracy between both 3D maps.

Figure 1: 468 facial landmarks estimated in 3D using a basic camera.

A framework was established using this algorithm, incorporating an initial camera depth calibration (Figure 2a), and tracking points in the eyes (Figure 2b) and mouth (Figure 2c). The patient is then asked to rotate their eyes as far to the left as possible, and similarly to the right. Additionally, they are asked to elongate their mouth, and contract it as much as possible. All of these are commonly used as part of the clinical assessment of MD by trained practitioners.

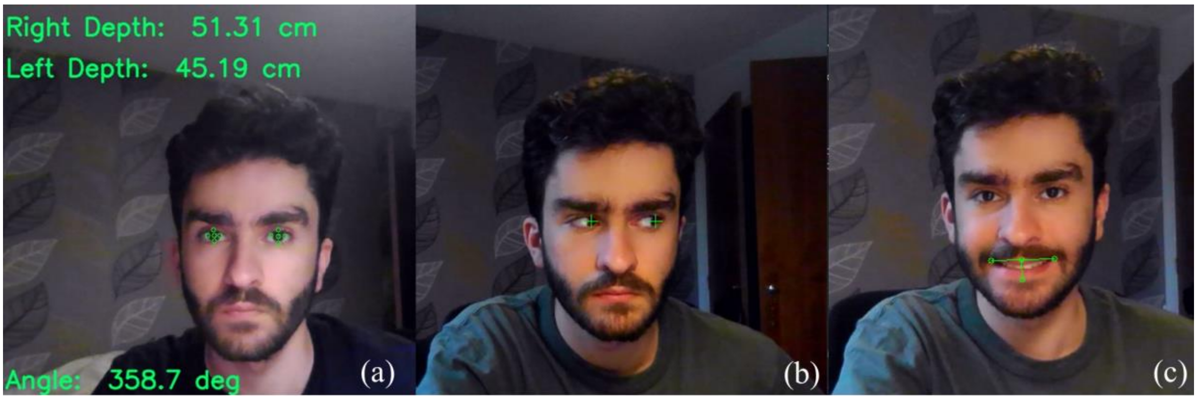

Figure 2: Simplified framework using (a) Depth calibration, (b) eye tracking, and (c) mouth tracking.

This simple two minute test is then able to retrieve a significant amount of data on the patient, mainly looking at maximum eye rotation on both the left and right directions (Figure 3), as well as lip length and snout index (Figure 4). These are effectively percentages of the mouth opening and closing. The maxima and minima of these tests are then retrieved from each test, and, since the eye rotation is controlled almost entirely by a number of muscles at the back of the eyes, they can be directly linked with the extent to which the patients' muscles are weakened - these trends are then assessed to investigate the progression of the individual's MD.

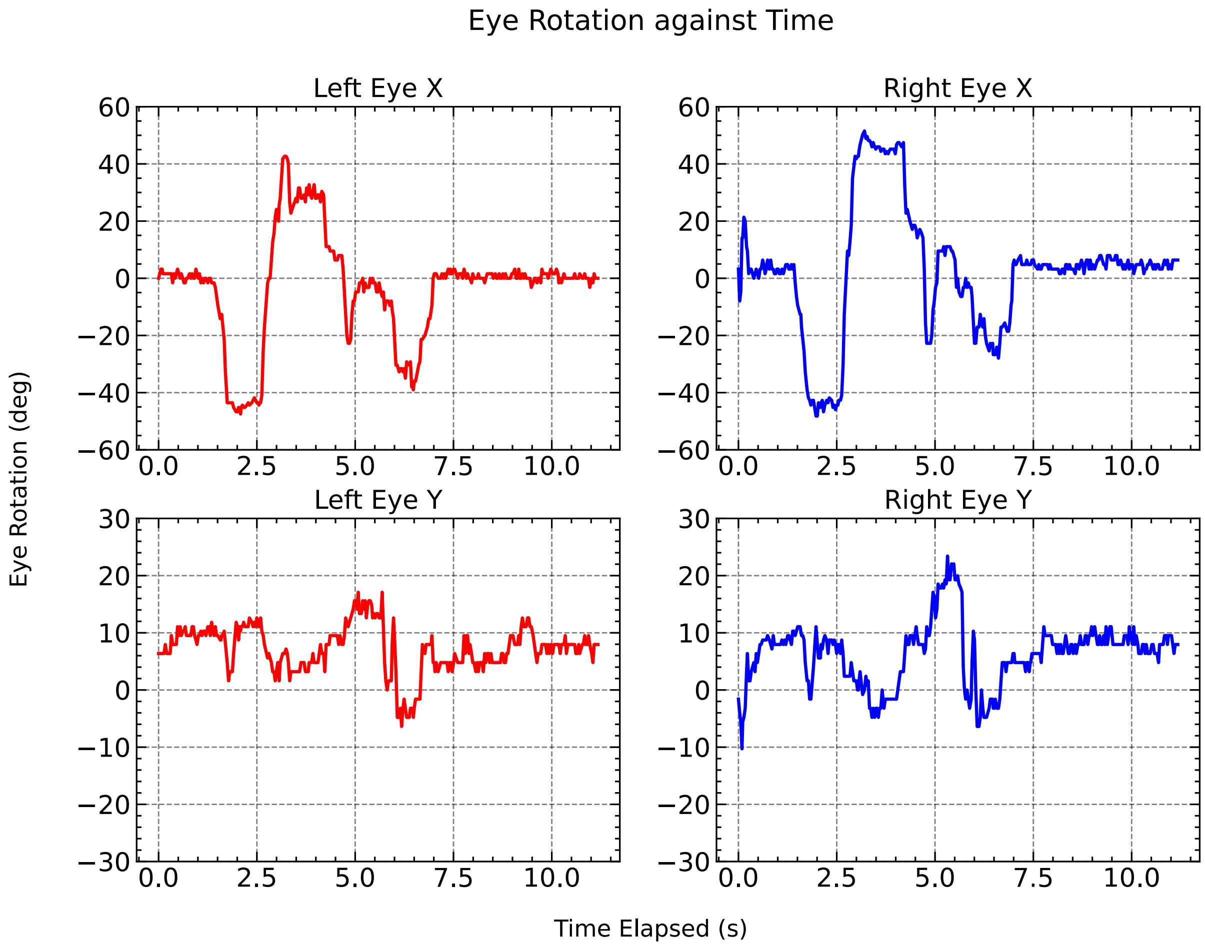

Figure 3: Left and right eye rotations over time.

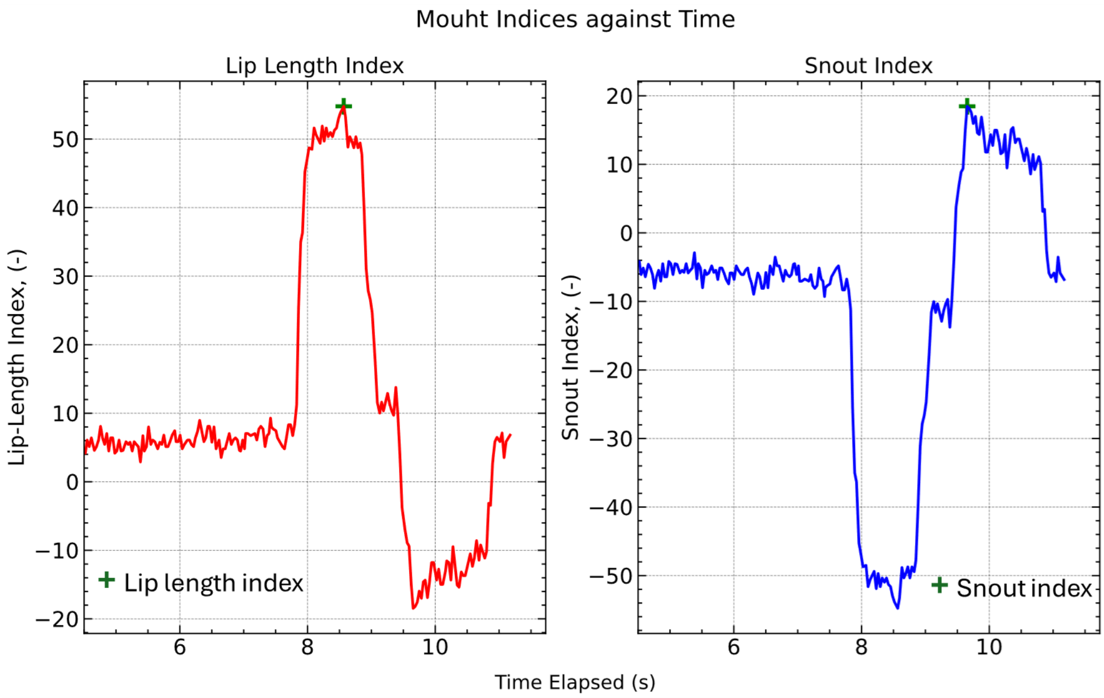

Figure 4: Recorded lip length and snout indices.

Project Value

This algorithm has the potential to remotely monitor the progression of MD by assessing a patient's muscle health. This would make assessments more affordable and convenient for patients with mobility issues, while also reducing strain on NHS clinics.

For Scottish patients, who currently have to travel to Newcastle for specialized MD testing, this tool could save significant time, provided they have access to a smartphone.

The project also explores additional facial markers, such as the lips and cheeks, to create a more comprehensive assessment beyond just eye and mouth movements. In the future, this algorithm could be adapted to assess other neurodegenerative diseases or even full-body motion (e.g., gait analysis).

Visit to Newcastle University

In March 2025, I had the opportunity to visit our research partners at Newcastle University during the *Celebration of Research Excellence Community Event*. There, I showcased the algorithm to professors in neurology and other biological fields, professionals in biomedical technology, and government officials (Health). I also gained insights into research on rare disease awareness, including its medical, social, and psychological aspects.

Figure 5: Presenting the work to our research partners at the *Celebration of Research Excellence Community Event*. Left: The Hammermen Scholar; Middle: Dr Renae Stefanetti (MD specialist and NHS physiologist); Right: Prof. Yuhang Chen.

A key highlight of the visit was presenting the progress of my algorithm to our research partners and patients/public and receiving feedback on how to refine it. This feedback, which focused on the anatomical relationship between eye rotation, mouth movement, and muscular effort, will help improve the framework. A follow-up trip is planned for late April to give a poster presentation and technology demonstration to a MD-specific workshop involving researchers and patients with MD and their families.

Value to Student

This research and my visit to Newcastle significantly contributed to my development as a researcher. It deepened my appreciation for interdisciplinary collaboration, integrating biomechanics with computer vision and anatomy to develop an effective remote MD assessment tool. This was also one of my first experiences developing a project with the potential to be translated into a mobile application. Moreover, it allowed me to apply my biomechanics knowledge in a practical setting.

The project also enhanced my communication skills, particularly when explaining technical concepts—such as pixel-to-real-world coordinate conversion—to academics unfamiliar with computer vision. Attending the conference improved my presentation skills, as I had to effectively convey the framework, algorithm, and its potential applications to academics, professionals, and patients. As engineers, we often focus on making things work, but this scholarship has given me invaluable experience in presenting my work to and discussing it with public and patient groups – end-user-centred research is indeed what I feel engineering is able to contribute to the most, particularly in the area of biomechanics and biomedical engineering.