Senior Design Project
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Brain Health: Concussion Diagnosis

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Abstract

This project aimed to develop of a novel objective method for diagnosing concussion by tracking eye movement. We determined a solution combining smart phones cameras and machine learning could be employed to detect concussions. The prototype was realized through the development of a mobile application on the iPhone 11 that prompted users to complete a vertical saccade test and recorded user response. The video was then processed using computer vision to determine the results of the saccadic test. Through statistical analysis, we demonstrate that our application can collect data that is coherent with historical values. Machine learning was leveraged on the data to determine a percent confidence of whether the patient was concussed. Head stabilization further improved the reliability of results by incorporating of a a custom headset.

Introduction

Current existing concussion diagnostic tests deployed in the field are subjective and can be “beat” if the patient chooses not to be truthful with the test administrator. Concussed athletes may attempt to conceal symptoms to avoid removal from play. Furthermore, the administrator must be well acquainted with the patient to detect subtle changes in personality.

1.6 to 3.8 million sports-related concussions occur every year in the United States. Currently, the market lacks a user-friendly, cost-effective product that objectively calls on indicators to more reliably diagnosis trauma to the brain. It also lacks a product that harnesses the power of machine learning and big data. Our team seeks to capitalize on this market gap by combining diagnostic examinations with ubiquitous technology and predictive machine learning.

At the core of the project is the vertical saccade test. The test relies on gathering data to evaluate the number and speed profile of vertical eye movements between two distinct points. This test was selected based on its high sensitivity and ability to detect traumatic brain injury.

Methods | Design | Analysis

- Implement saccade test in phone app
- Extract positional eye data from video
- Denoise signal with 3 order Butterworth Filter
- Determine number of saccades
- Provide value as input to ML model
- Run ML model on Amazon Web Service
- Compare output to expected values using t-test

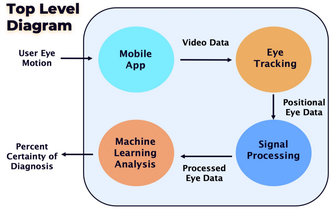

Figure 1. Diagram of system

Figure 2. Screen captures of Iris app

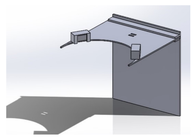

Figure 3. CAD File Drawing & Rendering

Figure 4. User testing product

Results

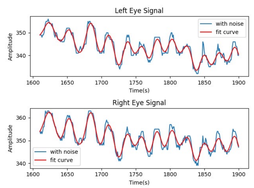

Figure 7. Sample 1 of denoising using Butterworth Filter

Source	Mean # Saccades	Standard Deviation	Number of Data Points
Paper – non concussed	22	2	57
Paper - concussed	17	2	64
Prototype – non concussed	23	3	10

Figure 9. Sample 1 of denoising using Butterworth Filter

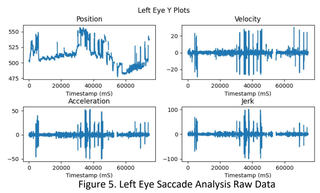

Figure 5. Left Eye Saccade Analysis Raw Data

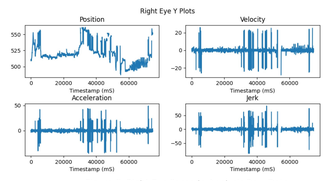

Figure 6. Right Eye Saccade Analysis Raw Data

Figure 9. Saccade Analysis Processed Data

Figure 10. Machine Learning Hosted on a Local Server Returning Percentage Probability of Concussion

Conclusion

- Intended to be sideline deployable where the incidence of concussion concussion is high
- Tested product on 10+ healthy patients
- T statistic 1.015 fell well within the range of $-2.228 < t < 2.228$ when comparing non-concussed patients, demonstrating no significant difference between the normals
- T statistic of 15.36 fell outside the range of $-2.178 < t < 2.178$ when comparing normal data with that of concussed patients
- Results support that the creation of an accurate, objective, and accessible concussion diagnosis using smart phone cameras is both plausible and achievable
- Future improvements include adding supplementary vision tests to improve diagnostic accuracy and integrating computer vision processing directly on the mobile application

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References

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