CAVA: A System for Identifying Nystagmus

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***Abstract*—As populations age, dizziness is becoming an increasing burden on health services. Dizziness is often episodic and can have many possible causes. When dizziness is due to inner-ear malfunctions, it is usually accompanied by abnormal eye-movements called nystagmus. The CAVA (Continuous Ambulatory Vestibular Assessment) device has been developed to provide continuous monitoring of eye-movements to gain insight into the physiological parameters present during a dizzy attack. We describe the development of the device and the accompanying algorithms for detecting nystagmus. In a blinded trial involving 17 healthy subjects who induced periods of nystagmus artificially, the system achieved a detection accuracy of 98.77%.**

I. Introduction

In England and Wales, symptoms of dizziness or imbalance are experienced by 30% of the population by the age of 65 years [1]. Dizziness can be hard to diagnose, as it is often absent upon examination [2]. When dizziness is due to malfunction in the pathway involving the eyes, brain and inner ears, an abnormal eye-movement called *nystagmus* usually occurs. We have developed the CAVA device to record eye-movements continuously over 30 days. After this time, the data is analysed offline by computer algorithms for signs of nystagmus, a concept that reflects existing technology for ambulatory cardiac monitoring [3]. There is much previous work on automatic nystagmus detection [4], but none applied to long-term data such as this. The information provided by the device may assist diagnosis and may increase our understanding of inner-ear disorders.

II. Methods

A formal clinical investigation was conducted, involving seventeen healthy subjects wearing the device continuously, for thirty days. A blinded experiment was performed using the data captured, to assess our algorithms and to evaluate the device. On eight dates, our healthy subjects induced nystagmus by watching a 30 s video on a VR headset. This video showed a single black dot moving repeatedly across a white screen. The dots moved either leftward or rightward, and at one of three speeds (0.8 Hz, 1.0 Hz or 1.2 Hz, relative to the screen). The tasks were to identify the 112 files containing the 30 s of nystagmus within in a full day of data, and also the direction and speed of the moving dot.

The nystagmus detection algorithm used Fast Fourier Transform (FFT) recognition features. Three classifiers were trained using features derived from the training data: A Support Vector Machine, a Linear Discriminant Analysis transformation and an Ensemble classifier of boosted trees. These classifiers were trained to identify nystagmus, irrespective of direction and speed, and their output was combined by majority vote. To classify direction, a weighting was assigned, reflecting the proportion of positive and negative velocities in the candidate signal. To classify speed, the modal frequency bin was identified from an FFT, and the closest class to that bin classified the signal.

TABLE I. Results from the classification algorithm

	Presence	Direction	Speed
# Corr.	400	110	109
# Incorr.	5	1	2
Acc. (%)	98.77%	99.10%	98.20%

III. Results & Discussion

A high degree of accuracy was attained for the tasks of identifying the presence of the nystagmus waveform, and also the speed and direction of the moving dots (Table I). These promising results also serve to validate the design of the CAVA device itself, which was successfully deployed among seventeen trial subjects, who in total captured around 9000 hours of eye and head movement data.

IV. Conclusion

These results are an incremental step towards a system for diagnosing dizziness. The algorithm has shown to be effective at detecting artificially induced nystagmus, but it is unclear how this technique will perform when applied to nystagmus produced as a symptom of *real* dizziness. Therefore, our next body of work will include a clinical study on patients suffering from vertigo. We have collected the first corpus of 24/7 continuous eye-movement data from several subjects, which will find applications in other areas.

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