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Spike removal through multiscale wavelet and entropy analysis of ocular motor noise: A case study in patients with cerebellar disease

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ABSTRACT

Wavelet decomposition of ocular motor signals was investigated with a view to its use for noise analysis and filtering. Ocular motor noise may be physiological, depending on brain activities, or experimental, depending on the eye recording machine, head movements and blinks. Experimental noise, such as spikes, must be removed, preserving noise due to neuro-physiological activities. The proposed method uses wavelet multiscale decomposition to remove spikes and optimizes the procedure by means of the covariance of the eye signals. To measure the noise on eye motor control, we used the wavelet entropy. The method was tested on patients with cerebellar disorders and healthy subjects. A significant difference in wavelet entropy was observed, indicating this quantity as a valuable measure of physiological motor noise.

1. Introduction

Eye movements are arguably the most frequent of all human movements and an essential part of human vision (Yarbus, 1967): they drive the fovea and consequently the attention towards regions of interest in space. This enables the visual system to fixate and to process an image or its details with high resolution (Leigh and Zee, 2006): act of fixation. Fixations are samples of points around a point, called centroid, with long duration. An average of three eye fixations per second generally occurs during active looking (300 ms).

These eye fixations are intercalated by rapid eye jumps, called saccades, that can be defined as rapid movements with velocities that may be higher than 500 deg/s and durations of about 30 ms; Fig. 1 illustrates a small portion of gaze during visual exploration on a psychological task, showing five clusters of data points (fixations) and three saccades. Eye movements may be recorded by eye-tracking technologies (see Duchowski, 2002 for a review). Eye-tracking is the process by which eye movements are measured during visual exploration of a scene or during the execution of specific tasks. This measurement, can be obtained either by measuring the position of an eye in the orbit, relative to the head, or the point of regard, which extracts the coordinates x, y of the eye in space.

Eye gaze analysis and extraction of gaze features is an exciting and challenging field of research for neuro physiologists and neuro scientists, since it offers a good, reproducible method for studying basic mechanisms of brain motor control (from motor command to reached position, see Girard and Berthoz, 2005 for a review) and cognitive behavior. Indeed, the human gaze is direct or indirect evidence of human cognition in terms of memory, attention (Corbetta et al., 2002), intention and decision (Shimojo et al., 2003).

Generally speaking, the gaze signal is processed by extracting two main classes of features: motor abilities (Table 1 for a short summary of the subsystems involved and related features) which studies the ocular motor control, and task specific execution, which provide insights into ocular motor control, and task specific execution, which provides information about the ability of subjects to perform a command, such as searching for an object, remembering, forming a sequence, making up the mind.

1.1. *Eye movements in clinical applications: measuring the physiological characteristics of motor control noise*

The main advances in the study of ocular motor control have been obtained by lesion studies in monkeys and recording patients

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