Considerations on Strategies to Improve EOG Signal Analysis

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ABSTRACT

Electrooculogram (EOG) signals have been used in designing Human-Computer Interfaces, though not as popularly as electroencephalogram (EEG) or electromyogram (EMG) signals. This paper explores several strategies for improving the analysis of EOG signals. This article explores its utilization for the extraction of features from EOG signals compared with parametric, frequency-based approach using an autoregressive (AR) model as well as template matching as a time based method. The results indicate that parametric AR modeling using the Burg method, which does not retain the phase information, gives poor class separation. Conversely, the projection on the approximation space of the fourth level of Haar wavelet decomposition yields feature sets that enhance the class separation. Furthermore, for this method the number of dimensions in the feature space is much reduced as compared to template matching, which makes it much more efficient in terms of computation. This paper also reports on an example application utilizing wavelet decomposition and the Linear Discriminant Analysis (LDA) for classification, which was implemented and evaluated successfully. In this application, a virtual keyboard acts as the front-end for user interactions.

Keywords: Autoregressive, Electrooculogram, Human-Computer Interfaces, Virtual Keyboard, Wavelet Decomposition

INTRODUCTION

As part of the Human-Computer Interface (HCI) research field, the electrooculography (EOG) has been established as a promising modality among other sources like electroencephalography (EEG) or electromyography (EMG). In this context various eye-based applications have been proposed, acting as hands-free interfaces to a general computer system (Estrany, Fuster, Garcia, & Luo, 2009) or even wearable embedded system, in order to aid the context awareness of machines (Bulling, Roggen, & Tröster, 2008).

Applying a combined approach of Continuous Wavelet Transform (CWT) and threshold comparisons for feature extraction, Bulling et al. has shown that it is possible to detect saccade movements revealing clues about the context and in particular the reading activity of a subject (Bulling, Roggen, & Tröster, 2008).

Apart from those applications, parts of the research have been motivated by the idea to enhance the quality of life especially for disabled people who suffer from severe motor impairments (Barea, Boquete, Mazo, &

People suffering from neurodegenerative diseases like amyotrophic lateral sclerosis (ALS) are often locked into their own body, whereas the oculomotor system, being one of the last capabilities remaining, has a certain resistance to the derogating process (Dhillon, Singla, Rekhi, & Jha, 2009).

With respect to that motivation, several eye-based spelling devices using a virtual keyboard on a screen have been designed to provide a means of communication for that particular target group (Dhillon, Singla, Rekhi, & Jha, 2009; Hori, Sakano, Miyakawa, & Saitoh, 2006; Usakli & Gurkan, 2010).

Those interfaces were proposed as an alternative to already existing, commercial applications as described by Krolak et al. (2009), which are vision-based and entail the necessity of a bulky headgear.

The work presented here embraces the idea of a virtual keyboard to form the context for the investigation of different methods of feature extraction, which is the main focus of this study.

Further, most keyboard interfaces use the eye blink, for the selection command. However, eye blinks can also occur involuntarily, wherefore a long blink is proposed here as an alternative as it is more distinguishable from involuntary ones which tend to be shorter.

The methods underlying most of the approaches mentioned earlier are time-based and some are even designed without significant feature extraction stage in the reasoning that the interface should be kept simple and without complicated algorithms (Usakli & Gurkan, 2010).

Thus, the investigation being done here attempts to answer the question, whether simplicity does always correlate with efficiency. It aims at a comparative study of time, frequency-based methods as well as hybrid approaches, which combine both domains.

With regards to spectral analysis, only parametric methods are applicable to EOG signals, the amplitudes of which range between 50 to 3500 µV, with its major components below 35 Hz (Barea, Boquete, Mazo, & López, 2002). A non-parametric FFT would hence result in a very poor frequency resolution due to a small amount of samples available for a particular time interval.

Parametric approaches, on the contrary, attempt to model the system based on a set of coefficients. Those models, which are mostly autoregressive (AR) systems due to their good prediction results, have successfully been utilized for the analysis of EEG characteristics (Faust, Acharyaa, Allen, & Lin, 2008; Tseng, Chen, Chong, & Kuo, 1995), but have not sufficiently been taken into account for eye-based interfaces.

Further on, investigations have revealed that wavelet-based procedures are superior to frequency-based methods for certain applications (Fargues & Bennett, 1995) and are even found to be promising for biomedical systems (Unser, 1996).

The multi-resolution approach, considering the given signal at several distinct scales, was employed for signal compression (Bhandari, Khare, Santhosh, & Anand, 2007), which is noise reduction in more general terms, as well as for the extraction of specific information.

The latter aspect led Magosso et al. to propose solutions capable of detecting slow eye movements (SEM) during certain sleep phases in the EOG signals (Magosso, Ursino, Zaniboni, & Gardella, 2006) and moreover of identifying patterns in the brain activity during an epileptic seizure (Magosso, Ursino, Zaniboni, & Gardella, 2009).

In contrast to the examination of energy distributions across all scales, as studied in the articles mentioned, this study utilizes the discrete wavelet transform (DWT) to obtain an efficient representation of the data within the chosen feature space.

The results are compared with AR-modeling as well as straightforward time-based template matching used by Usakli and Gurkan (2010) for instance.

Efficiency is hence studied here as a combination of sufficient performance, which is
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