Reconstruction of Eye Movements Signal using Inductive Model Detecting Saccades

Aleš Pilný, Pavel Kordík

Dept. of Computer Science and Engineering, Karlovo nam. 13, 121 35 Praha 2, Czech Rep.

pilnya1@fel.cvut.cz, kordikp@fel.cvut.cz

Abstract. *This article describes a method for reconstruction of eye movement signals interfered with saccades and post-determination of inherent frequencies in the signal. For healthy patients, a signal of their eye movements should contain the same frequencies as movements generated by special rotating chair. To determine frequencies in eye movements, saccades have to be removed first. This is not an easy task, because saccades can have various shapes. To detect saccades, we use inductive models trained on various saccadic eye movement signals. To remove saccades and to reconstruct the eye movement signal we wrote special script replacing saccades with estimated trend of signal based on the output of the inductive model. When the reconstructed signal is transformed to the frequency domain, it is easy to decide, whether the eye movements signal contains the same frequencies as the original signal of the rotating chair.*

Keywords

Inductive modeling, biological signals, saccades,
eye movements, frequency analysis.

1 Introduction

Balance disorders of patients can be detected by means of special examination on a rotating chair. In Motol Hospital, Prague, new examination procedure is being prepared. The movement of the rotating chair is superposed from more frequencies. Patients head is fixed to the chair and during rotation the patient is watching a static light point on the wall. During the examination, both signal of eye movements and driving signal of rotating chair are recorded.

Eye movement signals contain correction movements, so called "saccades", bringing the observed target back to the visual field of the patient (see Figure 1.1.). The aim is to find out, if eye movements of patient contain the same frequencies as the driving signal of rotating chair – in other words, if the patient is able to track the stimulus (light point).

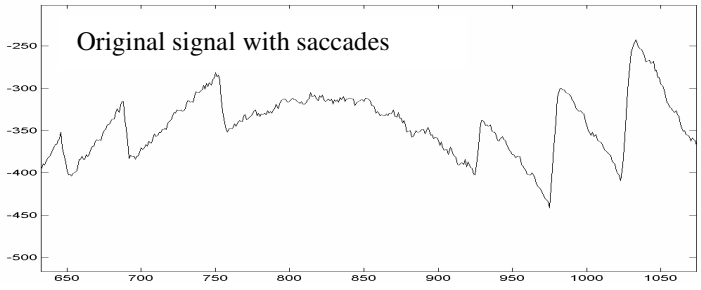

Fig. 1.1. Example of eye movement signal with saccades. The center part of this picture is without saccades, while parts on left and right side contain saccades.

The analytic tool used in Motol Hospital to evaluate eye movement signals simply transform measured signals to frequency domain. The problem is that saccades disturb the frequency spectrum of eye movements' signal; therefore it is necessary to filter them out.

2 Process of reconstruction

The reconstruction of the eye movement signal can be described in three steps: training data synthesis, identification of saccades and the reconstruction.

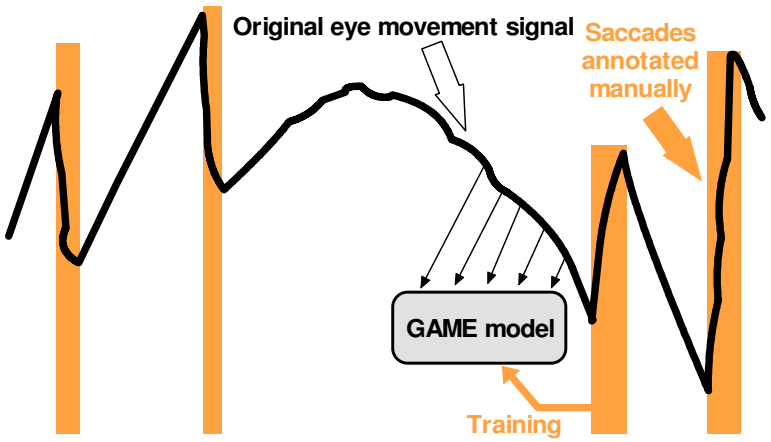

Fig. 2.1. Saccades are manually annotated and the original eye movement signal together with the annotation is used to prepare the training set for GAME method.

The first step is to prepare the training data. The key task is to define the saccades in the eye movement signal. For this we purpose are using CowGraph [], a program which allows us to manually annotate the saccades in signal and save this information as a target signal for training. We prepare training data set consisting of several samples of eye movement signal as input variables and presence of saccade as the output.

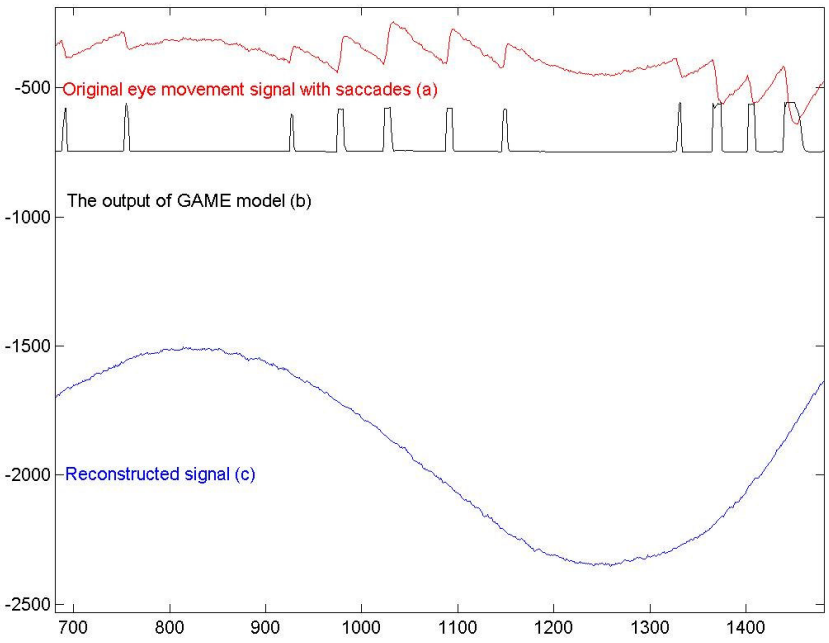

Fig. 2.2. The original signal (a), the output of GAME model (b) and reconstructed signal (c).

In the second step the data set used to generate inductive models using the GAME method []. We have evaluated the accuracy of the models on testing data [see table to be added in final version].

In the third step we reconstruct the signal using a script, which have two inputs (original eye movements signal and GAME model saccade estimation) and one output, the reconstructed signal. The method of reconstruction is based on information about signal character in the neighborhood of saccades. When saccade is estimated, the original signal is replaced with linear approximation of trends in the beginning and the end of the saccade. The original eye movement signal with saccades (a), the output of the GAME model (b) and the reconstructed signal (c) is displayed on the Figure 2.2.

3 Frequency analysis of original and reconstructed signals

Signal is smoothed by Sawitzky-Golay filter (See Figure 3.1), cut to the whole period and the FFT transform is performed. The results for original and reconstructed signals are on the Figure 3.2.

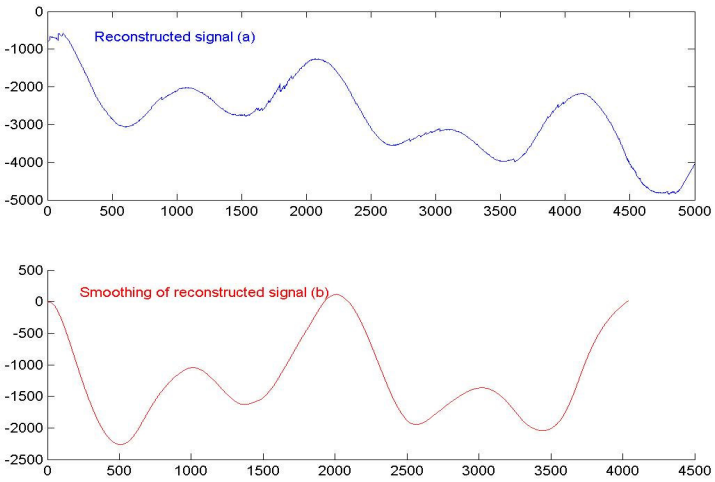

Fig. 3.1. Reconstructed signal (a) and smoothing of reconstructed signal (b).

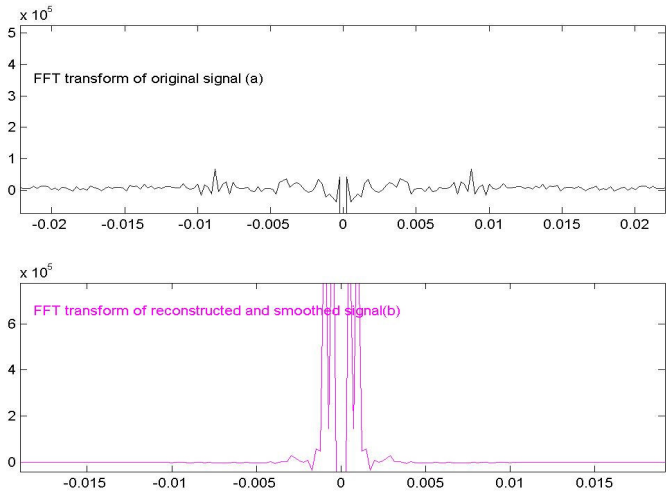

Fig. 3.2. FFT transform of original (a) and reconstructed signal (b).

When you look at the Figure 3.2, you can observe two peaks in the FFT of the reconstructed signal (in fact four peaks because of FFT symmetry). In the frequency domain of the original eye movements signal no peaks are apparent.

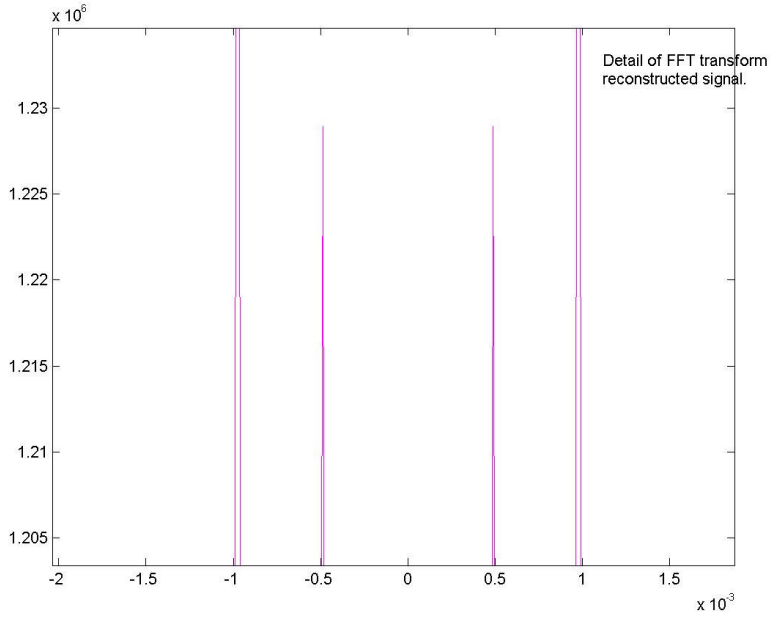

Fig. 3.3. Frequencies of the rotating chair can be found in the reconstructed signal.

The data are taken from the examination where a patient was sitting on the chair rotating at combined frequencies 0.1 and 0.05 Hz. These frequencies can be found also on the Figure 3.3, where the relevant part of the previous figure is displayed in detail.

4 Conclusion

In this paper we presented successful medical application of inductive modeling. We trained the inductive model to detect saccades in the eye movements signal. Subsequently we used this model to filter out saccades and reconstructed signals. In reconstructed signals as against to the original ones, we are able to detect frequencies of the rotating chair. This allows experts to recognize abnormal eye movements signals of patients with balance disorders.

5 Acknowledgements

This research is partially supported by the grant Automated Knowledge Extraction (KJB201210701) of the Grant Agency of the Academy of Science of the Czech Republic and the research program "Transdisciplinary Research in the Area of Biomedical Engineering II" (MSM6840770012) sponsored by the Ministry of Education, Youth and Sports of the Czech Republic.

References

[1] Ivakhnenko A. G.: Polynomial theory of complex systems. *IEEE Transactions on Systems, Man, and Cybernetics*, SMC-1(1):364378, 1971.

[2] P. Kordik. Fully Automated Knowledge Extraction using Group of Adaptive Models Evolution. PhD thesis, Dep. of Comp. Sci. and Computers, FEE, CTU Prague, Czech Republic, September 2006.