Automatic detection of open and closed eye states in the electroencephalographic (EEG) record for background EEG interpretation by the trigger method

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Abstract—Automatic detection of open and closed eye states in electroencephalographic (EEG) records was investigated in this study as a part of procedures for the precise interpretation of the background EEG to achieve a comprehensive automatic EEG interpretation system. The features of eye open and closure were extracted from the EEG using a Markov process amplitude (MPA) EEG model, which could efficiently express the features of the EEG using a small number of parameters. A new technique, named the trigger method, was also developed to overcome the difficulty resulting from large differences in the EEG features among different subjects, because an accurate detection could not be obtained by using the conventional threshold method. The proposed method gave satisfactory results which conformed with those of visual inspection by a qualified EEGer and could be clinically used as a preprocessing method for the automatic interpretation of the awake background EEG.

Key words: Automatic detection; open eye state; closed eye state; Markov process; EEG model; trigger method; background EEG.

1. INTRODUCTION

A computer-aided system for automatic interpretation of the background electroencephalograph (EEG) will be an effective and complementary tool for EEGers because EEG interpretation by visual inspection is a rather laborious task. We have studied quantitative EEG interpretation (e.g. [1]) in order to establish a practical and entirely automatic system for background EEG interpretation. In the EEG interpretation system, a problem was encountered regarding the detection of the subject’s state with eye open and closure because the characteristics of the EEG remarkably
change depending on whether the eyes are open or closed [2, 3]. In clinical practice, subjects are normally asked to keep their eyes closed, but eye open is unavoidable. Although it is simple and accurate for EEGers to distinguish eye open and closure, visual inspection is ineffective and tedious. Therefore, the automatic detection of eye open and closure plays an important role in achieving correct EEG interpretation. Automatic detection has been investigated in a previous study by Kirkup et al. [4], in which they used hardware to detect and display eye open and closure. Until now, however, there has been no attempt, to our knowledge, to develop a computer-based automatic detection of eye open and closure as the preprocessing of the EEG interpretation system.

Differences among individual subjects cause the major difficulty in the automatic detection of eye open and closure. In this study, the automatic detection of eye open and closure, using the Markov process amplitude (MPA) EEG model [5] and the trigger method, was investigated. The MPA EEG model was designed to represent the features of the EEG using a small number of parameters and the trigger method was proposed to solve the problem of large differences among subjects. The results of the automatic detection were compared with those of an EEGer’s visual inspection to validate its applicability to the preprocessing of EEG for the background EEG interpretation system.

2. METHODS

2.1. Characteristics and automatic detection of eye open and closure on the EEG

The segments of eye open and closure were first detected by the comments described by an EEG technician on the record during recording. Then, an EEGer chose the segments from the EEG data in which eye open and closure were clearly recognized. Figure 1 illustrates typical traces of those EEG data which contains the second (0–5 s) and the third (5–10 s) segments of the total 10 segment data from one subject.

The automatic detection of eye open and closure was investigated on each 5 s segment. Each EEG segment was categorized into: open eye, closed eye or open and closed eye state. The segment was categorized into the open and closed eye state if there were both open and closed states in the same segment.

The detection criteria suggested by the qualified EEGer were utilized for the automatic detection of blink artifacts as follows [6]:

1. Components within the frequency band of 0.5–4 Hz (existence property).
2. Symmetric positive peaks maximally at the fronto-polar region of the scalp (symmetric property).
3. Rapid decline of amplitude posteriorly (extension property).

An example of the existence property of the blink artifacts is shown in Fig. 2a and b. The blink artifact greatly increases the δ band (0–4 Hz) components in the