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Automatic EEG processing for the early diagnosis of Traumatic Brain Injury

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Abstract

Traumatic Brain Injury (TBI) is recognized as an important cause of death and disabilities after an accident. The availability a tool for the early diagnosis of brain dysfunctions could greatly improve the quality of life of people affected by TBI and even prevent deaths. The contribution of the paper is a process including several methods for the automatic processing of electroencephalography (EEG) data, in order to provide a fast and reliable diagnosis of TBI. Integrated in a portable decision support system called EmerEEG, the TBI diagnosis is obtained using discriminant analysis based on quantitative EEG (qEEG) features extracted from data recordings after the automatic removal of artifacts. The proposed algorithm computes the TBI diagnosis on the basis of a model extracted from clinically-labelled EEG records. The system evaluations have confirmed the speed and reliability of the processing algorithms as well as the system's ability to deliver accurate diagnosis. The developed algorithms have achieved 79.1% accuracy in removing artifacts, and 87.85% accuracy in TBI diagnosis. Therefore, the developed system enables a short response time in emergency situations and provides a tool the emergency services could base their decision upon, thus preventing possibly miss-diagnosed injuries.

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1. Introduction

Traumatic brain injury (TBI) is caused by an external force that damages the brain. This brain dysfunction results as possible physical, cognitive, social, emotional, and behavioral effects on the subject[1]. The severity of the injury

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ranges from mild to severe as well as the associated impacts on the quality of life of the person with TBI[2,3,4,5]. TBI has been recognized as an important cause of death in the US[6] as well as in Europe[7]. Moreover, it leads to a great economic burden[7].

Irreversible brain damages can result from a trauma that is not properly diagnosed, or too late. Hence there is a need for a reliable tool that can be used by emergency services in order to obtain a quick diagnosis of TBI at the place of injury. However, current methods and devices that provide TBI diagnosis are limited to clinical environments. In particular, contrary to other medical imagery technologies, Electroencephalography (EEG) techniques have the potential for being used in a portable way. In addition, Quantitative Electroencephalography (qEEG) is a sensitive diagnostic method of brain injury after mild head injury. It has shown over 80% accuracy in discriminating between normal and traumatic brain-injured subjects[2,3,4].

The EmerEEG project addresses this problem by proposing a portable decision support system based on EEG technology for early diagnosis of TBI at the point of need. This system includes a head device for fast and simple acquisition of EEG data during emergencies, as well as necessary devices enabling processing power, interfacing and communication capabilities. This paper focuses on the processing part of the system, which, once integrated to the rest of the system, provides a tool for the automatic diagnosis of TBI and decision support. The idea is to enable anyone from the emergency services with minimal training to assess the severity of a brain injury.

The remainder of the paper is organized as follows. Related processing and diagnostic techniques, are reviewed in section 2. Section 3 outlines the EEG processing method and TBI diagnosis. Section 4 describes the evaluation of the system in terms of the quality of the EEG pre-processing and TBI diagnostics. Finally, section 5 summarizes the paper and highlights future work.

2. Literature review

This section reviews methods for EEG data processing and TBI diagnosis.

The clinical criterion most widely used to classify TBI severity is the Glasgow Coma Scale (GCS), which grades the condition of a patient on a scale from 3 to 15 based on verbal, motor, and eye reactions to stimuli[8,9]. However, the GCS is a qualitative method of assessment, which has its limitations. Advanced neuroimaging techniques like Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are now widely used in hospitals for the assessment of neurological damage. The size and non-portability of the equipment, in addition to their limitations in diagnosing mild TBI[10,11,12], however, constrain their use in portable systems. By comparison, the EEG technique provides a direct measurement of brain activity without the need for external radiation or injected substances.

Rather than only analyzing raw recordings through visual inspection, the extraction of quantitative EEG data, such as frequency and coherence, has shown its relevance in recent years in supplying relevant and re-producible features for the development of diagnostic tools[13]. The discriminant accuracy of qEEG is reported as 95.67% in the detection of mild head injury[3] and 75.8% in predicting the outcome one year after the injury[14]. Moreover, qEEG demonstrates 96.39% classification accuracy, 95.45% sensitivity and 97.44% specificity in discriminating between groups with mild and severe TBI[4]. The EEG discriminant score is also used to measure intermediate severity in moderate TBI patients. Significant correlations between EEG discriminant scores, emergency admission measures, and post-trauma neuropsychological test scores have validated the discriminant function as an index of severity of injury and a classifier of the extremes of severity[4].

The procedure for computing a TBI diagnosis using EEG data normally involves pre-processing the raw recording to reduce the impact of the low signal-to-noise ratio and to obtain a more accurate representation of the pure brain activity. Artifacts are the most important cause of noise once errors directly due to the instrumentation have been eliminated. Artifacts are electrical signals detected along the scalp that do not arise from the cerebra. Typical artifacts include electrocardiography (ECG) artifacts caused by heart beats[15], ocular artifacts (EOG) caused by eye blinks or low-frequency patterns caused by eye movements[16,17], and muscle activity (EMG) caused by movements of the head, body, jaws, or tongue. EOG and EMG activities are unavoidable in EEG recording[16,17,18]. Conventional clinical approaches reduce noise by discarding epochs with artifacts through visual inspection by specialists. This manual process is time-consuming and subject to intra-observation differences, and useful information of the brain activity embedded in the discarded epochs might be lost.