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Portable decision support for diagnosis of Traumatic Brain Injury

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Abstract

Early detection and diagnosis of Traumatic Brain Injury (TBI) could reduce significantly the death rate and improve the quality of life of the people affected if emergency services are equipped with tools for TBI diagnosis at the place of the accident. This problem is addressed here by proposing a portable decision support system called EmerEEG, which is based on Quantitative Electroencephalography (qEEG). The contributions of the paper are the proposed system concept, architecture and decision support for TBI diagnosis. By the virtue of its easily operable mobile system, the proposed solution for emergency TBI diagnosis provides valuable decision support at a very early stage after an accident, thereby enabling a short response time in critical situations and better prospects for the people affected.

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1. Introduction

Traumatic brain injury (TBI) is brain dysfunction, which may have physical, cognitive, social, emotional, and behavioral effects[1]. It is caused by an external force, which traumatically damages the brain as a result of a fall, car accident, violence, contact sports, recreational activities or explosion blast. Symptoms are dependent on the severity of the brain injury, which can be mild, moderate, or severe. The symptoms associated with mild TBI include reduced concentration, decreased information processing capacity, behavioral or mood changes, as well as headache, vomiting, nausea, difficulty balancing, blurred vision and changes in sleep patterns[2,3,4]. Despite the recent advances in the diagnosis and treatment of TBI, which have led to decreased death rates and improved outcome, the number of people suffering from TBI continues to rise. For example, the total combined rate for TBI-related emergency

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department visits, hospitalizations, and deaths have increased from 521.0 in 2001 to 823.7 per 100,000 US citizens in 2010[5]. Similarly, in Europe, the TBI statistics based on twenty three European reports from 1980 to 2003 show average mortality rate of around 15 per 100,000 people[6]. The total economic burden caused by TBI in Europe is estimated at 33 billion Euros annually[7].

Early detection and diagnosis of primary brain injury can reduce significantly the death rate and improve the quality of life of the people affected by TBI. Primary brain injury occurs during the initial insult at the moment of trauma and is often followed by secondary brain injury, which could lead to irreversible outcomes. Therefore, there is a need for portable, accessible and reliable medical devices, which can be deployed quickly by emergency services at the place of injury. Quantitative Electroencephalography (qEEG) is a sensitive diagnostic method of brain injury after mild head injury, and has shown over 80% accuracy in discriminating between normal and traumatic brain-injured subjects[2,3,4]. However, its use is currently limited to clinical environments.

This paper addresses the above problem by proposing a portable decision support system based on EEG technology for early diagnosis of TBI at the point of need. A system capable of providing a medical diagnosis at the place of the accident has to be highly mobile and provide an automatic diagnosis along with remote medical advice from experts. Moreover, anyone from the emergency services with minimal training must be able to operate it using a simple and intuitive interface.

The remainder of the paper is organized as follows. Related diagnostic techniques, portable devices, and decision support systems are reviewed in section 2. Section 3 discusses an emergency scenario, outlines the technical requirements and describes the concept of the developed system called EmerEEG. Section 4 details the system architecture. Section 6 presents the decision support provided by the system. Section 7 describes the evaluation of the system in terms of the communication and decision support. Finally, section 8 summarizes the paper and highlights future work.

2. Literature review

Portable medical devices have become prevalent in the health care environment, thanks to advances in electronic systems integration and wireless communication. Bluetooth and Wi-Fi wireless technologies have been used in the development of health monitoring systems[8] and in particular in systems involving EEG data acquisition and processing[9]. Internet and especially mobile network architectures play an increasing role in the development of real-time monitoring systems that enable emergency telemedicine support[10,11,12]. Those systems are usually composed of two main parts connected over the network. On one side, a small unit enables the interaction with the patient and data acquisition. On the other side, a remote doctor's workstation enables real time monitoring. These systems also take advantage of small but powerful devices such as smartphones, laptops or micro-pc, i.e. small units including embedded processors with increased processing power, storage and wireless communication capabilities.

A clinical decision support system is defined as any computer program designed to help a healthcare professional make a clinical decision[13]. It includes tools for information management, tools for focusing the operator's attention on important elements, and tools for providing patient-specific recommendations. Decision-support systems are characterized along five dimensions: the system's intended function, the mode by which advice is offered, the consultation style, the underlying decision-making process, and the factors related to human-computer interaction. Decision support has to be carefully considered in the case of mobile medical system with integrated telemedicine capabilities, because the end-user might not be a medical expert and thus have the appropriate knowledge and training to provide a diagnosis.

The decision-making process can be supported by methods such as numerical analysis, Bayesian modelling, decision analysis, artificial neural networks, and artificial intelligence. Some of these methods have been used in the processing of EEG data for the detection of epileptic seizure[14], the discrimination of children with controlled epilepsy[15,16,17], the classification of EEG signals[18,19], or the incorporation of expert advice in automated systems[19].