

Chapter 66

A Review of Automated Methodologies for the Detection of Epileptic Episodes Using Long-Term EEG Signals

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ABSTRACT

Epilepsy is a chronic neurological condition caused by abnormal electrical activity of the human brain that affects up to 1% of the global population. Since seizures may occur at any time, long-term EEG recordings are more suitable to record ictal activity. To assist the inspection process various automated seizure detection methodologies have been reported demonstrating high performance. In this chapter the majority of such long-term EEG signal processing techniques and methods, used in the seizure detection domain, are presented. Emphasis is particularly given on providing a complete overview of the wide variety of methodologies from the last few years, which were evaluated using two well-known public EEG databases consisting of long-term scalp and intracranial EEG recordings. The purpose of this chapter is to provide an evaluation of the methods' performance under a common reference dataset to assess their suitability for implantable or ambulatory seizure detection devices.

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INTRODUCTION

Epilepsy is a neurological condition that affects the nervous system and disturbs the brain's normal electrical activity. It is a chronic disease since it persists for a long time and it is characterized by recurrent epileptic seizures (Greenway, Ahern, Leavy, Rawnsley, & Duncan, 2013). While there is evidence that epilepsy is a well known disease since the ancient years, the Greek physician and philosopher Hippocrates (460-377 BC) was the first to consider that epilepsy starts in the brain (Reynolds & Kinnier Wilson, 2008; Wilson & Reynolds, 1990). According to the latest World Health Organization (WHO) reports, in world scale, epilepsy affects about 50 million people targeting mostly children (from infants to adolescents) and in increasingly rates elders. Among general population about 4-10 per 1000 people are estimated to suffer from active epilepsy, meaning that they constantly endure the occurrence of seizures in varying time intervals (WHO, 2012). Additionally, epilepsy shows a very even geographical, sexual and social distribution of affected people, making it impossible to affiliate the disease with racial or economical factors. In fact, epilepsy has been detected in many mammals besides humans, amplifying the claim that every species' brain could suffer from epileptic symptoms, with likelihood increasing with complexity.

According to recent studies the total cost (direct & indirect) for treating epileptic patients was estimated to be around € 13.8 billion and \$ 15.5 billion in Europe and the United States, respectively (DiLuca & Olesen, 2014; Pugliatti, Beghi, Forsgren, Ekman, & Sobocki, 2007). Around 70% of patients respond to anti-epileptic medication while the vast majority of people with epilepsy (around 80%) is found in developing regions where inferior health care systems and inaccessibility to Anti-Epileptic Drugs (AEDs) are met (Bell, Neligan, & Sander, 2014). It is also estimated that about three hundred thousand new cases of epileptic patients are diagnosed in Europe each year. Finally, although epilepsy is not by nature a fatal disease, a United Kingdom government report showed that Sudden Unexpected Death in Epilepsy (SUDEP) is annually responsible for 33.000 deaths in the European Union (IBE, 2013).

Under normal conditions the human brain transmits information in the form of electric pulses between its different parts and the rest of the body. In the case of epilepsy, however, this normal electrical activity is altered through mechanisms that are not completely studied and understood, leading to the initiation of a seizure. In most of the cases a seizure is caused by a certain malfunctioning region of the brain (called the epileptogenic zone) accompanied by bursts of intense electrical pulses followed by rapid discharges. The result is the disruption of the brain's communications leading to invocation of mixed signals, loss of coherence or consciousness, involuntary movement and other symptoms. The exact way each patient reacts can be different but is primarily defined by the location of the epileptogenic zone and whether the abnormal activity is spreading in other areas of the brain. In general, the more areas of the brain are malfunctioning at the same time, the more intense and noticeable are the symptoms of an ongoing seizure. The duration of a seizure usually does not exceed a minute, with greater time intervals reported only in severe incidents, and is self-terminated with the brain usually immediately returning to its normal pre-seizure state.

The most common mean to observe and study such abnormalities in brain's electrical activity is the electroencephalogram or EEG. EEG investigation of patients with suspected epilepsy serves two main purposes: (a) to support the general diagnosis of epilepsy and (b) to aid seizure and syndrome classification (Smith, 2005). The routine diagnostic EEG tests last for no more than half an hour and usually demonstrate inter-ictal (i.e. between seizures) brain activity. The primary concern is to demonstrate epileptiform activity supportive of epilepsy diagnosis. However, some diagnostic problems cannot be adequately addressed by routine inter-ictal recording and in order to establish the diagnosis in such pa-

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