Computers in Biology and Medicine 70 (2016) 139–147

Contents lists available at ScienceDirect

Computers in Biology and Medicine

journal homepage: www.elsevier.com/locate/cbm

Parallel scheme for real-time detection of photosensitive seizures

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A R T I C L E I N F O

Article history:
Received 25 November 2015
Accepted 11 January 2016

Keywords:
Health safety
Multicore parallel processing
Pattern recognition
Photosensitivity
Photosensitive epilepsy
Real-time video streaming

A B S T R A C T

The production and distribution of videos and animations on gaming and self-authoring websites are booming. However, given this rise in self-authoring, there is increased concern for the health and safety of people who suffer from a neurological disorder called photosensitivity or photosensitive epilepsy. These people can suffer seizures from viewing video with hazardous content. This paper presents a spatiotemporal pattern detection algorithm that can detect hazardous content in streaming video in real time. A tool is developed for producing test videos with hazardous content, and then those test videos are used to evaluate the proposed algorithm, as well as an existing post-processing tool that is currently being used for detecting such patterns. To perform the detection in real time, the proposed algorithm was implemented on a dual core processor, using a pipelined/parallel software architecture. Results indicate that the proposed method provides better detection performance, allowing for the masking of seizure inducing patterns in real time.

1. Introduction

More than 50 million people worldwide suffer from epilepsy, making it the second most prevalent neurological disorder [1]. About 3–5% of those people have a particular form of epilepsy (called photosensitivity or photosensitive epilepsy) in which seizures can be evoked visually by high temporal contrast, high spatial contrast, or even particular colors. For these people, common stimuli, such as flashing emergency lights, flickering fluorescent lights, or lights seen through the blades of a moving ceiling fan can be hazardous. Another possible source of high-contrast spatiotemporal stimuli is viewed video [32].

With the dramatic advances in digital information technology over the last two decades, video has become an increasingly dominant type of content transported across the worldwide web (For example, see YouTube [2]). Video streaming now accounts for about 68% of the downstream data traffic during peak periods, and it is expected to continue rising in the coming years [3].

In addition, more and more of the video content being streamed over the web is being self-published, and is not always scrutinized, before being published, for compliance with video safety standards using video post-processing tools such as the *Photosensitive Epilepsy Analysis Tool* (PEAT) [4].

While photosensitivity has gained a lot of attention in neurology, as well as in multimedia research fields, there has not been adequate research done toward the development of real-time hazardous pattern detection, for use on video that is streamed from Internet video servers. This is important for both PC and game consoles users, to assure that the observed videos/games do not induce harmful seizures.

Game consoles such as Xbox, Play Station, and Steam box encourage freelancers and indie game developers to develop and publish their own content through webstores. In addition, several games, such as Minecraft and Little Big Planet, allow users to develop their own game stages and environments, and then share them with other game users. Many active gaming communities develop customized modifications to games (known as *mods*) that extend and augment the features provided by the original games [5].

All of these unprecedented abilities to self-publish both videos and videogames increase the possibility of distributing malicious or unintended hazardous video content that might induce seizures in people with photosensitivity. Since there is no *mechanism* for the enforcement of any governing restrictions on such multimedia content, there is little, if any, enforcement at all [6]. This leads to health and safety concerns for those who suffer from photosensitivity. One famous example was an episode of the cartoon Pokémon, which was broadcast in 1997, which induced seizures and affected thousands of Japanese children [7].

One of the main challenges in working with photosensitivity is that most people are not aware that they are vulnerable to this type of seizure until they either experience it, or they undergo a

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http://dx.doi.org/10.1016/j.compbiomed.2016.01.008
0010-4825/

specialized epilepsy test involving an electroencephalogram (EEG) test, under the supervision of a neurologist [8].

These factors have motivated not just scientists and media specialists, but even law makers in recent years have taken actions (a) to increase public awareness of the problem, (b) to suggest research to better understand the types of content that evoke seizures, and (c) to institute regulations to reduce the risk of seizures while playing video games [29].

Most of the published research conducted to identify the types of content that evoke seizure in those with photosensitivity has been done by neurologists, who have employed one of two different methodologies. The first methodology *surveys* patients with photosensitivity, in an attempt to discover what types of spatio-temporal patterns tend to evoke seizures [9–13]. The second methodology employs EEGs that are recorded during intermittent photic stimulation (IPS), to identify photoparoxysmal responses (PPR) [8,14–17]. Some of the research done using these two methods has suggested some practical solutions to photosensitivity, such as the use of optical filters or colored glasses [18,19].

Additional published research has been conducted by *multimedia* researchers, who tend to focus on identification of spatio-temporal video characteristics that might evoke seizures in people with photosensitivity [6,20–25]. Based on video characteristics identified by this methodology, guidelines and standards have been developed. However, not enough research has been done toward the development of software tools to identify such characteristics in recorded videos [4]. What is needed are tools that can analyze streaming video in *real time*, to filter out any content that might trigger seizures.

This paper proposes a *pipelined/parallel* scheme for identifying seizure inducing patterns during *real-time* video streaming. The paper compares the performance of the proposed method with the PEAT post-processing tool [4] which is used for detecting such patterns in recorded videos. The experimental results show that the proposed method is able to provide accurate identifications of the seizure inducing patterns in real time. This paper includes the following contributions:

- *Real-Time Detection:* The proposed method detects seizure inducing patterns in streaming video in real time.
- *Multicore Parallel Computation:* The proposed method harnesses parallelism in multicore hardware, to meet real time requirements, and to achieve better performance.
- *Pattern Inducer:* To evaluate the proposed method, a set of testing benchmarks is developed, in the form of video clips with spatiotemporal patterns that have the potential to induce seizures. These benchmarks can be used to provide a ground truth for this type of work.

This paper is organized as follows: Section 2 surveys the existing work done in Photosensitivity. Section 3 describes the system architecture and its main components. Section 4 describes the implementation details of the system. Section 5 conducts the evaluation experiments, and provides comparisons of the results. Section 6 proposes a parallel scheme for real-time detection of the seizure inducing patterns. The paper is concluded in Section 7.

2. Literature review

There has been a considerable amount of published research on photosensitivity, by both neurologists and multimedia researchers. However, research has not yet focused on the problem of preventing seizures caused during real-time video streaming of untested video. This section reviews the existing research on photosensitivity in neurology, as well as in the multimedia field.

2.1. Photosensitivity in neurology

Ishiguro et al. [9] used a questionnaire to conduct follow-up surveys 1 and 3 years after the incident in which epileptic patients had seizures while watching an animated cartoon TV program "Pocket Monster" in 1997. The study showed that more than two thirds of those who had seizures during the incident had no seizures during the subsequent 3 years. Ishida et al. [10] also studied the incident of watching the animated cartoon TV program "Pocket Monster". That study investigated the clinical symptoms of 4 patients who experienced seizures while watching the program. Shiraishi et al. [11] examined the distribution of epilepsy patients for (a) different ages, (b) different types of epilepsies and epileptic syndromes, and (c) different ethnic and geographical groups. The study found that the rate of photoparoxysmal responses (PPR) in eastern Asia was relatively low, compared to the studies performed in European countries. Further, it showed that there is a measureable relationship between the subject's age and positive PPR.

Prasad et al. [12] discussed the effects of 3D television and cinema in triggering seizures in patients with photosensitivity, and contrasted it with 2D movie risks. In general, that study did not find anything new to 3D television, compared to conventional 2D television. The paper's discussion section includes some suggestions for minimizing the risk of seizures, which could be used by neurologists when advising their patients.

Wilkins et al. [13] summarized the different methods used to study the physiology of human visual sensitivity, including (a) the study of the physical characteristics of the trigger, (b) the study of the topographic distribution and probability of the PPR to elementary visual stimuli, and (c) the use of Visual Evoked Potentials (VEPs) to characterize the mechanisms of control of cortical excitability below the critical levels that trigger paroxysmal activity.

Guerrini and Genton [14] reviewed the clinical characteristics of the different types of photosensitivity, and the main epileptic syndromes. While this study identified the various seizure types triggered by visual sensitivity, it did not characterize the *causes* of such sensitivity. The study stated that rapid changes in color are believed to be responsible for the photosensitive seizures. In a later study, Trenite identified various variables that contribute to the photosensitivity. he called for defining a standardized methodologies that take into consideration these variables [33].

Lopes da Silva and Harding [15] investigated whether changes in neuronal activity preceding the transition to an epileptic PPR can be detected. Significantly, this work defined an index of the pre-ictal transition to seizures in photosensitivity. The index, called the *relative Phase Clustering Index* (rPCI), is computed from human EEG signals.

Smith [8] discussed the areas in which interictal and ictal EEG are useful in epilepsy diagnosis and management. Kasteleijn-Nolst Trenité et al. [16,17] developed a new algorithm for visual stimulation in the EEG laboratory, with the aim of standardizing the intermittent photic stimulation (IPS) procedure used to identify seizures. Their proposed algorithm consists of several steps.

Takahashi et al. [18] suggested compound filters composed of two different types of optical filters that can inhibit two identified mechanisms for the PPR. The first filter reflects the long-wavelength red light that can evoke a wavelength-dependent seizure response, and the other filter absorbs light across the visible spectrum evenly, which can evoke a quantity-of-light–dependent seizure response. The study found that both filters individually inhibited PPR insufficiently.

Wilkins et al. [19] designed an open trial to ascertain whether colorimetry assessment is safe for the investigation of photosensitive