Automatic Detection of Flashing Video Content

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Abstract— **Epilepsy is a disease that affects around 50 million people worldwide, 3-5% of which had seizures triggered by pulsating lights, or by patterns with light and dark areas, a condition known by photosensitive epilepsy (PSE). Video content with fast luminance variations, or with spatial patterns of high contrast - referred to as epileptogenic visual content - may also induce seizures on viewers with PSE, and even cause discomfort on users not affected by this disease. To avoid this type of effects, harmful visual content should be detected before being distributed or displayed. In this paper we propose a method for the automatic detection of flashing video content, compliant with recommendation ITU-R BT. 1702. A key aspect of the proposed method is its computational efficiency, allowing real time implementation at the end-user equipment.**

Keywords — QoE; photosensitive epilepsy; PSE; flashy video detection.

I. INTRODUCTION

Photosensitive Epilepsy (PSE) is a form of epilepsy where seizures are triggered by visual stimuli, such as flashing lights and high contrasting geometric patterns [1][2]. Both natural and artificial light may trigger seizures. Flashing lights (as in clubs, around emergency vehicles, or resulting from photographers' flashlights) and fast changing images (as in action movies, anime or computer games) are the most common triggers. The seizure is generated by excessive electrical activity in the brain, that can be the a result of irregularities in the wiring of the brain and/or imbalance of neurotransmitters (chemical messengers in the brain). Individuals affected by PSE experience what is called a generalized tonic-clonic seizure, that involves the entire body and usually happens at the time of, or shortly after, looking at the trigger. People with PSE usually develop this condition before the age of 20, mainly between the ages of 9 and 15 years old. This condition is more likely in females than in males. Stimulus avoidance and stimulus modification can be an effective treatment in some patients and can sometimes be combined with antiepileptic drug treatment.

Around 50 million people worldwide have epilepsy, 3-5% of which had seizures triggered by luminance flashes or spatial patterns on images or videos. This type of visual content may also cause discomfort on people not affected by PSE, conditioning their quality of experience while watching TV programs, films, or playing video games. Several television material was directly related to the occurrence of the following incidents:

1993 - A broadcast advertisement *Golden Wonder Pot Noddles* [7] precipitated epileptic seizures in 3 viewers in the U. K.
1997 - The 25th episode of the anime *YAT Anshin!Uchu Ryok¨o* [8] was related to seizures in 4 children in Japan.
1997 - The 38th episode of the 1st season of *Pokemon* [9] was broadcasted in Japan and caused 685 direct seizures.
2012 - The London Olympic Games promotional film [10] was blamed for triggering seizures in 4 people.

Those incidents have led to clinical studies on PSE [1]-[6] and to the formulation of national guidelines in the U.K. [11] and Japan, extended internationally in recommendation ITU-R BT - 1702 [12]. With the emergence of wide screen and panoramic video displays, providing to the viewers a richer video immersion experience, the risk is more real than ever; therefore, the implementation of guidelines preventing PSE triggers on media content production and broadcasting, should be mandatory. Since it is unfeasible to detect harmful images and videos using a manual control on real time, automatic tools have to be developed.

In this paper we propose a method for flashing video content detection, compliant with recommendation ITU-R BT. 1702. A key aspect of the proposed method is its computational efficiency, allowing real time implementation at the end-user equipment. Very few scientific publications have been dedicated to the topic of automatic detection of epileptogenic video content [13]; some commercial products have been developed [14][15], but the technical details about the implemented techniques are not easily available.

This paper is organized as follows: section II presents the main characteristics of epileptogenic visual content, and summarizes the ITU-R and Ofcom guidelines for preventing this type of content. Section III describes the proposed algorithms for automatic flashing video detection. Section IV presents some experimental results, allowing the assessment of the proposed method, both in terms of accuracy of the detection and on processing time. Finally, section V concludes the paper.

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II. EPILEPTOGENIC VISUAL CONTENT CHARACTERIZATION

The first guidance notes related with the characterization of potential harmful video/image content were developed between 1993 and 2001 by UK's Independent Television Commission, ITC, further Ofcom. The first version was released in 2001; the current version can be found in [11]. The Ofcom guidelines on potential harmful flashes have been adopted by ITU-R in 2005, through recommendation ITU-R BT. 1702 [12], and can be summarized as:

- A potentially harmful flash occurs when there is a pair of opposing changes in luminance (i.e. an increase in luminance followed by a decrease, or a decrease followed by an increase) of 20 cd/m^2 or more. This applies only when the screen luminance of the darker image is below 160 cd/m^2. Irrespective of luminance, a transition to or from a saturated red is also potentially harmful.
- A sequence of flashes is not permitted when both the following occur: 1) the combined area of flashes occurring concurrently occupies more than 25% of the displayed screen area; 2) the flash frequency is higher than 3 Hz.
- A sequence of flashing images lasting more than 5 s might constitute a risk even when it complies with the guidelines above.
- Rapidly changing image sequences (for example, fast cuts) are provocative if they result in areas of the screen that flash, in which case the same constraints apply as for flashes.

In order to reduce the risk of seizure for susceptible individuals, filtering techniques may be applied at the end-user equipment, and whenever an harmful condition is detected [11][12].

Concerning the patterned pictures characterization, although ITU-R refers that regular patterns clearly discernible in normal viewing conditions should be avoided, the patterns' characteristics are not described. Ofcom states that:

- Stationary patterns containing more than 5 light/dark stripes, in any orientation, should not occupy more than 40% of the screen area. Such patterns that oscillate, flash or reverse are restricted to 25% of screen area.
- Patterns that violate the above conditions may still be allowed if the contrast between light and dark is less than 20 cd/m^2 or if the darker component is lighter than 160 cd/m^2.

III. FLASHING VIDEO DETECTION

This section describes the algorithm developed for the detection of flashing video content that can precipitate seizures, and according to the guidelines of ITU-R Rec. BT.1702 [12].

A. Conversion from luminance to screen brightness

Although Rec. BT.1702 [12] is relative to brightness values of the display (i.e. emitted light output), expressed in cd/m^2, in digital video the picture elements are usually represented in terms of the digital values of the luminance (Y) and chrominances (C_r and C_b) components. To convert from luminance (expressed in mV), to screen brightness, L (expressed in cd/m^2), ITU-R suggests the use of the graph shown in Appendix 2 of [12], which can be considered as representative of the gamma characteristic for most TV screens; by curve fitting of that graph, and assuming that the luminance black and white peak levels are represented, in digital values, by Y=0 and Y=255, results:

$$L(\mathrm{cd/m}^2) = 413.435\,(0.002745\,Y + 0.0189623)^{2.2} \qquad (1)$$

Equation (1) was implemented through a look-up table procedure, in order to reduce the associated computation time.

B. Detection of luminance flashes

To introduce the developed algorithm for detecting luminance flashes, consider fig.1, that represents the average screen brightness, $\overline{L}$, per frame, for 1 second of video. In this example, the frame rate is 25 Hz and the luminance component of every pixel has the same variation, corresponding to a flash area percentage of 100% of the frame area. Figs. 2 and 3 show, respectively, the average brightness variation between consecutive frames ($\overline{\Delta L}$) and the accumulated value of this variation ($\overline{\Delta L}$_acc) between the local extreme of $\overline{L}$, i.e., only consecutive variations of the same sign are accumulated.

Table 1 presents the list of relevant events for detecting an harmful situation, namely: the value of the local extremes of $\overline{\Delta L}$_acc, the number of frames between these values and the average values of L at the local extremes of this component. From figs. 1 to 3, the following correspondences can be directly established:

- absolute value of the local extremes of $\overline{\Delta L}$_acc: flash intensity;
- sign of the local extremes of $\overline{\Delta L}$_acc: flash evolution (a positive sign indicates an increase of L followed by a decrease; a negative sign indicates a decrease of L followed by an increase);
- number of frames between local extremes of $\overline{\Delta L}$_acc: flash duration;
- average value of L at the local extremes - luminance of the darker frame (if $\overline{\Delta L}$_acc < 0), or of the ligther frame (if $\overline{\Delta L}$_acc > 0).

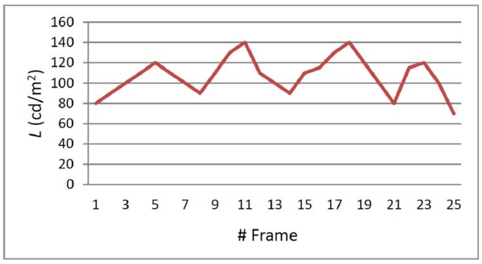

Fig. 1. Average brigthness per frame.

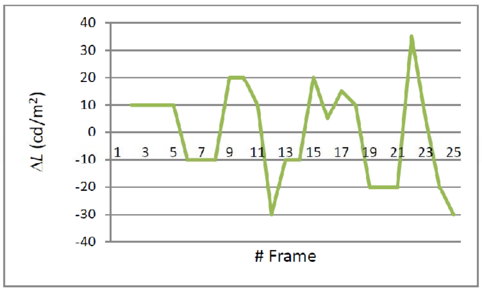

Fig. 2. Average brigthness difference per frame.

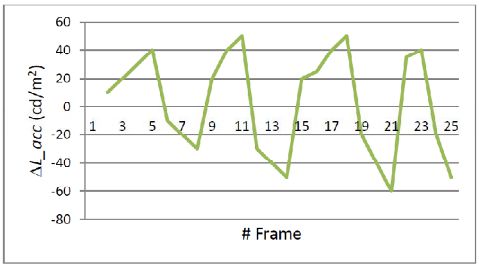

Fig. 3. Accumulated average brightness difference per frame.

From the analyse of table I we may concluded that the brigthness evolution represented in fig. 1 corresponds to an harmful situation with 4 consecutive flashes (with an intensity higher than the limit of 20 cd/m^2 recommended by ITU-R in [12]), during 1 s, resulting in a flash frequency of 4 Hz (so, also above the maximum value of 3 Hz specified by ITU-R in [12]) .

The method proposed for detecting luminance flashes is based on two main actions that are executed continuously along the video sequence: 1- generation of the events list (Algorithms 1 and 2, described below); 2- analyses of the events list for detecting, and signalizing, harmful situations. Before executing it, the following parameters should be defined:

- minimum flash area percentage, $area_f$ (by default, and according to [12], $area_f$ = 25%); if N represents the number of pixels per frame, the minimum number of pixels for defining the flash area will be given by $area_f \times N$;
- flash intensity, ΔL_{max}, and flash frequency, *fflash*, above which flashes are considered harmful (by default, and according to [12], ΔL_{max} =20 cd/m^2 and *fflash* = 3 Hz);
- image frequency, f_i (in Hz).

TABLE I. EVENTS LIST

$\overline{\Delta L}$ _acc extremes	40	-30	50	-50	50	-60	40	-50
# frames	5	3	3	3	4	3	2	2
$\overline{L}$ (at extremes)	120	90	140	90	140	80	120	70

Algorithm 1 is composed of 6 steps; the goal of steps 1 to 5 is to evaluate the trend of the brightness variation, and to detect the occurrence of the local extremes (maximum and minimum) of $\overline{\Delta L}$ _acc; step 6 computes the value of those extremes and the distance (in frames) to the previous local extreme.

Algorithm 1 - Events list generation

Step 1. For each frame, compute the brightness difference (pixel by pixel) using the precedent frame, $\Delta L_k(i,j) = L_k(i,j) - L_{k-1}(i,j)$, where (i,j) are the pixel spatial coordinates and k is the frame index.

Step 2. Generate the histograms, h_k^+ and h_k^- of, respectively, the positive and negative brightness differences obtained in step 1.

Step 3. Scan h_k^+ and h_k^-, starting in each case from the highest (in module) bin, and until the number of elements in the bins equals the minimum number of pixels for defining a flash, i.e., $area_f \times N$.

Step 4. Compute the average value, $\overline{\Delta L}_k^+$ and $\overline{\Delta L}_k^-$, of the scanned elements, according to (2); B^+ and B^- are the set of bins scanned in step 3. If in any of the scans the number of elements is lower than $area_f \times N$, the corresponding average is set to zero. The average brightness variation at frame k, $\overline{\Delta L}_k$, represented in fig. 2, will be given by the highest value (in module) of $\overline{\Delta L}_k^+$ and $\overline{\Delta L}_k^-$.

$$\overline{\Delta L}_k^+ = \frac{\sum_{b\in B^+} h_k^+(b)\times b}{\sum_{b\in B^+} h_k^+(b)} \quad \text{and} \quad \overline{\Delta L}_k^- = \frac{\sum_{b\in B^-} h_k^-(b)\times b}{\sum_{b\in B^-} h_k^-(b)} \qquad (2)$$

Step 5. Compare the signs of the current and previous average brightness variation, $\overline{\Delta L}_k$ and $\overline{\Delta L}_{k-1}$, respectively. If the signs are equal (or if the average value is zero), the brightness variation has maintained the trend, and is accumulated in an array whose size matches the frame size

$$\Delta L\_acc_k(i,j) = \Delta L\_acc_{k-1}(i,j) + \Delta L_i(i,j); \qquad (3)$$

the procedure is repeated from step 1 for the next video frame. If the signs are different, the brightness variation has inverted his trend, resulting in a local extreme of it; the value of this local extreme is computed by step 6.

Step 6. The average value of the accumulated brightness variation (a local extreme of figure 3), which is also the flash intensity, is computed by first obtaining the histogram of ΔL_acc_k, and by a procedure similar to the one described in steps 3 and 4 (but only the histogram and average brightness variation corresponding to the trend will be computed); this average variation, the number of video frames since the last local extreme of ΔL_acc, and the average value of L_k, are stored in the events list; the array ΔL_acc is set to zero and the procedure is repeated from step 1 using the next video frame.

Algorithm 2 - Events list generation (simplified version)

A slightly simpler procedure was also implemented by accumulating the average brightness variation, $\overline{\Delta L_k}$, found in step 4, instead of accumulating the pixel-by-pixel brightness differences, using (3); in that case, once a modification on the trend of L is detected, the value of the flash intensity is immediately given by the accumulated variation, and step 6 is skipped. However, in some particular cases this approach may lead to a incorrect flash detection, since it cannot distinguish brightness variations that change position from frame to frame, from those that happens at the same position.

Irrespective of which algorithm is being used to generate the events list, whenever a new event occurs, each line of the list is analyzed using a window of $2\times fflash$ consecutive elements, ending at the last element (the factor 2 comes from the fact that a flash is defined by a pair of opposing brightness transitions). Let the total number of frames on that window be N_{frames} (second line of the events list); accordingly, the corresponding time interval will be given by N_{frames} / f_i, where f_i is the image frequency. In compliance with [12], an harmful video segment is detect when the three following conditions are simultaneously verified:

- $\boldsymbol{C_1}$ - N_{frame} / f_i is lower than 1s, resulting in a flash frequency higher than *fflash*;
- $\boldsymbol{C_2}$ - every flash has an intensity (first line of the events list, in module) equal to, or higher than, $\Delta L_{\max}$;
- $\boldsymbol{C_3}$ - the average brigthness intensity of the darker images (third line of the events list) is lower than 160 cd/m^2.

A sequence of flashing images lasting more than 5 s might constitute a risk even when *fflash* is lower than 3 Hz and $\Delta L_{\max}$ is lower than 20 cd/m^2. In order to detect this situation, *fflash* and $\Delta L_{\max}$ are relaxed to (by default), 1 Hz and 10 cd/m^2, respectively. A warning will be settled if, when analysing the events list in a window comprising, at least, $5\times f_i$ frames (i.e., a time window of, at least, 5s), conditions $\boldsymbol{C_2}$ to $\boldsymbol{C_3}$ listed above, and condition $\boldsymbol{C_4}$ defined below, are simultaneously verified:

- $\boldsymbol{C_4}$ - $F_n / (N_{frame} / f_i)$ is higher than than *fflash* (1 Hz, by default),

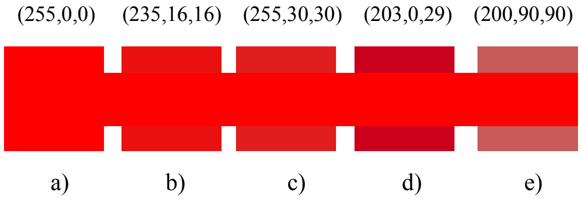

Fig. 4 - Resulting colours for different combinations of (R,G,B). The overlapping colour has colour components of (255,0,0).

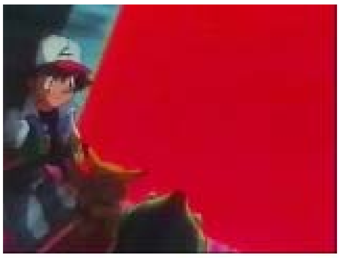

Fig. 5 - One frame of the *Pokemon* episode [9].

where F_n and N_{frame} are, respectively, the number of flashes and the exact number of frames, on the window.

C. Detection of saturated red transitions

Besides luminance flashes, PSE seizures may also be triggered by changes to, or from, a saturated red [12]. In the RGB color space, a saturated red occurs when the R component is at its maximum possible value and the remaining components, B and G, are at their minimum value. However, other hues can also be perceived by the viewers as saturated reds, as can be inferred from figure 4. In particular, fig. 4-d), corresponds to the red hue used on the problematic *Pokemon* episode (fig. 5 displays an example frame of it). Therefore, the developed algorithm allows the user to define a range of harmful “saturated red” colors, through the set of conditions (4)

$$R > R_{min} \text{ and } G < G_{max} \text{ and } B < B_{max} \tag{4}$$

with, by default, R_{min}=200, G_{max}=90 and B_{max}=90 (fig. 4-e).

In the YC_bC_r colour space, the saturated red with RGB components of (255,0,0) can be obtained applying (5), and assuming that the colour components may take values in the range [0..255] [16]; this results in $YC_bC_r^{sat}$ = (76,85,255).

$$\begin{bmatrix} Y \\ C_r \\ C_b \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.168736 & -0.331264 & 0.5 \\ 0.5 & -0.418688 & -0.081312 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 0 \\ 128 \\ 128 \end{bmatrix} \tag{5}$$

Varying the RGB components on the range defined by conditions (4), and using the default values for R_{min}, G_{max} and B_{max}, we get the limits of variation for the resulting color components in the YC_bC_r space, which are represented in table 2; the maximum euclidean distance between the resulting colors and $YC_bC_r^{sat}$ = (76,85,255) was 89.6. A colour with components (Y,C_b,C_r) is considered to belong to the range of harmful red hues, if each component lays inside the limits defined in table 2, and has an euclidean distance to the reference saturated red lower than 89.6.

TABLE II. LIMITS (BY DEFAULT) OF YC_BC_R IN THE HARMFUL RED RANGE

Y		C_b		C_r	
min	*max*	*min*	*max*	*min*	*max*
66	104	72	110	218	255

Let represent by P_k^{sat} the percentage of pixels in frame *k* with a colour inside the harmful red hue region. A transition to a saturated red situation is detected and signalized when $P_k^{sat} \geq P_T$ and $P_{k-1}^{sat} < P_T$, where P_T is a predefined threshold (by default, we consider P_T = 25%); a transition from a saturated red situation is detected and signalized when $P_{k-1}^{sat} \geq P_T$ and $P_k^{sat} < P_T$; frames with a percentage of harmful red pixels equal to or higher than P_T, but outside a transition, are signalised with a warning.

IV. RESULTS

In order to evaluate the algorithm performance some of the videos associated to seizures, namely those available in [7][8][9][10], have been used. All these video sequences fail Rec. ITU-R BT.1702 [12] at some point; also, there is a high correlation between the video segments detected as harmful by the algorithm, and the results of a subjective evaluation of the videos. However, the absence of the "ground truth" associated to those video, prevents a quantitative assessment. To get an objective evaluation of the algorithms, synthetic flashing video sequences were generated [17]. The characteristics of the different sequences are detailed below (A_f stands for the simulated flash area percentage, *ff* is the simulated flash frequency; the frame frequency is 25 Hz, and the spatial frame resolution is 400 × 400 pixels):

- *Sequence 0*: 100 frames with luminance alternating between *Y*=0 and *Y*=255; A_f = 100% and *ff* = 12.5 Hz.
- *Sequence 1*: 100 frames with luminance alternating between *Y*=16 and *Y*=235; A_f = 50% and *ff* = 12.5 Hz.
- *Sequence 2*: 100 frames with luminance alternating between *Y*=16 and *Y*=235; A_f = 10% and *ff* = 12.5 Hz.
- *Sequence 3*: 100 frames with luminances alternating between *Y*=16 and *Y*=235; A_f = 33% and *ff* = 12.5 Hz.
- *Sequence 4*: 100 frames with luminances alternating between *Y*=16 and *Y*=235; A_f = 33% and *ff* = 0.25 Hz.
- *Sequence 5*: 25 frames with *ff* =12 Hz + 100 black frames + 200 frames with *ff* =1.125 Hz + 100 black frames + 25 frames with *ff* =11 Hz. All flashes have luminance components alternating between *Y*=16 and *Y*=235, and A_f = 100%.
- *Sequence 6:* 100 frames alternating between *Y*=235 (~168 cd/m^2) and *Y*=255 (~200 cd/m^2), for testing the condition of the maximum brithgness value of the darker image (which should be lower than 160 cd/m^2).
- *Sequence 7*: 100 frames with a moving white bar (*Y*=235),with an area of 15%, that continuously cover a black background. The bar crosses the whole image in a time interval corresponding to 6 frames, followed by 4 black frames. There are 10 full screen crossings of the bar, along the video sequence, producing 10 flashes and a flash frequency of 2.5 Hz.
- *Sequence 8:* 100 frames with a transition to, and a transition from, a harmful red hue occupying 100% of the frame area, and 50 frames with a colour inside the saturated red range.

Sequences 0 to 3 allow to evaluate if the minimum required area for the flash is correctly identified by the algorithm; sequences 3 and 4 allows to assess if the algorithm identifies the correct flash frequency; sequence 5 contains harmful flashes and also flashes that, although with a low frequency, persist for 8 s, so a warning should be settled; in sequence 6, the darker image has a brightness higher than 160 cd/m^2, so flashes should not be considered as harmful; sequence 7 allows to verify the capacity of the algorithm for detecting flashes whose area accumulates from frame to frame.

For defining a flash as harmful, two sets of parameters have been used: set A, compliant with Rec. ITU-R BT.1702, and corresponding also to the default parameter values of the algorithms; and set B, with $area_f$ = 50% and *fflash* = 2 Hz.

Table III shows the expected and detected luminance flashes, or transitions to and from saturated red hue (both cases are signalized by F) and warnings (W), for the two implemented algorithms and the two set of parameters. In all except one case, the detection results match the expected values. The exception happens with algorithm 2, for sequence 7, because in this case the changing area between each consecutive frame is just 15% of the frame area, so below the minimum required area for defining a flash. Accordingly, for each frame, the average brightness difference is not considered. With algorithm 1, the changing area is accumulated from frame to frame, and the flashes are detected.

Table IV presents the processing time for each sequence and algorithm; the hardware used was a x86 machine with an Intel® Core™ i7-4770, at 3.40 GHz, with 16 GB of RAM. For both algorithms, the execution time allows a real time

TABLE III. ASSESSMENT OF THE FLASH DETECTION ALGORITHMS

Video	Set A			Set B		
	Expected (F / W)	Detected (F / W)		Expected (F / W)	Detected (F / W)	
		Alg 1	**Alg 2**		**Alg 1**	**Alg 2**
Seq 0	50 / 0	50 / 0	50 / 0	50 / 0	50 /0	50 /0
Seq 1	50 / 0	50 / 0	50 / 0	50 / 0	50 / 0	50 / 0
Seq 2	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Seq 3	50 / 0	50 / 0	50 / 0	0 / 0	0 / 0	0 / 0
Seq 4	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Seq 5	23 / 9	23 / 9	23 / 9	23 / 9	23 / 9	23 / 9
Seq 6	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Seq 7	0 / 0	0 / 0	0 / 0	10 / 0	10/ 0	0 / 0
Seq 8	2 / 50	2 / 50		2 / 50	2 / 50	

TABLE IV. PROCESSING TIME

	Processing time (ms / frame)	
Video	Algorithm 1	Algorithm 2
Seq 0	5.36	3.14
Seq 1	5.40	3.13
Seq 2	3.51	3.20
Seq 3	5.43	3.12
Seq 4	3.27	3.02
Seq 5	2.78	3.02
Seq 6	5.27	3.14
Seq 7	3.70	3.13
Average	4.34	3.11

implementation of it, even if higher spatial resolutions are considered.

V. CONCLUSIONS

In this paper we have proposed a computationally efficient method for the automatic detection of flashing video content; this type of content is potentially harmful to people who are prone to Photosensitive Epilepsy and may also cause discomfort on users not affected by this disease, conditioning their quality of experience while watching TV, films, or playing video games. In order to reduce the risk of seizures for susceptible individuals, filtering techniques (not considered in this paper) may be applied at the end-user equipment, and whenever an harmful condition is detected. The development, and vulgarization, of these type of automatic tools - that should be part of any video quality control system - is also important to increase the awareness of content creators and content providers, to the need of evaluating the risk of the digital video content that people (and in particular, children) watch.

Acknowledgment

This work was developed under project "MOG – QC on the GO", Ref. SIIDT/2013/034075, funded by the European Regional Development Fund / QREN - COMPETE, Portugal.

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