DETECTING FADE REGIONS IN UNCOMPRESSED VIDEO SEQUENCES

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ABSTRACT

The use of fade in video production to smooth scene changes and enhance the video quality complicates subsequent video compression or video editing. It is important to detect the fade regions in order to improve the quality of the compressed video or to allow automatic parsing of the video for the purpose of editing and database indexing. In this paper a fade detector that exploits the changes in the average luminosities as well as the semi-parabolic behavior of the variances of the frames in the fade region is developed. Simulation results indicate that the developed detector has over a 95% reliability rate.

1. INTRODUCTION

Soft cuts are frequently used in editing video footage in order to produce a 1/2-1 second smooth transition between scenes. Usually, this transition is linear in nature. It is called *fade* when one of the two scenes involved is a solid color; otherwise it is called *dissolve*.

Although the use of fades in video production enhances the video quality, it complicates subsequent video processing. For instance, it causes serious blockiness artifacts when the produced video is compressed using a typical motion-compensated video compression algorithm. These artifacts are due to the fact that typical motion compensation (MC) algorithms fail in fade regions and produce inaccurate motion vectors. The blockiness artifacts can be eliminated or significantly reduced by disabling MC in the fade regions and using a special compression technique for compressing fades to achieve the desired bit-rate in these regions. Therefore, it is essential to detect the fade regions before compression. Furthermore, fade detection is a crucial first step in identifying and separating the scenes in a given video sequence for the purpose of video editing and video database indexing.

Although considerable work has been reported on detecting abrupt scene changes [1-3], only a small effort has been directed toward gradual scene changes such as fade and dissolve [3,4]. In [3], the difference between the histograms of two consecutive frames was used to detect fade regions. In [4], the statistical characteristics of dissolve were used to detect dissolve regions.

In this paper, a novel fade detection algorithm that exploits the semi-parabolic behavior of the variance curve in fade regions is developed.

Section (2) summarizes the fade characteristics. In Section (3), the fade detection algorithm is detailed. In Section (4), simulation results and performance analysis of the developed fade detection algorithm are presented. Conclusions are presented in section (5).

2. FADE CHARACTERISTICS

A discrete linear fade-in sequence from the color C can be modeled using the following equation:

$$f_i(i,j,n) = \begin{cases} (1-\alpha(n))C + \\ \quad \alpha(n) f(i,j,n) & 0 \le n < M \\ f(i,j,n) & M \le n < N \end{cases} \quad (1)$$

where $\alpha(n) = \frac{n}{M}$, M is the length of the fade region, and N is the total length of the sequence. Similarly, a discrete linear fade-out sequence to the color C can be modeled using the following equation:

$$f_o(i,j,n) = \begin{cases} f(i,j,n) & n < M \\ (1-\beta(n)) f(i,j,n) + \\ \quad \beta(n) C & M \le n < N \end{cases} \quad (2)$$

where $\beta(n) = \frac{n-M}{N-M}$ and $N-M$ is the length of the fade region.

Assuming the video sequence $f(x,y,n)$ is Ergodic with mean m_f and variance σ_f^2, it can be shown that the absolute change in luminosity, $\Delta 1(n)$, between two consecutive frames in fade-in and fade-out sequences is given by equations (3) and (4), respectively.

$$\Delta 1_i(n) = \begin{cases} \left| \frac{(m_f - C)}{M} \right| & 0 < n < M \\ 0 & M \le n < N \end{cases} \quad (3)$$

$$\Delta 1_o(n) = \begin{cases} 0 & 0 < n < M \\ \left| \frac{(C - m_f)}{N - M} \right| & M \le n < N \end{cases} \quad (4)$$

It is obvious that equations (3) and (4) are positive constants in the fade region. Moreover, there is a large spike at the beginning of a fade-in region or at the end of a fade-out region due to scene changes. It can also be shown that the variances of the fade sequences of equations (1) and (2) are given below:

$$\sigma_i^2(n) = \begin{cases} \sigma_f^2 \alpha^2(n) & 0 \le n < M \\ \sigma_f^2 & M \le n < N \end{cases} \tag{5}$$

$$\sigma_o^2(n) = \begin{cases} \sigma_f^2 & n < M \\ (1-\beta(n))^2 \sigma_f^2 & M \le n < N \end{cases} \tag{6}$$

If the second order difference $d2(n) = f(n) - 2f(n-1) + f(n-2)$ is used with equations (5) and (6), then the second derivatives of the variances with respect to time can be approximated with the following equations:

$$d2_i(n) = \begin{cases} \dfrac{2\sigma_f^2}{M^2} & 1 < n < M \\ \dfrac{\sigma_f^2}{M^2}(2-M) & n = M \\ 0 & M < n < N \end{cases} \tag{7}$$

$$d2_o(n) = \begin{cases} 0 & 1 < n < M \\ \dfrac{\sigma_f^2}{(N-M)^2} \cdot \left(1 - 2(N-M)^2\right) & n = M \\ \dfrac{2\sigma_f^2}{(N-M)^2} & M < n < N \end{cases} \tag{8}$$

From the above equations, it is clear that the fade-in region ends with a negative spike of magnitude $\frac{\sigma_f^2}{M^2}(2-M)$ at location $n = M$. Also, it is clear that the fade-out region starts with a negative spike of magnitude $\frac{\sigma_f^2}{(N-M)^2}\left(1-2(N-M)^2\right)$ at location $n = M$. These spikes are essential for detecting the fade region.

3. FADE DETECTION ALGORITHM

The fade detection algorithm is depicted in Fig. (1). It starts by detecting all the negative spikes in the $d2(n)$ (equations (7) and (8)) of the video sequence. It then examines the vicinity of each negative spike to determine the existence of a fade region and its size.

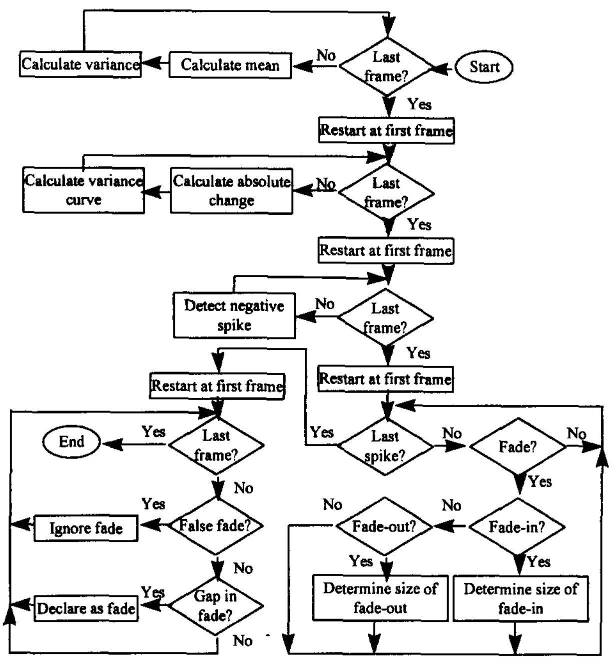

Fig. 1. Fade Detection Algorithm

A fade region is declared if $\Delta 1(n)$ (equations (3) and (4)) next to a negative spike evaluates to a positive constant. For this purpose, the right mean, m_r, and right variance, σ_r, of $\Delta 1(n)$ in an adjustable window on the right of the corresponding negative spike are evaluated. Similarly, the left mean, m_l, and left variance, σ_l, of $\Delta 1(n)$ in an adjustable window on the left of the corresponding negative spike are evaluated. The sizes of both windows are adjusted such that they include all the frames with positive $\Delta 1(n)$ greater than a predefined threshold. If $m_r > m_l$, then a fade-out is declared. If $m_l > m_r$, then a fade-in is declared. If both means are equal then the side with the smaller variance is declared as a fade region. The size of the fade is equal to the size of the window used in calculating the corresponding mean.

Since fades of small sizes are not common, any detected fade region of small size is considered a false alarm and ignored. A small non-fade region within a large fade region is considered a miss; therefore, two consecutive fade regions separated by very small gaps are bridged to form a longer fade region. Also to avoid the false alarms caused by the motion of large objects of solid color into or out of the scene, the frame is split into four quarters and the algorithm is applied to each quarter independently. In this case a fade is declared only if three or more of the frame quarters have fade characteristics in them.

4. RESULTS AND DISCUSSION

The developed fade detection algorithm was implemented in the C programming language and tested with video sequences with variety of fade sizes. Some test results are summarized in Table (1) for the Sequences *"All"* and *"King"*.

Sequence Name	Actual Fade Range	Detected Fade Range	Remarks
"All"	0-9	0-9	fade-in
	85-99	85-99	fade-out
	149-153	149-153	fade-out
	234-253	234-253	fade-out
	296-320	296-320	fade-out
	376-387	376-387	fade-out
	459-484	459-484	fade-out
"King"	0-7	0-7	fade-in
	41	-	hard cut
	66-79	66-79	fade-out
	132	-	hard cut
	160-181	160-181	fade-in
	215-232	215-232	fade-out
	249	-	hard cut
	304-311	304-311	fade-out
	360-375	360-375	fade-out

Table 1. The detected fade regions in the test sequences

Figures (2) through (10) show the results obtained for the *"All"* sequence at various stages of the developed algorithm. Figure (2) shows the average luminance of each frame. The small variations in the average luminance in the non-fade regions is due to motion in each scene and to non-ideal lighting. Variations due to motion are very clear in the fifth scene from frame 320 to frame 376.

Figure (3) is a zoom into figure (2) which shows the linear behavior of the fade region between frames 234 and 253. Figure (4) shows the variance of each frame, and figure (5) is a zoom into figure (4) which shows the semi-parabolic behavior of the variance in the fade region between frames 234 and 253. Figure (6) approximates the first order derivative of figure (2). Figure (7) is a zoom into the fade region between frames 234 and 253 which shows the spike at the end of the fade and the constant positive derivative through out the fade region. Figure (8) approximates the second order derivative of figure (3). Figure (9) is a zoom into the fade region between frames 234 and 253 which shows the double spikes at the end of the region. The change due to the vigorous motion in the fifth scene reflects itself as high amplitude noise at the corresponding frames in figures (7) and (9). The mean of this noise in $\Delta 1(n)$ is relatively small compared to that of the mean of a fade region.

Figure (10) is the final result, which indicates the positions of the detected fade frames. To help detect the fades at the beginning and at the end of the sequence two negative spikes were first assumed; one at the first frame and the other at the last frame of the sequence. Then $\Delta 1(n)$ was evaluated around each spike to determine if there is a true fade or not.

All fades in the *"King"* sequence were similarly detected. This sequence contains "hard cuts", which were not detected with the developed fade detector. Other test sequences were also used to test the developed fade detector, and results indicate a reliability rate over 95%.

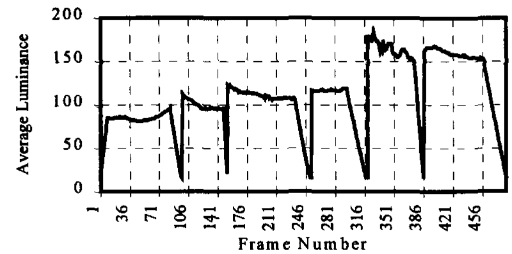

Fig. 2. The absolute luminance of the *"All"* Sequence

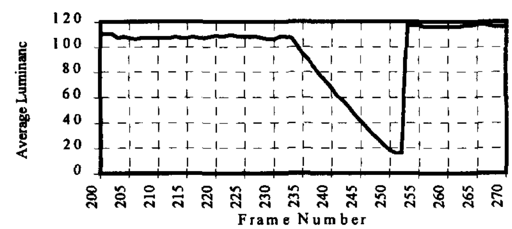

Fig. 3. Absolute luminance of frames 200-270 of *"All"*

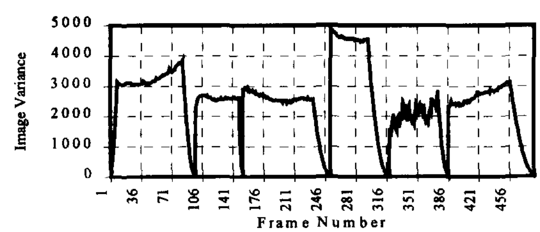

Fig. 4. The variance of the *"All"* Sequence

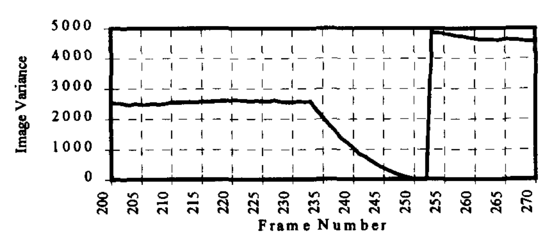

Fig. 5. The variance of frames 200-270 of *"All"*

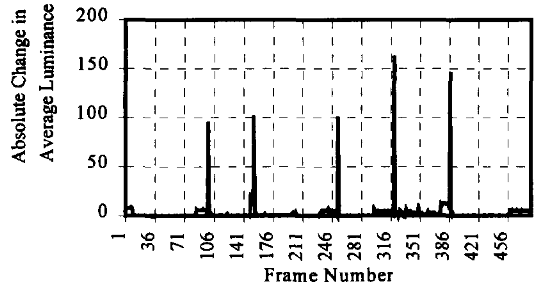

Fig. 6. Approximation of the first derivative of Fig. (2)

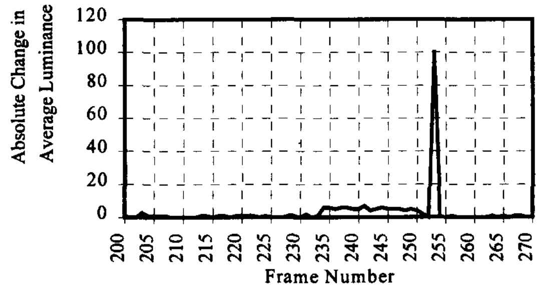

Fig. 7. Approximation of the first derivative of Fig. (3)

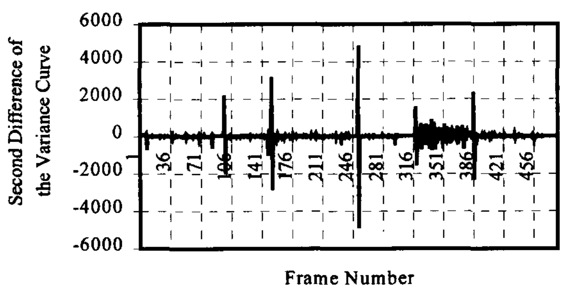

Fig. 8. Approximation of the second derivative of Fig. (4)

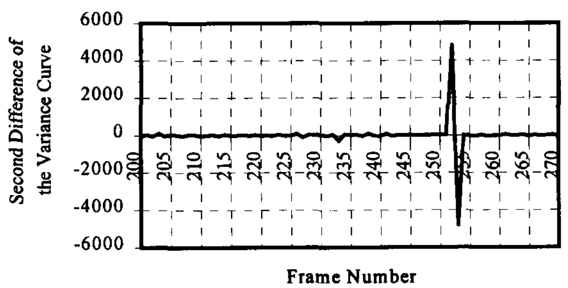

Fig. 9. Approximation of the second derivative of Fig. (5)

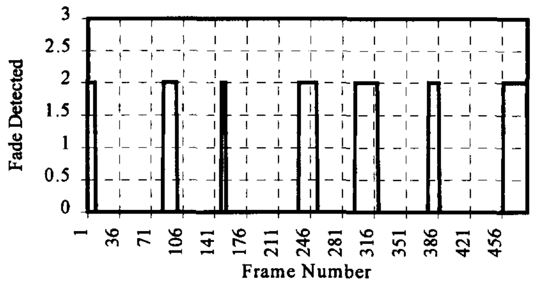

Fig. 10. Detected fade regions in the *"All"* sequence

5. CONCLUSIONS

A novel fade detector that exploits the semi-parabolic behavior of the variances of the frames in a fade region was developed and implemented. Results indicate that the developed detector has an over 95% reliability rate. Hence, this detector can be used in video editing to automatically segment the input video sequence into its scenes. Similarly, it can be used to identify the transition regions between scenes for the purpose of improving the quality of compressed video using off-line video compression algorithms such as MPEG-I & II.

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