SCRATCH DETECTION SUPPORTED BY COHERENCY ANALYSIS OF MOTION VECTOR FIELDS

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ABSTRACT

In this paper, a solution for detecting scratches in old films and videos is presented. The focus is on automation and to enable fast, cost-effective processing of mass archives enabling a later reuse and repurposing.

A common problem of line scratch detectors are the distinction of real scratches from strong vertical image features. Nearly all common solutions require a user interaction in the detection process. We propose a solution, which minimizes the false detection caused by strong vertical image features. Therefore, we utilize the fact that scratches are typically uncorrelated to the underlying image content and behavior.

The detection is done by a structural analysis of the image, taking into account precise motion information and textures to separate scratches from real image content. After coherency analysis of spatial and temporal information, the false detected scratches are rejected.

The proposed method allows a fast scratch detection and removal in an automatic environment without human interaction. Preliminary tests and results are presented and discussed.

Index Terms— Scratch Detection, Scratch Removal, Old Films, Film Artifact

1. INTRODUCTION

The work towards this solution is related to the research program THESEUS [1] initiated by the German Federal Ministry of Economy and Technology (BMWi), with the goal of developing a new Internet-based infrastructure in order to better use and utilize the knowledge available on the Internet.

The program will contribute towards preserving cultural heritage and maintaining cultural diversity through the sub-project CONTENTUS. With the help of CONTENTUS, content owners in Germany and Europe, like broadcasters and cultural institutions, will be able to prepare their cultural goods and artworks in an innovative and structured way, in order to make them electronically accessible to a wide audience.

However, even if solutions exist today for high-speed audiovisual content digitizing, usually the post-processing (restoration, quality control and analysis, indexing, metadata enrichment) is done manually and thus limiting the process efficiency.

Line scratch detection and removal is especially a time consuming process and often requires a manual post processing. Beside dirt and dust, they are the primary artifacts in old and archived films. They can be seen as thin, long and vertical lines of bright or dark intensity.

The width of the lines ranges from approximately 3 to 10 pixels at the standard definition television resolution. They are caused by the abrasion of the film material during its transport or in the developing process [2, 3]. A part of the film surface, i.e. the emulsion, is lost and the result is a visible scratch over a number of frames. The bright or dark characteristic of the scratch is related to the type of film material, i.e. whether it is a positive or a negative print.

Scratches are categorized according to their spatial and temporal properties:

- If they cover more than 90% of the height of the image they are said to be a primary scratches, the others are called secondary scratches.
- They are observed at the same spatial position for at least two consecutive frames.
- If they are observed on a single frame they can be regarded as a blotch [4, 5] and single frame defect restoration methods can then be applied.

All spatial scratch detectors use textural information in a single frame in order to detect the scratch. Textural information can be found when a scratch has lower or brighter brightness than neighboring pixels in its vicinity [6, 7, 8] or that a cross section of a scratch approximates to a damped sinusoid [3, 9, 10]. However, a natural part of an image can have the same textural information of the underlying detection model and cause false detection, which is undesired in a full automatic process. Temporal examination of the scratch gives additional information for false detected scratches. Temporal scratch detectors detect the temporal tracks and check them against plausible movement [11, 12, 13]. Generally, scratches are highly uncorrelated with the underlying background in the temporal and spatial domain. Therefore, we propose to use background movement as an additional information source to minimize false detection.

2. SCRATCH DETECTION

Line scratch detection is complicated by the fact that natural parts of the image have the same characteristics of scratches in an image sequence. The proposed system detects strong vertical image features from the original scene and observes the background movement in the image sequence. This is accomplished by the system depicted in Figure 1.

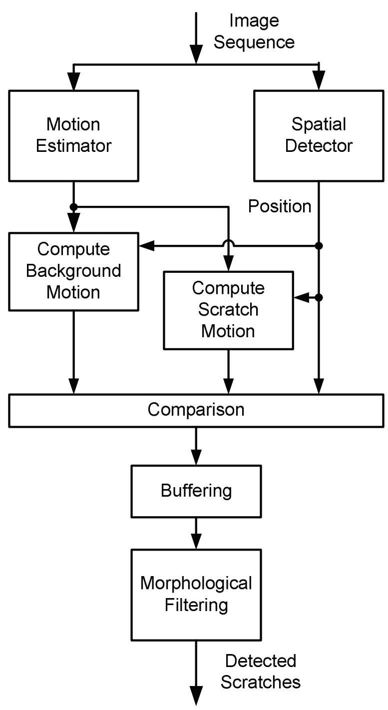

Figure 1: Proposed Scratch Detector System

The image sequence is fed to a spatial detector. The spatial detector detects strong vertical image features and forwards the position of computed scratch candidates. A motion estimator computes the motion vector fields based on the original image sequence. The movement and vicinity of the scratch candidates are computed. Scratch and background movements are uncorrelated, therefore both movements are checked against each other and the correlation result is exploited to reject wrong detected scratches. As a test sequence for our algorithm, we used the "Mount" movie available from the Prelinger Archive at www.archive.org, depicted in Figure 2. The scratch on the figure was enhanced in order to increase visibility.

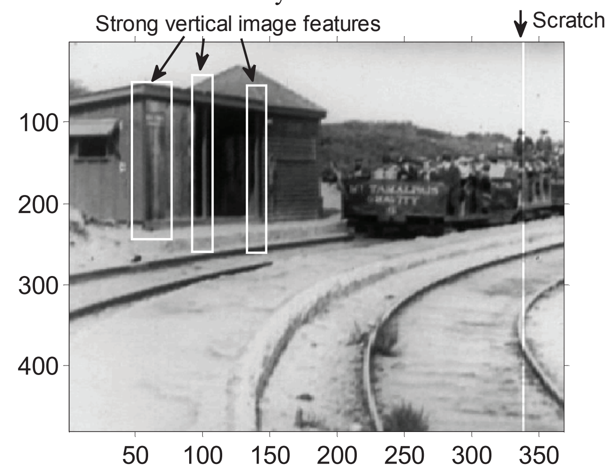

Figure 2: Frame 1767 from "Mount" movie

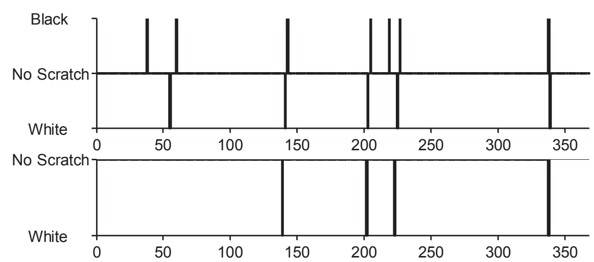

Figure 3: Spatial detected scratches using big window; (top) Proposed Detector, (bottom) Detector by [9]

2.1 SPATIAL DETECTION

First, a three scale overcomplete wavelet expansion is applied on the received image. Therefore, quadratic spline wavelets [14] are used for the filter coefficients. In [9] a scratch is approximated by a triangle with an underlying model of a damped sinusoid. The error of the surrounding scratch, as well as the visibility according to Weber's law, are estimated and considered in the decision. The only drawback of that solution is that the color has to be predefined by the operator. Therefore, the basic idea has been modified into the wavelet domain, which allows a color independent detection. Additionally, color variations nearby the scratches are considered during the width selection [10]. A 1-D signal is generated from the horizontal detailed coefficients and after a width selection the scratch is approximated by two triangles. The errors in the vicinity of the scratch are estimated and considered in the decision as well as the visibility of the scratch. In that way the thresholding is performed adaptively and the only parameter which is needed by the operator is an approximation of width of the scratches. The scratch in our test sequence (Figure 2) has a width of 3 pixels. The number of detected scratches depends on the width of the search window in the width selection. Applying a search window of about 2 to 7 pixels results in a huge number of false detected scratches caused by strong vertical image features (as shown in Figure 3).

With engagement by the operator, the scratch can be isolated by narrowing the search window. However, this is an undesirable process in a full automatic restoration scheme. The spatial detection result over time with coarse width is depicted in Figure 4. The scratches are displayed in white and black, respectively for white and black detected scratches.

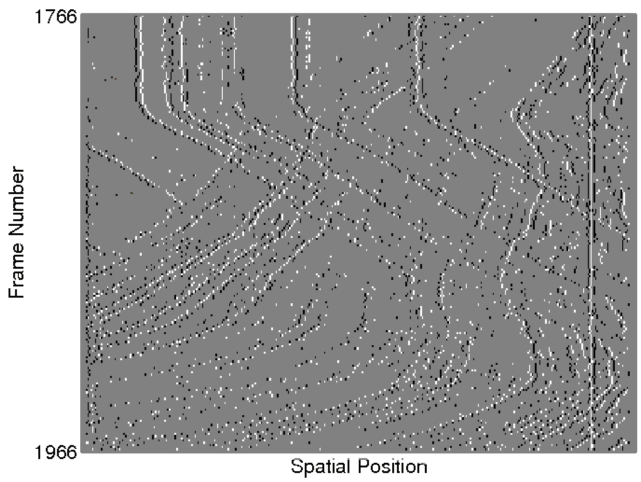

Figure 4: Spatial Detection results over the time

The number of false detected scratches, caused by strong vertical image features is high, even with detector of V.Bruni [9] as pointed out in [15].

2.1 COMBINING TEMPORAL AND SPATIAL

First, the motion vector field (ξ, ψ) is computed for the original image I_0, so $I_0(x,y) = I_1(x+\xi(x,y), y+\psi(x,y))$. For the motion estimation we used here a hierarchical block-matching algorithm of block size 8x16 pixels. But preferably the motion estimation should be optimized toward tracking vertical objects. The horizontal motion field $\xi(x,y)$ of frame 1824 of the "Mount" movie is presented in Figure 5. The dark level represents a movement to the right, while the grey level represents no movement and bright values movement to the left. In order to decide if movement belongs to a scratch, the mean value $\frac{1}{Y}\sum_{y}\xi(x,y)$ is computed as depicted in Figure 6. As one can see, the scratch at position 338 has nearly no movement compared to its vicinity. With the help of that vector field, it is possible to reject wrong detected scratches. The algorithm works in this manner:

1. For each detected scratch three averages are computed: the average value $\frac{1}{Y}\sum_{y}\xi(x,y)$ of horizontal movement for x at the scratch and in the vicinity of left and right side of the scratch.
2. If the background movement of left and right side of the scratch reaches a certain level, the temporal detector is enabled. In the presented material, the threshold was set to 0.2 pixels per frame.
3. In the next step, the scratch movement and the background movement are compared. If the scratch movement exceeds 70% of background movement, the scratch is rejected and marked as a false detected scratch.

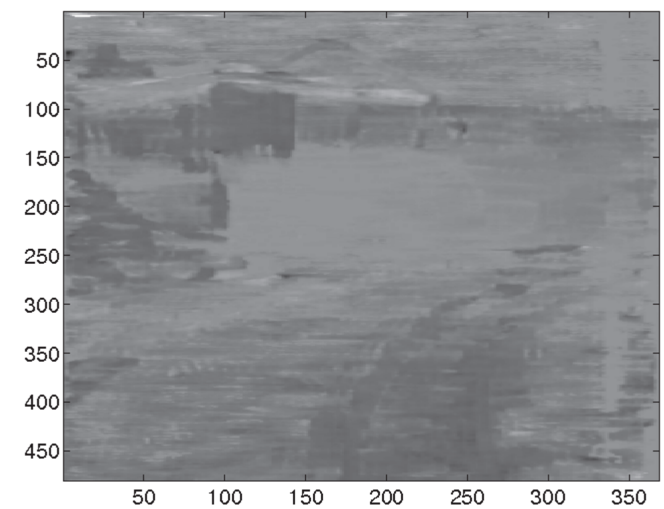

Figure 5: Horizontal Motion of Frame 1824

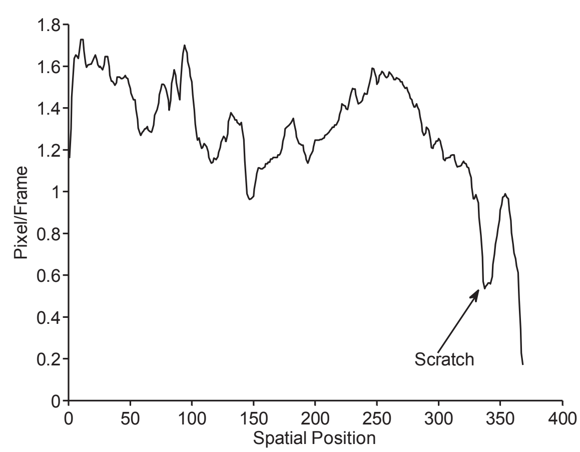

Figure 6: Column-wise mean horizontal Motion

The result after the combination of spatial and temporal detection is depicted in Figure 7. Now we use morphological filtering on the buffered spatial positions (Figure 7) to isolate the scratches.

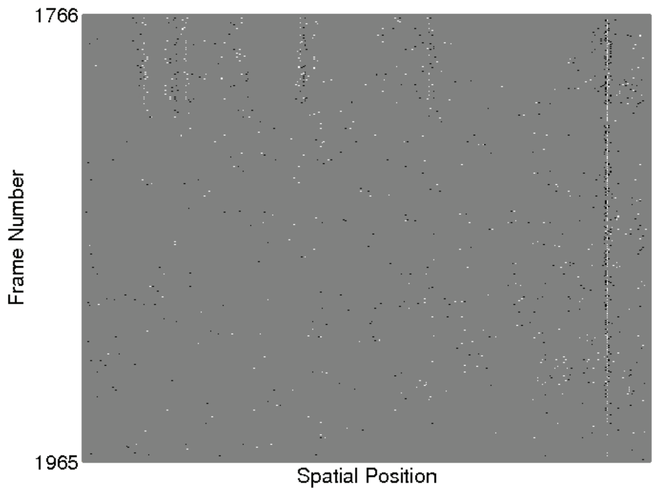

Figure 7: Detection after consideration of motion vectors

3. CONCLUSION

In this paper, a scratch detector which exploits spatial and temporal aspects has been presented. Possible scratch candidates are computed in the spatial domain, then the movement of background and scratches are compared against each other and likely false detected scratches are rejected. The operator estimates roughly the width and a maximal movement displacement of scratches and background. This ensures a high reliability and minimizes the interaction of an operator. Therefore the proposed system is especially suited for an automated restoration system.

4. ACKNOWLEDGEMENT

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