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Detection and removal of video defects using rational-based techniques

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Abstract

This paper presents a Rational and Vector Rational based interpolator methods for reconstruction of missing data in video sequences. The interpolation of missing data is important in many areas of image processing, including the restoration of degraded motion pictures, reconstruction of dropouts in digital video and automatic re-touching of old photographs. Here, a detection technique is investigated for 1ocalization of the defects, and then a spatial vector rational interpolator algorithm is proposed to, reconstruct the missing data. This algorithm exhibits desirable properties, such as, edge and details preservation and accurate chromaticity estimation. In such approach, color image pixels are considered as three-component vectors in the color space that is more appropriate for the human visual system. Therefore, the inherent correlation that exists between the different color components is not ignored. This leads to better image quality compared to that obtained by component-wise or marginal processing. The experimental results demonstrate the usefulness of the vector rational interpolator in an application involving the restoration of defects in video sequences. The resulting edges obtained using the proposed interpolator are free from blockiness and jaggedness. The complexity evaluation of the algorithm shows that the implementation of the algorithm on a dedicated IMAP-based parallel hardware architecture can lead to an execution time of 5.7 and 15.6 ms for (256×256) binary and color images, respectively.

Keywords: Video sequences; Interpolation; Vector rational interpolator; Missing data; Defect reconstruction; Hardware implementation

1. Introduction

Film and video archives nowadays go through an accelerated process of degradation. Even if films are stored in protective conditions, the degradation process is not stopped, but rather slowed down. Missing data and noise are common forms of degradation in real film and video data. Video data manifests as dropout in the digital stream in the case of digital broadcasting. While there are several chemical and physical treatments that are able to clean, or at least slow down some types of degradations, in many cases it is impossible to do so, or the costs involved get too high. In fact, since the preservation of the cultural heritage plays an important role in our society, motion picture restoration has drawn a lot of attention lately. As a result, quite a number of digital restoration algorithms using powerful computers are now available [9,12]. Some of these algorithms use spatial information to recover a damaged area, while others use temporal information from consecutive frames, or a combination of them.

In film the degradation problem is caused by abrasion of the film material and the effect is called ‘Dirt and Sparkle’. Numerous work have considered the removal of this artifact as a two stage process, first detect the missing locations [6,11] and then reconstruct the underlying image data using a spatio-temporal image sequence interpolation process. The reconstruction stage may be further specified as a motion reconstruction followed by an image reconstruction stage. The motion interpolation stage is a crucial step in generating useful interpolated data since in the regions of missing data motion estimates are completely unreliable. Indeed, most of techniques in use today for cinematographic film restoration are based on chemical and mechanical manipulations.

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In contrast to classical image sequence restoration, an automatic digital film restoration system is further complicated by severe constraints:

- The old films must be scanned at high resolutions in order to preserve the definition and the visual quality of the motion picture images.
- The restoration algorithms must also preserve the visual quality of the films.
- The processing power has to be cheap, processing time as short as possible and the restoration process should be automated, to cut exploitation costs.

This paper addresses the problem of missing data detection and reconstruction for black and white image sequences and then the forward extension to color image sequences. It introduces an alternative efficient adaptive detection algorithms and the reconstruction of missing information in an easy manner. Firstly, we are concerned by the detection of damaged regions. The algorithm is working on spatial domain, which makes it faster than that using motion estimation. Secondly, the interpolation's algorithm is based on rational and vector rational filters which were recently proposed in [7,8]. In fact, the adaptive algorithm using this vector approach yields better interpolated images than those obtained with a number of linear and nonlinear techniques [2,10]. Furthermore, the nonlinearity of the operator can reconstruct the defects, which have been detected by the pre-localization step, without introducing overshoot artifacts in the restored image frames.

The reconstruction algorithm is based on the fact that, although images are highly non-stationary signals, a strong correlation does exist between pixels belonging to the same region. For this reason, the interpolation of a defect should take into account the statistics and properties of the regions that hypothetically contain the defect. Thus, our interpolation algorithm first checks the existence of edges in order to take them into consideration; the edge orientation is estimated and the most convenient data to be used in the reconstruction of the missing pixels are selected.

In our algorithm we assume that:

- The direction of edges does not change inside the defect region.
- The contrast of edges remains unaltered inside the defect region.

This is equivalent to assuming the stationarity of features of edges inside the defect region and permits an easy but effective reconstruction. The reliability of these assumptions depends on the size of the defect; therefore, the smaller the defect is, the more accurate the interpolation is. In addition, a parallel and low cost hardware architecture based on the IMAP hardware is proposed in this paper. The complexity evaluation shows that the algorithm can be performed in 5.7 and 15.6 ms for binary and color images, respectively (i.e. under frame rate).

2. Detection of defects in black and white sequences

2.1. Classification

A classification, of motion picture defects, has been produced based on their spatio-temporal characteristics. The main interest of this classification is that each category needs to be treated using different sorts of algorithms:

- Global defects. These defects affect each frame of the sequence in a global way. For example, the brightness of the images may vary along the sequence in a periodic way. Often, these defects are not visible on one single frame; we have to view the sequence in motion in order to see them.
- Local time-correlated defects. These defects are local (i.e. they affect a relatively small part of each frame) and correlated in time (i.e. their position in one frame gives us clues about their position in the next frame). For example, white scratches running vertically across many frames belong to this category. They are produced by abrasion and their position is almost the same in each frame they appear in.
- Local non-time-correlated defects LNTC defects have been defined in the introduction as satisfying two characteristics:
  (1) They are local: they affect a relatively small part of an image, destroying the data present in this area. They have a more or less well-determined shape.
  (2) They are not correlated in time. The position in a frame does not give any information about their position in the other frames.

White dots produced by electrostatic electricity at shooting time, crackles of the varnish layer and dark blotches caused by dirt accumulation belong to this category. These defects are very common in old motion pictures. In this paper we develop an algorithm for the restoration of LNTC defects. The restoration of the other kinds of defects will not be treated here.

2.2. Detection technique

The description of the detection algorithm is as follows:

- A horizontal segment of length D_x is applied to the test image in order to detect the width of the scratch. If the detected width was greater than D_x, then the detected horizontal segment would be considered as background. Otherwise, it would be considered as the width of the scratch. Checking each pixel with pixel after it does this. If the difference between the pixel under consideration