Efficient Digital Image Restoration for Analog Video Tape Archives

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Abstract: This paper introduces a research project, which addresses problems associated with the image restoration process for digitization and archiving of analog video tapes. The goal of this work is the development of a new model of image restoration and its application to real video sequences. This research will focus primarily upon the digital imaging and restoration process chain; its main thrust will be the removal of real-world distortion effects. The research will also include a refinement of common image restoration strategies. A preliminary survey of user experience with analog tapes has given some insights into how to set up a new restoration process, and it has highlighted opportunities to define a ranking of issues to be solved within this framework. The main effects of image degradation, sources and constraints are presented within this paper.

1 Introduction

There is still a considerable amount of movies produced with analog video tapes by contemporary artists, TV production, public organizations, scientists and ordinary individuals. The discussion about whether and how to preserve, restore and store the contents digitally is still in progress. As a preliminary result one will find a common consensus, which is very important to define the next steps of developments relating to this discussion [GC99, Bes01, WC02]. The original video tape content is expected to decrease in quality over time, and to show deterioration caused by material properties of analog tapes. The most important issue is to preserve the movie content as intellectual property and to restore contents which suffer from system intrinsic and aging related image degradation. It is of less importance to preserve the tape material itself.

From initial interviews of users, the common video archiving consists of periodically performing tape copies, either analog-analog or analog-digital, without any further processing. Analog video tapes are likely to have failures, which will affect the quality of the image content. Several image defects and ongoing degradation are mentioned by users: noise, scratches, coloring and synchronization problems. Many noise suppression techniques have been investigated [SL03, PZP03, GKF02, BV04, SA96]. Scratches are removed by filtering techniques [AD00]. Color correction is widely applied in video production [HM02]. Synchronization problems introduce several visual effects, like video line jitter [She02, LCF01].

It is important to notice, that the above-mentioned filtering techniques do not take into account real hardware-related causes of video distortion. Instead they assume simple models, such as white Gaussian noise. However, additional electronic interference and correlation of noise terms will introduce image degradation at a high intensity level comparable with the content intensity; for example color speckle noise as a sum of these terms. In this context, application of common noise removal software to analog video sequences will either leave these effects untouched, or destroy video content, depending on the threshold used by a simple noise removal algorithm. The purpose of our work is to identify and discuss these real-world distortion and to develop video processing techniques to be integrated in new complete image restoration process for analog video tapes.

2   Investigation on user experience

For defining and implementing an image restoration process of analog video tapes it is important to find out, which effects of image degradation will be noticed and how these are classified by user. Another important issue is to determine technical aspects which will affect further production steps like video editing and storage, e.g. using compressed video tape or file formats. Users can be divided into two groups: producers (e.g. TV production professionals) and consumers (e.g. people watching TV). As the producers are expected to have a more detailed knowledge about technical issues, we started to collect indicative source data by questioning TV journalists.

The interviews revealed the following. Tape material is likely to have material defects and fails and it is be heavily affected by aging, even within a short period of time. Moreover, each tape copy causes quality degradation. The worst case being a complete destruction, which is caused by abrasion of magnetic tape layers. This even can be observed with new tape materials. It is very important to notice, that the issues discussed within this paper are not only related to old video tapes, but also to modern magnetic tape material. Specifically some interviewees reported the destruction of a newly delivered batch of video tapes within a short time frame.

Asked about video tape restoration, professionals suggest, that this is often performed as mechanical tape restoration. This is a result of (a) the traditional manual work with film material in the past decades, and (b) trying to apply film restoration approaches to destroyed tapes, such as cleaning tape surfaces and mechanical repair of tapes. Asked about image degradation of analog video tapes and digital image processing, people mention between two and six main types of image degradation, which should be corrected. Scratches and noise are mentioned first. Special noise appearance is not singled out, although it can easily be noticed (see section 4). Other effects, like failure of synchronization, are known, but do not seem to be given high priority. The interview data does not give a clear indication of why such effects are not given high priority, or what happens to tapes with this kind of errors. From private communication with TV production professionals, we suggest that producers easily notice such defects and therefore do not use the tapes for further production. The quality of tapes suffering from synchronization problems is considered as absolutely unacceptable. Further user survey is planned, for gaining a more insights into

the process of restoring analog video tapes; this survey will also include other user groups like artists and non-professional end-users.

3 Solving the restoration problem for analog video tapes

To improve the digital archiving process for analog video tapes the following elements shall be included in our research framework:

– Questioning: collect users experience about symptoms of image degradation
– A description of the main effects of image degradation
– Ranking of the effects to be compensated
– Development of a theoretical model of video image degradation
– Implementation of new or improved image restoration algorithms in software
– Application of the software to degraded videos and evaluation of the result by viewers

A new theoretical model of the image degradation will be developed. This model will be the basis for refining of common removal techniques for noise, additional side effects and terms, which can be detected and separated from the video image content. Based on this theoretical model we will develop and implement new removal algorithms to form a complete digitization process. The algorithms will then be applied to collected video tapes from different sources and evaluated by a different independent user group.

4 Description of image degradation

We have already identified the following effects of image degradation by inspecting analog tapes and asking users: Resistor and tape noise, color speckle noise, drop-outs, coloring, color bleeding, oversampling or undersampling of the signal, image blur, oscillations, sampling errors, additive signals from the production environment and/or the apparatus itself, image flicker, video line jitter, total loss of image synchronization. In a first approach here, we want to describe the most significant effects. Their sources and constraints shall be described.

Many noise removal techniques have been invented using different techniques. The Wavelet transform is a state-of-the-art tool for noise removal and it has been shown tp provide better results than Wiener filters and other techniques [SL03, PZP03, GKF02]. Different coring functions are used to calculate a threshold for noise removal [BV04, SA96].

Color speckle noise will be identified as a variation of the color or greyscale intensity within two-dimensional areas of pixels, and will become obvious when switching between consecutive images which do not show significant variation of content. We suggest that the effect is a sum of noise, additional periodic interference, sampling errors, and oscillations at different frequency scales. Color speckle noise introduces distortion in compressed video, like blocky artefacts.

Coloring is a technique widely applied within the video production process. Coloring

is used to manually or automatically harmonize image colors of different tapes [HM02]. Coloring includes these types of color correction: (a) white balancing, (b) artificial coloring, i.e. to create some kind of corporate identity for a movie, and (c) applying a color correction using old tapes or digitized film movies.

Moiré is well known from watching video tapes or a television broadcast under bad recieving conditions. Fourier methods are used to measure and remove Moiré from the content [SK01, SK02]. Residual Moiré at noise level cannot be determined in this way, as its Fourier spectrum is too weak compared to the contribution of the content. An analysis of the deviation of the image signal is proposed to resolve this issue.

Electronic oscillations depend on the signal variation, e.g. dark shadows near bright image structures in the direction of video scan lines. These oscillations shall be described by a physical model.

Spikes and drop-outs (scratches) require a different and destructive error removal approach. Abbas and Domanski define a simple synthetic model of spike appearance and apply it with their removal process [AD00]. As drop-outs will also introduce oscillations, a new model of oscillations is expected to obtain better results.

The effect of video image flicker is different from flicker of film movies [Pit02]. Video image flicker appears as a variation of the bias of the video scan lines. The time-scale of the variations is smaller than the frame rate. Thus, these variations will be detected within a single image.

Video synchronization failure will introduce several problems. The worst case is an image roll-through, if the hardware is unable to restore the image sync signal. Professional digitizer hardware uses time-base correctors (TBC) to stabilize the image. Their success still depends on side effects, like noise and interference. The best (usual) case is a horizontal disalignment of consecutive video lines by a few pixels or within sub-pixel range [She02, LCF01]. As it is impossible to access these portions of the analog video signal with factory built video digitizers, it is proposed to perform a detailed analysis to clarify whether there are correlations between line jitter and other terms identified within the digitized content subframe.

Color bleeding appears as a smear of some colors in video images, i.e. red or blue colors. The user survey suggests that color bleeding depends on the format of TV and video images. As the effect will also be observed as a two-dimensional smear, an analysis of this effect shall be done to separate tape and system intrinsic sources from optical sources (=video content).

5 Conclusion

The survey from professional users of video tapes confirm the need for new techniques for restoring analog tapes. The survey also highlighted the need for performing the restoration process in the digital domain. The paper has listed and described the most significant image degradation effects including new kinds of effects and constraints observed for analog

video tapes. Possible solutions have been presented in this paper. The survey outcomes will be used in the development of a theoretical model and a concept for the digital image restoration process, which then shall be implemented, applied and verified.

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