BLOTCH REMOVAL USING MULTI-LEVEL SCANNING, SHAPE ANALYSIS, AND META HEURISTIC TECHNIQUES

By

MOHAMMAD REZA KHAMMAR

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Doctor of Philosophy

July 2015
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DEDICATIONS

To

My lovely family
And my dear parents
Abstract of thesis Presented to Senate of Universiti Putra Malaysia in Fulfillment of the Requirement for the degree of Doctor of Philosophy

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By

MOHAMMAD REZA KHAMMAR

July 2015

Chairman : Assoc. Prof. Mohammad Hamiruce Marhaban, PhD
Faculty : Engineering

Valuable resources of artistic, historical, and cultural development of human life are stored in huge number of archives. These archives are suffering from a diversity of degradations and need to be restored. Blotches refer to the major degradations that mostly affect old films. In the current techniques of blotch detections, when high correct detection is required, the number of false alarms is high. Therefore, error in detection can cause some unnecessary changes in the uncorrupted pixels. On the other hand, due to restoration of blotches, fidelity may be affected and decreased because of the complex scene and large areas which are common in old archives. Thus, this research was aimed to enhance the performance of blotch detection comparing to the other available methods and to find a way to reconstruct blotches regardless of their sizes and scene complexity.

In order to remove blotches from digitized old archives, two steps are necessary: detection of the position of blotches and restoration of the missing data. Regarding the detection, a post processing method based on a combination of pixel-based and objects-based methods was proposed. This post processing algorithm was provided based on a multi-level scanning and shape analysis which was presented for the better performance of high correct detection and lower false alarms for each given threshold. After identifying the position of blotches, reconstruction of missing data was the next step.

Interpolation was organized based on just spatial information, and also spatial and temporal information. If the sizes of blotches are small, for example, less than 20 by 20 pixels, the process of reconstruction can be handled with traditional heuristic or previous model based methods, such as, Auto Regressive and Markov Random Field methods. Interpolation of the missing data for large area based on heuristic methods do not lead to a reasonable result, but the meta-heuristic techniques have the ability to remove small and large areas with better fidelity even in a scene with a complex background. Genetic algorithm and multi-layer back propagation neural network algorithm were adopted and consequently applied to a variety of benchmark samples of image sequences. These methods were proposed to find the missing data in a better way than the existing approaches.
The final results were objectively and subjectively evaluated. Sign, Car, and Calendar image sequences were corrupted artificially with blotches of random size, shapes, and intensity. For objective assessment, in the field of detection of blotches, false alarms and correct detection were calculated and comprehensive comparisons were prepared based on Receiver Operation Characteristic. In addition, Mean Square Error, Normal Correlation, Image Enhancement Factor, and Peak Signal to Noise Ratio were calculated for restoration and the results were collected for comparison. The subjective evaluation also was done by requesting some respondent to judge the results. The algorithms were applied to two real image sequences which were contaminated to unknown blotches and the results were extracted for evaluation of proposed methods.

Finally, a successful platform including blotch detection and correction was presented in this study, the proposed blotch removal approaches proves to have the potential to be applied to real blotches to restore old archives in real restoration process.
Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENYINGKIRAN KETOMPOKAN MENGGUNAKAN PENGESANAN PELBAGAI LAPISAN, ANALISIS BENTUK DAN TEKNIK META HEURISTIK

Oleh

MOHAMMAD REZA KHAMMAR

Julai 2015

Pengerusi : Prof. Madya Mohammad Hamiruce Marhaban, PhD
Fakulti : Kejuruteraan


dicadangkan untuk mencari data hilang dengan cara yang lebih baik daripada pendekatan sedia ada.

Keputusan akhir telah dinilai secara objektif dan subjektif. Jujukan imej bahasa isyarat, kereta, dan kalender telah dirosakan secara buatan dengan ketompokan yang rawak dari segi saiz, bentuk dan intensiti. Untuk penilaian objektif, dalam bidang pengesanan ketompokan, isyarat palsu dan pengesanan benar telah dikira dan perbandingan komprehensif telah disediakan berdasarkan kepada 'Receiver Operation Characteristic". Di samping itu, ralat min kuasa dua, korelasi normal, faktor peningkatan imej, nisbah puncak signal kepada hingar telah dikira untuk pemulihan dan keputusan telah diambil untuk perbandingan. Penilaian subjektif juga telah dilakukan dengan meminta beberapa responden untuk menilai keputusan. Algoritma telah digunakan dalam dua jujukan imej sebenar yang tercemar kepada ketompokan tidak diketahui dan keputusan telah diambil untuk penilaian bagi cadangan kaedah.

Akhir kata, platform yang berjaya termasuklah pengesanan dan pemulihan ketompokan telah dibentangkan dalam kajian ini. Pengesanan ketompokan yang dicadangkan terbukti mempunyai potensi untuk digunakan bagi mengesan kedudukan ketompokan sebenar dalam memulihkan arkib lama.
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I certify that a Thesis Examination Committee has met on 28 July 2015 to conduct the final examination of Mohammad Reza Khammar on his thesis entitled "Blotch Removal using Multi-Level Scanning, Shape Analysis, and Meta Heuristic Techniques" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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Performance of detectors applied on 60 frames of Car sequence

Ratio of correct detection to false alarm for each frame based on a tradeoff threshold

Blotch detection for frame number 465 a-frame 465 from “the night before charismas “b- SDI-a, c- ROD, d-Paper (4), e-Proposed method

Blotch detection for frame number 761 a-frame 761 from “the night before charismas “ b- SDI-a , c- ROD , d-Paper(4) , e-Proposed method

Illustration the results of different algorithms for six frames with even number starting from frame 20 of Car sequence. Top row: original frames second row: pattern and results for SDIa, ROD, Ref.4, MLSSA the rest of rows, respectively

Illustration of results for simple GA based implementation based on a single point of reference applied on Car image

Restoration of frame 40 of Calendar sequence. a) Original frame b) binary pattern c) corrupted frame d) restored frame

Illustration of variation of cost function in different iteration for frame number 40 of Calendar sequence

Results include training, validation and test and all for last sample of population in latest iteration for frame number 40 of Calendar sequence

Demonstration of mean square error in 55 epochs for training, testing and validation for last sample of population in latest iteration for frame number 40 of Calendar sequence

Illustration of running window for last sample of population in latest iteration for frame number 40 of Calendar sequence

Restoration of frame 30 of Sign sequence. a) Original frame b) binary pattern c) corrupted frame d) restored frame

Illustration of variation of cost function in different iteration for frame number 30 of Sign sequence

Comparison of different reconstruction neural network approaches on frames 40, 42, 44 of Calendar sequence based on PSNR and NC

Comparison of different reconstruction neural network approaches on frames 46, 48, 50 of Sign sequence based on PSNR and NC

Results for different scenarios applied to frame 50 of Sign sequence a-original frame b-artificial pattern c-corrupted frame d-output of method 1 e- output of method 2 f-output of method 3

Results for different methods applied to frame 50 of Calendar sequence a-original frame b-artificial pattern c-corrupted frame d-output of method 1 e- output of method 2 f-output of method

Demonstration of performance of different algorithms using PSNR, NC, BCR, and MSE based on spatial information which is applied to 60 frames of Car sequence

Demonstration of performance of different algorithms using PSNR, NC, BCR, and MSE based on spatial-temporal information which is applied to 60 frames of Car sequence

Demonstration of subjective results on Car sequence
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<tr>
<td>2DAR</td>
<td>Two dimensional AR model</td>
</tr>
<tr>
<td>3DAR</td>
<td>Three dimensional AR model</td>
</tr>
<tr>
<td>AR</td>
<td>Autoregressive</td>
</tr>
<tr>
<td>ADF</td>
<td>Adaptive Median Filter</td>
</tr>
<tr>
<td>AURORA</td>
<td>Arbeitsgemeinschaft der öffentlich – rechtlichen P undfunkanstalten der Bundesrepublik Deutschland</td>
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<td>ARD</td>
<td>Automated Restoration of Original film and video Archives British</td>
</tr>
<tr>
<td>BBC</td>
<td>British Broadcasting Corporation</td>
</tr>
<tr>
<td>BPNN</td>
<td>Back Propagation Neural Network</td>
</tr>
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<td>BRAVA</td>
<td>Broadcast Restoration of Archives by Video Analysis</td>
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<tr>
<td>BFGS</td>
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<td>CNN</td>
<td>Cable News Network</td>
</tr>
<tr>
<td>CCF</td>
<td>Cross-Correlation Function</td>
</tr>
<tr>
<td>DBN</td>
<td>Dynamic Bayesian Network</td>
</tr>
<tr>
<td>FFBP</td>
<td>Feed Forward Back Propagation</td>
</tr>
<tr>
<td>HMM</td>
<td>Hidden Markov Model</td>
</tr>
<tr>
<td>INA</td>
<td>Institut National de L’Audiovisuel</td>
</tr>
<tr>
<td>IERB</td>
<td>Islamic Republic of Iran Broadcasting</td>
</tr>
<tr>
<td>IEF</td>
<td>Image Enhancement Factor</td>
</tr>
<tr>
<td>MLFF</td>
<td>Multi-Layer Feed-Forward</td>
</tr>
<tr>
<td>MAE</td>
<td>Mean Absolute Error</td>
</tr>
<tr>
<td>MC</td>
<td>Markov Chain</td>
</tr>
<tr>
<td>ME</td>
<td>Motion Estimation</td>
</tr>
<tr>
<td>MMF</td>
<td>Multilevel Median Filter</td>
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<tr>
<td>MPEG</td>
<td>Motion Picture Experts Group</td>
</tr>
<tr>
<td>MLSSA</td>
<td>Multi-Level Scanning &amp; Shape Analysis</td>
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<td>MRF</td>
<td>Markov Random Field</td>
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<td>MSR</td>
<td>Mean Square Error</td>
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<td>MV</td>
<td>Motion Vector</td>
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<td>NN</td>
<td>Neural Network</td>
</tr>
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<td>NC</td>
<td>Normal Correlation</td>
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<td>GA</td>
<td>Genetic Algorithm</td>
</tr>
<tr>
<td>PDC</td>
<td>Pixel Difference Classification</td>
</tr>
<tr>
<td>PSNR</td>
<td>Peak Signal to Noise Ratio</td>
</tr>
<tr>
<td>ROC</td>
<td>Receiver Operating Characteristic</td>
</tr>
<tr>
<td>ROD</td>
<td>Rank Order Detector</td>
</tr>
<tr>
<td>SAD</td>
<td>Sum of Absolute Difference</td>
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<tr>
<td>SDI</td>
<td>Spike Detection Index</td>
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<tr>
<td>SNR</td>
<td>Signal to Noise Ratio</td>
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<td>SDI</td>
<td>Spike Detection Index</td>
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<tr>
<td>SMF</td>
<td>Standard Median Filter</td>
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</table>
CHAPTER 1

INTRODUCTION

1.1 Background and Motivation

Even with the advancement of new technologies, video enhancement and restoration systems are still important. There are several positions in which recorded image sequences will possibly suffer from severe corruptions (Harvey & Marshall, 1997). The low quality of recorded image sequences may be due to, for example, lack of or uncontrollable recording environments, such as many applications in astronomy, medical imaging, and forensic sciences. Another function of video enhancement and restoration is that of maintaining the video tapes and motion pictures which are documented over the last decades (A. Kokaram et al., 2002). These distinctive archives are fading quickly due to aging effects of physical reels of film and magnetic tapes that convey the information.

These valuable resources of artistic, historic, and cultural development of human life are stored in a huge number of archives in British Broadcasting Corporation (BBC), Cable News Network (CNN), Institut National de L’Audiovisuel (INA), and other local broadcasters which belong to different countries like Islamic Republic of Iran Broadcasting (IRIB). These archives are suffering from a variety of degradations and need preservation and restoration. Most of them are in a breakable position which decreases their worth frequently (P. M. B. van Roosmalen, 1999). Another motivation for video restoration is that digital broadcasters want to create new channels (Ghaderi & Kasaei, 2004), thus, the broadcasters need new programming. Enormous collection of old archives can be considered as a cheap alternative option comparing to the high price of producing new programs, but reusing them is possible when their quality is enhanced approximately to the new product’s level (A. C. Kokaram, 1993). Video restoration has been essential in these applications not only to promote the visual quality, but also to raise the performance of the following tasks, such as image and video investigation and understanding (Schallauer, Bailer, Morzinger, Furntratt, & Thallinger, 2007). A complete workflow of preservation, conversion, restoration, and storage to access and delivery is presented in Figure 1.1 (Addis, Choi, & Miller, 2005).

Basically, archives can include different media such as video, film, and audio (J. B. Thompson, 2013). In order to apply any digital algorithm for restoration purposes, first, all of the archived motion pictures and videos are converted from their original format which can be either film reels or magnetic tapes into digital media. Then, these new format of archives are investigated for all kind of possible degradations. After that, the best efforts are done to remove defects and enhance the quality of image sequences as much as possible. Figure 1.1 is showing the different tasks related to the old archives in terms of conversion, preservation, restoration, storage, metadata and finally delivery for a variety of applications. The main production chain is the journey from analogue to digital material, including, stock evaluation, identification and selection, digitization process and its control, restoration, storage, production of content information (metadata) allowing for access, and finally delivery to the users.
In this study which is concerned about the improvement of restoration algorithms for film and video archives, the researcher made sure that old archives are converted to digital format before. In addition, the format of these digital media was not under investigation, because the researcher assumed that all frames are considered as a chain of image sequences. Due to restoration, automated image and video restoration approaches are desirable because of the large amount of archives (Kozlov, Petukhov, & Zheludev, 2010). Moreover, it is a tedious activity to detect and then remove artifacts manually through traditional methods (Huo, Tan, He, & Hu, 2013). The term semi-automated shows the efforts of the researchers to reduce the amount of parameters which is necessary to define for the user before applying the restoration process for a given image sequences. Hence, different algorithms can be evaluated based on computational complexity and accuracy, as well as, user dependency. Therefore, this is a requirement for an automated device of image sequences restoration due to the huge volumes of archived film and video and commercial limitations. Existing commercial restoration system tools need a lot of operator intervention, and hence, do not let for automatic restoration of most common artifacts (A. C. Kokaram, 1993). As a result, the field of image sequence restoration has been an active research topic since 1970’s.
large variety of artifacts are available in film and video archives, and so, finding a single algorithm which can be able to restore these artifacts is impractical, hence, different algorithms are necessary to cover all of them. Moreover, a modular artifact detection and removal can provide the opportunity to implement a restoration system with the ability to utilize parallel computing in order to reduce the total running time in some cases (P. M. B. van Roosmalen, 1999). Figure 1.2 shows the block diagrams of an image sequence restoration system. The input of restoration system is digital image sequences instead of video tapes or physical reels of film. This obviously indicates that despite the type of original format of sources and their possible coding, they have been quantized by expert people and applied to the restoration system. Image sequences are a serial of digital frames which come one after another.

Figure1.1: General Block Diagram of a Modular Image Sequence Restoration System.

Blotches refer to the major degradations that mostly affect old archives (A. C. Kokaram, 1993). They randomly occur in the frames as dark spots inside the brighter surrounding area or bright spots inside the darker surrounding area and have arbitrary size, shape, and intensity. There are several factors causing blotches on films, such as, covering the dirt spots on the frames, damage of the gelatin on the film, and the physical interaction of the film mate rial with projecting tools (Tilie, Laborelli, & Bloch, 2006). The research have shown that it is rarely possible that two blotches
happen at the same positions in two consecutive frames; it means that the temporal discontinuity is the most important characteristic of blotches which helps to detect them (Chong, Liu, Goh, & Krishman, 1997). After detection, interpolations of the missing data is vital (A. C. Kokaram, Morris, Fitzgerald, & Rayner, 1995b). Detection and interpolation of blotches are studied in this research.

Figure 1.3 demonstrates the source of different artifacts in a chain of recording, storing, transferring, conversion and digitization for film and video (P. M. B. van Roosmalen, 1999). This information for a new data acquisition system can help us to avoid contamination of new product by these defects, but as for old archives, the final footage is already polluted with different defects. Therefore, all efforts should focus on how to detect and restore them regardless of the time they had joined the original signal.
Figure 1.2: General Block Diagram of a Modular Image Sequence Restoration System.
1.2 Problem Statement

In terms of film and video restoration, automated or at least semi-automated restoration methods are desirable because of the large amount of archives (Kozlov et al., 2010). Hence, three items are important aspects for different algorithms; performance, computational complexity, as well as, user dependency. Blotch removal system is an important module of image sequence restoration. In the existing techniques of blotch detection, when generally the high correct detection is necessary, the number of false alarms is also high (JPMB Biemond, van Roosmalen, & Lagendijk, 1999; Ghaderi & Kasaei, 2004). It means that some non-blotch positions are wrongly considered as corrupted parts of image and will be unnecessarily changed later in the restoration process (JPMB Biemond et al., 1999). For this reason, a correct detection rate bigger than 90% and the corresponding false alarms rate less than 1% is desirable for any single frame in different image sequences. In fact, increasing the ratio of correct detection to false alarms is vital action in terms of blotch detection in a blotch removal system (X. Li, Zhang, & Zhang, 2013). Normally, the performance of blotch detection is at risk because of error in motion estimation and noise which is common in old archives. However, any increase in terms of preset threshold in pixel-based methods will reduce the false alarms; consequently, the correct detection also will be reduced in this case as well. Thus, this is not considered a good solution. In addition, many available pixel-based algorithms such as SDIa, ROD need to define some parameters as initial values which show a close interaction of the user and the restoration system to do the image sequence restoration as well (Gullu, Urhan, & Erturk, 2008). In fact, a desirable approach needs a minimum user dependency.

On the other hand, after the detection of the position of blotches, it is vital to restore them (A. C. Kokaram et al., 1995b). Thus, reconstruction of the missing data is another important step after identifying the position of the blotches (Raghunathan, 2004). Interpolation can be organized based on just spatial information, or on spatial and temporal information. Interpolation of the missing data for large area especially in a complex scene is a debatable field of study (A. C. Kokaram, 2004). Reconstruction of large areas based on heuristic approaches does not lead to a reasonable result (A. C. Kokaram, 1993). A large blotch in a complex background will be kept in touch with more edges in different directions. Thus, lack of local characteristics cannot prepare a robust method to reconstruct missing data as much as possible. In fact, there is no guarantee that all blotches in a given frame cause in small sizes, consequently it is desirable to provide a situation to restore defects regardless of their sizes and scene complexity. In the process of restoration the fidelity is very important and every effort in order to handle the procedure of restoration with better quality is appreciated.

In conclusion, design the blotch detection precisely with minimum false alarms, and to restore the missing data regardless of their sizes and the complexity of the scene is desirable. Therefore, design and implement of a blotch removal system in the field of image sequence restoration with better performance in terms of detection and correction can be considered as an interesting field of research.
1.3 Hypothesis

In order to setup the procedure of blotch removal with high efficiency, the following hypotheses are considered:

1- Pixel-based method can provide the best correct detection while object-based method has the ability to reduce the false alarms. The hypothesis is that devising a method that combines both pixel-based and object-based approaches will lead to higher correct detection and fewer false alarms because of taking the advantages of both methods.

2- The intensities of every single blotch are almost the same. Moreover, their intensities are clearly different from the neighboring pixels. This characteristic of blotches that makes them distinctive and visible in the frame helps to increase the accuracy of blotch detection.

3- Every spot in the frame is part of a bigger homogeneous area that shares features with its surrounding parts. Thus, locally available features of spatial and motion compensated temporal information for a given blotch would enhance the reconstruction of the missing data, regardless of their sizes and complexity.

4- Meta heuristic approaches can efficiently handle many problems because of their abilities to learn and estimate many unknown functions. Therefore, methods based on artificial intelligence techniques would be able to restore the missing data even in a complex scene or a scene with big blotches.

1.4 Research Objectives

This thesis aims to design and implement a new effective blotch removal system having the following sub objectives.

1- To develop an algorithm based on the multi-level scanning and shape analysis in order to achieve good ratio of high correct detection to false alarms in blotch detection.

2- To apply meta-heuristic techniques to develop restoration algorithms. These new algorithms supposed to correct the known missing data refer to blotches positions. They are designed based on genetic algorithm using single and multiple references as well as artificial neural network methods using global and local information. Moreover, spatial and temporal available data are utilized in the correction process. This enables to reconstruct missing data regardless of their sizes and complexity of the scene.

3- To make comprehensive comparisons of different blotch removal systems including, detection and correction. Therefore, pixel-based and object-based techniques are investigated for blotch detection. Furthermore, heuristic and model-based methods are compared with meta-heuristic techniques based on
only spatial or spatial and temporal information. The aim is to achieve better
visual quality objectively and subjectively.

As a result, the scope of this thesis is to design and implement a new blotch removal
system with better performance based on multi-level scanning and shape analysis, and
meta-heuristic methods.

1.5 Contribution

A successful platform including blotch detection and correction was presented in this
study. The proposed blotch detection approach based on multi-level scanning and
shape analysis was performed effectively to detect the position of blotches compared to
the other available methods. This technique is considered as a semi-automatic method
for detection. Therefore, the ratio of correct detection to false alarms showed a
significant improvement. In addition, the reconstruction of the missing data based on
meta-heuristic methodologies based on Genetic algorithm and Artificial Neural
Network provided a better fidelity as well. The corrections were made in two different
domains, spatial and spatial-temporal. Consequently, the proposed blotch removal
approaches proves to have the potential to be applied to real blotches to restore real old
archives.

1.6 Thesis Outline

This thesis was built on five chapters. The first chapter presents some general ideas and
the problem statement of the work.

Chapter Two reviews the literature about the existing video restoration systems and
investigates the major defects of film and video archives. This chapter presents a
comprehensive review on blotch detection approaches and also blotch removal
methods. A brief review to motion estimation is also presented.

Chapter Three develops a methodology for detection and removal of blotches in image
sequences. In order to detect the position of blotches, a post processing approach is
presented. Due to reconstruction of the missing data in image sequences, genetic
algorithm and neural network are studied and applied to a variety of benchmark
samples of image sequences.

Chapter Four investigates the results of blotch detection and also reconstruction of the
missing data in image sequences for different benchmark samples. Proposed methods
are compared objectively and subjectively to show their robustness and efficiency.

Chapter Five concludes the main findings and results of the thesis. Moreover, it
suggests some recommendations for future works.
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