SIMULATION OF GREYSCALE IMAGE COLOURING USING BLOB DETECTION

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To my beloved father and mother

Azimi bin Ismail and Wan Fauziah binti Wan Agil

and family

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ABSTRACT

Automatic colouring of greyscale images using computer is one of the important fields in digital image processing. It helps to produce more appealing visuals to human eye when one have to deal with medical images, night vision cameras or scientific illustrations. However, to produce images that are at par with the ability of human eyes, computerised colouring process takes a lot of time and ample calculation. Recent years, blob detection has shown a good development for finding features in an image. This method not only can run on low memory devices but also provides users with faster calculation. Encouraged by these advantages – work on low memory devices and enable faster calculation, two models of untrained colouring of greyscale images are proposed in this study. The maximum number of blob features is examined using *Centre Surround Extremas* (CenSurE) and *Binary Robust Independent Elementary Features* (BRIEF). The result of this study proves that the images coloured by these models look better with increment features of the key point if the minimum matching distance is as low as possible. In addition, when comparing feature descriptors using *Fast Retina Keypoint* (FREAK) solely and FREAK together with *Speeded-Up Robust Features* (SURF), it is concluded that the result is getting better with the decrement of minimum Hessian in the image. This experiment leads to the discovery that the selection of feature descriptors will influence the result of colouring.

ABSTRAK

Proses mewarnakan gambar berskala kelabu secara automatik menggunakan komputer adalah satu daripada bidang yang penting dalam pemprosesan imej digital. Ia membantu untuk menambahbaikkan penglihatan manusia apabila seseorang perlu berhadapan dengan imej-imej perubatan, kamera penglihatan malam atau ilustrasi saintifik. Walau bagaimanapun, untuk menghasilkan imej yang selari dengan kemampuan mata manusia, proses pewarnaan ini memerlukan masa yang lama dan pengiraan yang banyak. Beberapa tahun kebelakangan ini, pengesanan tompok telah menunjukkan perkembangan yang baik dalam mencari ciri-ciri dalam imej. Kaedah ini bukan sahaja dapat dijalankan pada peranti memori yang rendah, tetapi juga memberikan pengiraan lebih cepat kepada pengguna. Terdorong oleh kelebihan-kelebihan ini – kerja pada peranti memori rendah dan membolehkan pengiraan dengan pantas, dua model pewarnaan gambar berskala kelabu tanpa latihan telah disarankan dalam kajian ini. Bilangan ciri-ciri maksimum sesebuah tompok telah dikaji menggunakan *Centre Surround Extremas* (CenSurE) dan *Binary Robust Independent Elementary Features* (BRIEF). Hasil kajian ini membuktikan gambar yang diwarnakan menggunakan model ini semakin baik dengan penambahan ciri-ciri jika jarak kesamaan minimum adalah serendah yang mungkin. Tambahan lagi, kajian terhadap perbandingan hasil penggunaan *Fast Retina Keypoint* (FREAK) dan hasil penggunaan FREAK bersama *Speeded-up Robust Features* (SURF) sebagai pengesan ciri merumuskan bahawa hasil kajian akan bertambah baik dengan pengurangan nilai minimum Hessian di dalam gambar. Eksperimen ini membawa kepada penemuan bahawa pemilihan ciri-ciri pengesan akan mempengaruhi hasil mewarnakan objek di dalam gambar.

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LIST OF SYMBOLS

$I(x,y)$	-	intensity of the image
(x,y)	-	spatial coordinates in an image
US$	-	United State Dollar
I_c	-	colour image
I_g	-	grey image
l	-	luminance value
α, β	-	chromaticity values
$l(p)$	-	luminance pixel in the source image
μ_t , μ_s	-	mean of luminance for the target and source image
σ_t , σ_s	-	standard deviations of luminance for the target and source image
E	-	similarity measure
L^2	-	Euclidian metric
np_g	-	neighbourhood in the grayscale image
np_s	-	neighbourhood in the colourised image
l_s	-	luminance of the colourised swatch
p	-	pixels in neighbourhood
2D	-	two dimension
Y	-	monochromatic luminance channel
U , V	-	the chrominance channels
f_c	-	cost function

w_{ts}	-	weighting function
a_i , b_i	-	linear coefficients
$N(.)$	-	neighbouring pixels
$v(x; y)$	-	optical flow calculated at
t	-	time
W	-	pairwise affinities matrix
D	-	diagonal matrix
A	-	symmetric matrix
σ	-	scale
L_{xx}, L_{xy}, L_{yy}	-	approximations of Gaussian
$\frac{\partial^2}{\partial x^2} g(\sigma)$	-	second order derivative
$H(.)$	-	Hessian matrix
d_x, d_y	-	first order derivative

LIST OF ABBRIVIATION

LoG	-	Laplacian of Gaussian
DoG	-	Difference of Gaussian
CenSurE	-	Centre Surround Extremas
FREAK	-	Fast Retina Keypoint
SURF	-	Speeded-Up Robust Features
RGB	-	the red, green, and blue values
MRI	-	Magnetic Resonance Imaging
SEM	-	Scanning Electron Microscopy
GMM	-	Gaussian Mixture Model
MAP	-	maximum a posteriori probability
CML	-	coupled map lattices
FAST	-	Features from Accelerated Segment Test
SIFT	-	Scale Invariant Feature Transform
BRIEF	-	Binary Robust Independent Elementary Features
ORB	-	Oriented Binary Robust Independent Elementary Features
DAISY	-	Dense Descriptor Applied to Wide-Baseline Stereo
BRISK	-	Binary Robust Invariant Scalable Keypoints

CHAPTER 1

INTRODUCTION

1.1. Introduction

Colour is a powerful medium through which man views the world. Unlike most animals, which see only shades of grey, Bleicher [1] states that humans are exposed to this marvelous additional dimensions of vision. Colour influences human perception, preference, and psychology. When applied skillfully and intentionally, colour is a valuable communication tool especially for graphic designers.

Colours have been a part of our everyday lives in such ways that we could not imagine our life without colour. Human perception on colours has long gone an outstretched evolution process since it was first used as a survival method of our ancestors. We naturally react to colour as we have evolved with a certain understanding of it, partly because the survival of our ancestors depended on it with regard to what to consume and avoid [2]. What humans perceive as colour is actually wavelengths of light reflected to a surface. Surfaces absorb all the spectral hues except for those that bounce off in the form of visible colour.

Hues, Tints, Shade and Tones are four notions that are intimately related and consequently are often confused with one another. In simple words, hues are colours. We are talking about hues when we mention black, orange, red or brown. Different hues are the results of different wavelengths of lights. On the other hand, tint is lighter colour of the originals, shade is the original colour added with black thus making it seems darker, and tone is the original colour added with grey. The purity of a colour is attributed by the term Saturation. A colour turns greyer as the saturation of it decreases. The colour will turn a definite grey once it is saturated ultimately. Luminance or lightness blends in some amount of white in an original colour. The luminosity of a colour is directly proportional to the amount of white added in it. For an instance, if the luminosity of a colour decreases the amount of white in the colour lessens.

There has been an escalation in number of research done on automated image colourisation technique to date as in [3, 4, 5, 6, 7]. One of the areas frequently explored is greyscale image colouring process. Coloured greyscale image will make an image more visually appealing. Besides greyscale image, the colourisation process can also be applied to classic films and photographs, and scientific images. Furthermore, the fusion of automated colouring technique in image manipulation package would greatly benefit the common users. They will be able to automatically colour images instead of using the traditional colour mapping technique. Integrated colourisation technique is relatively more practical compared to independent applications because it allows users to fabricate and alter an image with the provided functionalities that come with the package.

1.2. Background of the Problem

The most important function of computer vision is to address or detect required features for further display processing. Many feature detections are developed to date, for example blob detectors and edge and corner detectors. In computer vision, detection of exact objects by their shape or colour, or both is essential to maximise the chance for further successful recognition. Detection, in computer vision context, refers to an image processing operation that is relatively simple yet often seems computationally expensive.

Nowadays, the available detectors varies in terms of speed and accuracy. The typical blob detection targets the detection of regions with different intensity values from its surroundings in an image. Among the popular approaches are the Laplacian of Gaussian (LoG) and the Difference of Gaussian (DoG). Convolution of the image by a Gaussian kernel and computation of the LoG or DoG operator are required for these approaches. Despite it being an effective technique, the convolving phase of the process with kernels 5 by 5 or higher is computationally expensive. Because of that, for a long time, the research in feature detection field is only concentrated on grey-scale images.

Colourisation is the process of adding colours to monochrome images or videos. This process plays a crucial role in the human perception of optical information. The process of colouring a greyscale image or video comprises the process of assigning the single dimension of intensity or luminance to the quantities that ranges to three dimensions for example green, red and blue channels. However, the process of mapping between colour and intensity has a range of ways and yet not predefined, thus it demands minor amount of human interference or external information.

1.3. Problem Statement

Numerous studies on blob detection method have been explored, especially on object detection, yet none has covered the colouring process. This gives an insight into exploring the process of grayscale image colouring using blob detection. As the method works perfectly fine on low memory bandwidth, it is expected that this untrained colouring technique can also be used on low memory devices such as on smartphones.

Thus, this study is conducted to examine the use of blob detection as a feature for an object in colouring process. To achieve this goal, a set of feature detector and descriptor is tested. By the end of this study, we hope to read the best result between the models and the feature characteristics in order to get good colouring result.

1.4. Research Question

This study answers the questions of:

i. Is it possible to colour a greyscale image using blob detection?
ii. What is the significance of maximised number of blob feature for CenSurE when colouring a greyscale image?
iii. What is the consequence of minimising the matching distance on colouring result?
iv. What are the effects of combining FREAK and SURF descriptor?

1.5. Objective of the Study

To guide this study, four objectives are formulated:

i. To introduce a new colouring technique using blob detection (CenSurE and SURF).
ii. To investigate the significance of featured maximised number for CenSurE in colouring the greyscale image.
iii. To inspect the consequence of minimising the matching distance on colouring result.
iv. To analyse the effects of combining FREAK and SURF descriptors.

1.6. Significant of the Study

The main purpose of this study is to develop and examine the efficacy of a new colouring technique for greyscale images using blob detectioon. Blob detection has widely been used in real time object detection and low memory application because of its speed in detecting features of an object. Encaurage by this advantages, an untrained automatic colouring technique has been proposed in order to surpass the previous technique which is mostly have to undergo the training process. This technique also expected to be apply in the real time colouring process since the detection used in this technique is finely used in real time object detection.

1.7. Scope of the Study

In this research two type of detectors and three descriptors are discussed in two different sections. First, feature detection by CenSurE is analysed using BRIEF descriptor before colouring a grayscale image. Then in the next section, the combination of SURF and FREAK descriptor is compared to the solely FREAK descriptor to choose one with better result.

1.8. Thesis Organisation

Chapter 1 starts with an explanation on the significant of colour in human's everyday life. The chapter then relates colour with one of the most important element of this study which is computer vision. Relevant backgrounds of this study are provided to shed light into the study problem. To understand the problem highlighted and to make sure the study is on the right track, problem statement, research questions and research objectives are also included in the chapter. The scopes that are required throughout the study is also reviewed at the end of the chapter.

Reviews on the principle of digital image and colouring trial are highlighted in Chapter 2. Concepts on matching and user define colouring approach are also stated besides a brief introduction on feature detection and description. At the end of this chapter, the proposed method is discussed in detail.

Chapter 3 presents the main ideas of colouring the grayscale image using CenSurE detector and BRIEF descriptor. This chapter provides a complete result of maximising the number of CenSurE feature on our colouring model. The analysis on minimum distance feature between images conducted is also shared.

Chapter 4 consists of the results of combining the two feature descriptors - SURF and FREAK. The conclusion of this study together with recommendations for future studies are in Chapter 5.

iv. The Levin *et al*. [13] spreading colouring technique was adopted in this study. We encourage the future study to explore the different kinds of spreading colouring technique.

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