UNIVERSITI PUTRA MALAYSIA

IMAGE PROCESSING ON INTEL EDISON MICROCONTROLLER FOR PORK DETECTION

ZAID HADI KHUDHAIR

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By

ZAID HADI KHUDHAIR

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

August 2016

DEDICATION

This work is dedicated to:

Allah

My precious Father

My darling Mother

My beloved Sisters and Sister in-law

My dear Brother

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

IMAGE PROCESSING ON INTEL EDISON MICROCONTROLLER FOR PORK DETECTION

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August 2016

Chairman : Nasri Bin Sulaiman, PhD
Faculty : Engineering

Around 0.5% of females and 8% of males are suffer from color vision deficiency (CVD) problem. Moreover, CVD becomes more critical in case of professional laboratory operators, including halal laboratories in terms of the need of visual inspection. Halal and haram are the two terms used to indicate the allowed and not allowed food for Muslims respectively. Recently, the researchers have demonstrated that it is essential to develop inexpensive, and reliable methods to support halal food detection systems. Hence, detecting pork meat cheating in beef and chicken meatballs visually has been researched by using gold nanoparticles (GNPs) which changes the color of pork DNA samples into a clearly remarkable color. The result of GNPs research cannot be reliable due to CVD errors, thus, spectroscopy device has been used to handle this issue. However, using spectroscopy device to solve CVD has various disadvantages including high cost, and it should be used immediately after preparing the chemical solution in which it returns back to its original color after few minutes.

In this research, implementing image processing techniques based on Intel Edison platform is used to handle CVD problem and decrease the detection cost. Moreover, image enhancement techniques have been used to label the color type of GNPs research. Color balance and brightness adjustments are applied for image enhancement aim, and the color type has been identified based on its intensity value. Python programming language and its Python Imaging Library (PIL) have been employed to implement the image processing tasks. On the other hand, Intel Edison and a traditional computer have implemented the Python algorithm, and the performance of each system has been recorded. The proposed work has been evaluated and compared to the performance of the traditional computer and to the result of absorption spectroscopy device.

The result of this research has indicated that, image processing techniques, which are based on Intel Edison, are efficient alternative method to the absorption spectroscopy device, since both techniques have identified color types and solved CVD.

Moreover, the proposed method is cost effective, and it can be used anytime since it is based on digital data. Thus, the proposed work can be used for future halal system designs, due to the tiny size (60×29×8 mm), light weight (32 g), low cost, and sufficient processing speed (500MHz Dual-core) of Intel Edison, and the promising results of image processing techniques.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMPROSESAN IMEJ BERDASARKAN INTEL EDISON MIKROPENGAWAL UNTUK MENGESAN DAGING BABI

Oleh

ZAID HADI KHUDHAIR

Ogos 2016

Pengerusi : Nasri Bin Sulaiman, PhD
Fakulti : Kejuruteraan

Kira-kira 0.5% daripada wanita dan 8% lelaki telah mengalami masalah kekurangan penglihatan warna (*CVD*). Selain itu, *CVD* menjadi lebih kritikal dalam kes pengendali makmal profesional, termasuk makmal halal dari segi keperluan pemeriksaan visual. Halal dan haram adalah dua istilah yang digunakan untuk menunjukkan makanan yang dibenarkan dan tidak dibenarkan untuk orang Islam masing-masing. Baru-baru ini, penyelidik telah menunjukkan bahawa ia adalah penting untuk membangunkan kaedah yang murah dan boleh dipercayai untuk menyokong sistem pengesanan makanan halal. Oleh itu, pengesanan daging babi yang ditipu dalam daging lembu dan bebola ayam secara visual telah dikaji dengan menggunakan nanopartikel emas (*GNPs*) yang mengubah warna sampel *DNA* daging babi kepada warna yang jelas yang luar biasa. Hasil kajian *GNPs* tidak boleh dipercayai disebabkan oleh kesilapan *CVD*. Dengan itu, peranti spektroskopi telah digunakan untuk mengendalikan isu ini. Walau bagaimanapun, penggunaan peranti spektroskopi untuk menyelesaikan *CVD* mempunyai pelbagai kelemahan termasuk melibatkan kos yang tinggi dan ia perlu digunakan dengan serta-merta selepas penyediaan penyelesaian kimia di mana ia kembali semula kepada warna asal selepas beberapa minit.

Dalam kajian ini, pelaksanaan teknik pemprosesan imej berdasarkan platform Intel Edison digunakan untuk menangani masalah *CVD* dan mengurangkan kos pengesanan. Selain itu, teknik peningkatan imej telah digunakan untuk melabelkan jenis warna penyelidikan *GNPs*. Keseimbangan warna dan kecerahan pelarasan digunakan untuk tujuan peningkatan imej dan jenis warna yang telah dikenalpasti adalah berdasarkan nilai intensiti. Pengaturcaraan Python bahasa bersama dengan Library Pengimejan Phyton (*PIL*) telah digunakan untuk melaksanakan tugas-tugas pemprosesan imej. Sebaliknya, Intel Edison dan sebuah komputer tradisional telah melaksanakan algoritma Python dan prestasi setiap sistem telah direkodkan. Kerja-kerja yang dicadangkan itu telah dinilai dan dibandingkan dengan prestasi komputer tradisional dan hasil daripada penyerapan peranti spektroskopi.

Hasil kajian ini telah menunjukkan bahawa teknik pemprosesan imej yang berdasarkan

Intel Edison adalah kaedah alternatif yang berkesan untuk penyerapan peranti spektroskopi kerana kedua-dua teknik telah mengenal pasti jenis warna dan menyelesaikan CVD. Selain itu, kaedah yang dicadangkan itu adalah efektif dari segi kos dan ia boleh digunakan bila-bila masa kerana ia adalah berdasarkan kepada data digital. Oleh itu, kerja yang dicadangkan boleh digunakan untuk reka bentuk sistem halal pada masa depan kerana saiz yang kecil (60 × 29 × 8 mm), keringanan berat (32 g), kos yang rendah dan kelajuan pemprosesan Intel Edison yang mencukupi (500*MHz* dwi teras) serta keputusan teknik pemprosesan imej yang menjanjikan.

ACKNOWLEDGEMENTS

I would like to express my thanks to my supervisor Dr. Nasri Bin Sulaiman as well as my supervisory committeefor their support throughout this work.

I am deeply grateful to my brother, sisters, and sister in-law for their valuable help that they provided during my study. Also, I extend my deepest thanks and special appreciation to my close friends for their patience and support.

Finally, I would like to express my most affectionate thanks and gratitude to my **father and mother** for their unconditional love, encouragement, and great support throughout my whole life.

I certify that a Thesis Examination Committee has met on 30 August 2016 to conduct the final examination of Zaid Hadi Khudhair on his thesis entitled "Image Processing on Intel Edison Microcontroller for Pork Detection" 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 Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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I hereby confirm that:

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Declaration by Members of Supervisory Committee

This is to confirm that:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CVD	Color Vision Deficiency
USD	United States dollar
PCR	Polymerase Chain Reaction
GNPs	Gold Nanoparticles
IoT	Internet of Things
IE	Image Enhancement
DDR	Double Data Rate
PBUH	Peace be upon him
SNPs	Silver nanoparticles
QDs	Quantum dots
MNPs	Magnetic nanoparticles
LOD	Limit of detection
UV-VIS	Ultraviolet-Visible
ISCC-NBS	Inter-Society Color Council-National Bureau of Standards
PIL	Python Imaging Library
RGB	Red, Green, and Blue
YUV	luminance; Y, blue–luminance; U, and red–luminance; V
HSL	Hue, Saturation, and Luminance
HSV	Hue, Saturation, and Value
CIE XYZ	Commission internationale de l'éclairage XYZ
CMYK	Cyan, Magenta, Yellow, and Key; Black
YCbCr	Luminance; Y, Chroma; blue, and Chroma; red
PNG	Portable Network Graphics Format
JPEG	Joint Photographic Experts Group Format
TIFF	Tagged Image File Format
LZW	Lempel-Ziv-Welch
GPIO	General Purpose Input/Output
PWM	Pulse Width Modulation
UAV	Unmanned Aerial Vehicle
MAV	Micro Air Vehicle
HE	Histogram Equalization
VED	Variable Enhanced Degree
OpenCV	Open Source Computer Vision
eMMIC	Energy, Minerals And Metals Information Centre
ROI	Region Of Interest
QVGA	Quarter Video Graphics Array
DPI	Dots Per Inch
WinSCP	Windows Secure Copy
SSH	Secure Shell

CHAPTER 1

INTRODUCTION

1.1 Background

Over 200 million individuals are suffering from color vision deficiency (CVD) problem [1]. People with color vision problems suffer from this disadvantage when they perform visual related jobs. Additionally, CVD is getting more complicated with the desired people when they want to select their future career. Police officer, firefighter, car driver or trainer, air traffic controller, airline pilot, some ranks in the armed forces, some electrical/electronic engineers, or any other task required a perfect color vision, are the professions that CVD individuals cannot be involved in [2]. In addition, CVD individuals are most likely to be rejected from exercising specific occupations [3]. However, professionals in biological or chemical laboratories such as halal laboratories, should be in a perfect color vision, especially with visual detection tasks.

Halal and haram are two terms that were found in the Holy Quran and they are written in Arabic language. Moreover, halal means approved, legal, authorized, allowed, permitted, lawful, licit or legitimate, whereas haram points out the opposite meaning to halal [4]. Therefore, the huge number of Islamic religion followers, make halal food trading to become a big concern for many countries.

Many non-Muslim countries and trading centers are interested in halal food trading due to its quality attributes and contributions in reducing the risk of zoonotic diseases [5] and [6]. In addition, halal food trading has exceeded USD 661 billion in collection [7]. Countries such as Malaysia, Indonesia, Thailand, China, India, Australia, New Zealand, Brazil, Turkey, and Singapore are trying to participate in halal food as well as being a part of halal food market [8]. Hence, any country tries to play a role in the global halal market should have a significant contribution, especially in haram food detection techniques and systems.

Pork or any haram components are a serious issue for Muslims' people and governments [9] and [10]. Recent development in halal science produced a significant improvement in haram food detection. Many techniques have been used to detect pork adulteration in food formulation, such as Radiometric (BACTEC), polymerase chain reaction (PCR), Visual detection, and Micro-ID [11]. The visual detection based on gold nanoparticles (GNPs) is faster, sensitive and cheaper than PCR method [11] and [12]. GNPs work with low concentrations and produce strong signals better than BACTEC and Micro-ID methods [11]. GNPs can produce visual results as two colors; pinkish-red represents non-pork DNA containing sample while the other color is gray-purple which represents pork DNA containing sample [12]. The visual results of GNPs work have supported by spectroscopy device due to color blindness errors.

Ultraviolet spectrophotometry or ultraviolet-visible spectroscopy refers to reflectance spectroscopy or absorption spectroscopy in the ultraviolet-visible spectral range. The concept of this machine can be understood as it calculates the amount of light absorbed by the chemical solution. In other words, it gives the absorption ratio by calculating the

output light subtract from the input light [13]. Absorption spectroscopy device is undoubtedly inexpensive, available, and reliable as what has been explained by [12], on the other hand, image processing techniques can produce same results with reasonable cost.

Image processing is a creative way to support human vision as it is based on the same concept of the three filters in human eyes, which are red, green, and blue channels [14]. There are several color spaces in digital color images; one of the most common color spaces is the RGB. RGB color space comprises three main channels, namely red, green, and blue channels, which are available in each pixel with the intensity ranging from 0 to 255 [15]. Color intensity varies from one image to another. Additionally, color intensity is widely used in face recognition, hand tracking, skin color detection, object recognition, and human-computer interface [16]. The images can be further improved and enhanced by applying image enhancement (IE) techniques.

IE is to produce images with suitable visual appearance. Moreover, the enhanced images can be used in many image processing applications. IE has been employed in many fields *e.g.,* geology, forestry, education, weather forecast, remote sensing, fingerprint matching, agriculture, etc. [17]. IE techniques classified into two groups: spatial domain and frequency domain [17]. In the spatial domain the enhancement techniques are applied directly to the image pixels [18]. While, in frequency domain, the images need to be transformed from spatial domain into the frequency domain. Hence, Fourier Transform equations can be applied on frequency domain, then inverse Fourier Transform is required to transform the image back to spatial domain. IE techniques have already been utilized to solve CVD problems [19]–[21]. Although, most of image processing techniques have been implemented on traditional computers, such systems considered expensive, bulky, and required long time for boot-up [22]. Hence, for further system improvement there is a need for low cost, tiny size, and fast initial boot-up time.

Recently, embedded system developments have dedicated the need for low cost, reliable, effective, and small size embedded system boards. Most of embedded system developing companies have made their board as open source platforms, hence, the price of these components is relatively low. Regardless their low cost, they can easily be adopted and programmed for processing, recording and controlling the data and the electronic components [23]. Intel Edison, is one of the most recent low cost and open source embedded system platforms, it has been used in many applications e.g., Internet of Things (IoT), aerial imaging, and wearable devices [24]–[28]. Intel Edison main specifications are 60×29×8 mm dimensions, weight 32g, Dual Core Silvermont Atom 500MHz, DDR3 1GB RAM, 4GB internal flash storage, internal Wi-Fi, and Bluetooth, etc. Furthermore, Intel Edison operated by Yocto Linux v1.6, and it can be programmed by Arduino IDE, C++, C, Python, Node.JavaScript, and HTML5 [29]. Therefore, Intel Edison is a reliable embedded system from Intel company with sufficient performances, and together with its low price and tiny size is preferable choice for this research.

1.2 Problem statement

Around 200 million individuals are daily suffer from CVD [1] and [3]. Recently, the American Optometric Association and others, have concluded that there is no cure for CVD yet, but in some cases there are some ways to improve their color vision a little [2] and [30]–[32]. Moreover, even the gene therapy treatment for CVD cannot cure people and

it still under development [3]. Hence, CVD become more critical in case of professional laboratory operators, including halal laboratories; for example in the visual detection of pork meat they will face problems due to their CVD problem and eventually the decision they make will not be reliable [12].

The result of GNPs research that detect pork DNA [12] can be inaccurate due to CVD errors. Moreover, GNPs work [12] has utilized absorption spectroscopy device to handle CVD issue and identify the two different colors of pork and non-pork DNA samples. However, using spectroscopy device to solve CVD has various disadvantages including high price [33] and [34], and it should be used immediately after preparing the chemical solution in which it returns back to its original color after few minutes [12]. Moreover, the difference between the absorbance of the two colors is very little approximately (6%) which may change due to the time limitation [12]. Additionally, the time limitation of using spectroscopy device may not be handled by all laboratory operators. Therefore, the disadvantages of spectroscopy device may be avoided by using image processing techniques as it can be implemented on low cost embedded systems.

Reliable techniques and methods (color labeling by image processing) that allow all CVD individuals making strong decision are required for future haram food detection systems [12] and [37]. Thus, implementing image processing tasks on portable and reliable is highly necessary, despite the complexity of their operating systems as long as it could help CVD individuals to proceed in visual detection tasks without problems.

1.3 Aim and objectives

The aim of this research is to implement image processing techniques on fast, tiny, reliable, and low cost embedded system. The main objectives of this thesis are:

1) To utilize image processing techniques for solving CVD problem in detecting pork adulteration visually by providing label for each color which is readable by CVD individuals.

2) To evaluate and compare the research's result with the result of using spectroscopy device in terms of color type classification, and complexity.

3) To employ Intel Edison platform as main processing unit to implement the required image processing tasks regardless the complexity of command prompt interface of Linux Yocto operation system.

1.4 Research scope

Figure 1.1 illustrates the flow of the research scope, in which the blue boxes show the topics related to this research. The research focuses on haram food detection, in particular, pork detection. Next, is to solve CVD problem that faces the individuals in the visual detection of pork adulteration in meatballs [12]. Image processing is one of the methods to handle CVD problem, and color labeling is one of several techniques that can aid individuals to make a strong decision regarding the two color types.

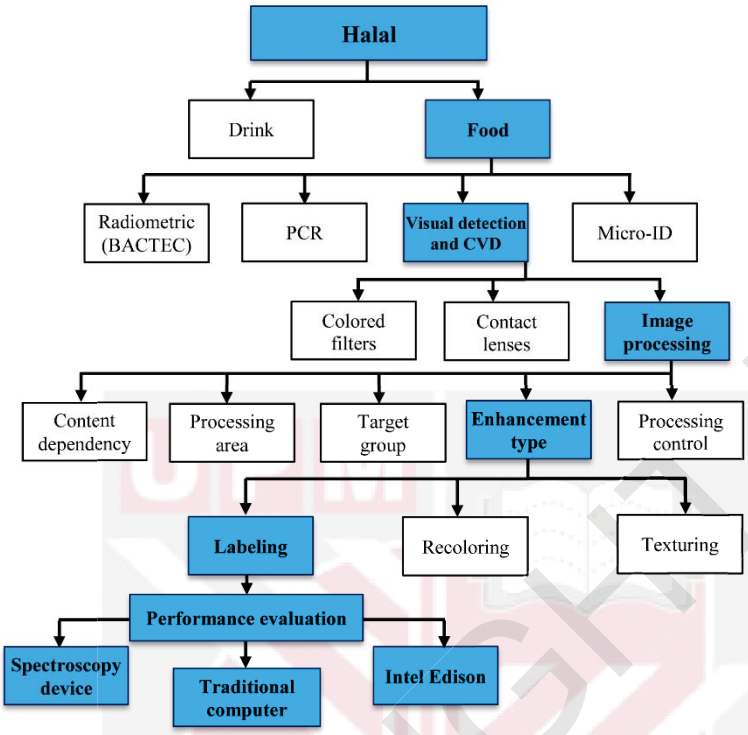

Figure 1.1: Flow chart of the research scope

The research concentrates on color labeling because it can assist all CVD individuals with different types of color vision problem. Meanwhile, the result of the proposed method have been evaluated and compared with the results of [12] which has employed a spectroscopy device to cope CVD. Furthermore, the research utilized two systems to implement the algorithm, a traditional computer and Intel Edison. However, the limitations of this research is that the images we are using [12] are not in high quality which affect the image processing, enhancement, and labeling steps. Moreover, execution time of the spectroscopy device is not available in the GNPs work [12], thus, the research will not consider the execution time as evaluation parameter.

1.5 Research contribution

The contribution of this research is implementing image processing techniques to solve CVD problem based on Intel Edison platform. The research employed Intel Edison embedded system, which is cost effective, light weight, and small size for future system design. Furthermore, despite Intel Edison low cost it still can implement image processing tasks in a sufficient performance.

1.6 Thesis organization

The thesis organized as follows:

Chapter 1 discusses the research background, problem statement, aim and objectives, research scope, research contribution, and thesis organization.

Chapter 2 which explains: a) halal concept, rules, and health issue. b) pork detection techniques, and the visual detection of pork cheating. c) CVD problem, daltonization methods to cope CVD, and color labeling technique. d) IE techniques; color balance adjustment, and brightness adjustment. e) image color spaces and file formats. f) low cost embedded system platforms; Intel Edison, Raspberry Pi, and other embedded system platforms.

Chapter 3 the research methodology phases are illustrated in this chapter as well as the research's design and implementation. Design and implementation part discusses; the image acquisition and pre-processing, Intel Edison setup and algorithm coding, IE in Python, object measurement, and classification.

Chapter 4, the results of IE of both stages are presented as well as the final image classification. Moreover, the results of image processing techniques based on Intel Edison are evaluated and compared with the specification and performance of the traditional computer. Next, the output of the proposed method has been evaluated and compared with the absorption spectroscopy device results.

Chapter 5 the research is concluded and future work recommendations are suggested.

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