DESIGN AND DEVELOPMENT OF SKIN DETECTION MODEL BASED DEEP LEARNING ON DIFFERENT SKIN TONES

MOHAMMED AHMED CHYAD AL-QAYSI

SULTAN IDRIS EDUCATION UNIVERSITY

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ABSTRACT

The aim of this study is to design and develop a systematic dataset for multiple skin tones and to analyse the reasons behind misclassifications of skin and non-skin, using different deep learning models, colour spaces, and different optimisation parameters. Related academic literature have cited three problems, namely data-related issues (e.g. skin-like), data volume (e.g. large volume requires high computer source), and technical issues (e.g. optimising parameters). Two articles on Deep Learning (DL) for skin detection failed to address the issues extensively. DL foundation is a training dataset and the quality of training depends on the quality of the data-input. To address the issues, a systematic dataset consisting of 17 million patches was created for multiple skin tones with (skin-like) images. The dataset was then converted into different colour spaces with multiple labels that characterise different scenarios, running different DL. Experimentally utilised YCbCr and CNN present high performance of binary and multi-class classifications. Binary classification of skin and skin-like resulted in 98% and multi-class classification of four classes 84% and 69% for five classes respectively. Furthermore, a binary classification between skin tone and skin-like (e.g. black skin tone and black skin-like) resulted in 97%, 81%, 60%, and 51% for black, brown, medium, and fair consequently. From empirical experiment, darker skin tone is a better classification accuracy followed by optimising parameters (Hidden-Layers, Neurons, Activations-Functions, Optimiser, Initialiser, Data-Input, and Data-Size). A hybrid CNN-RNN benchmark improves the accuracy by 99% compared with 98%, and 97% for SAE compared to 91% as reported. By studying different skin scenarios, one can analyse the reasons behind overlapping between skin and skin-tones. This is a promising study for further research by developing and applying a generalised version of skin detector with different applications.

REKA BENTUK DAN PEMBANGUNAN MODEL PENETAPAN KULIT BERDASARKAN PEMBELAJARAN DEEP BERASASKAN TON SKIN

ABSTRAK

Tujuan kajian ini adalah untuk merangka dan membina suatu set data yang sistematik untuk pelbagai tona kulit dan menganalisis sebab-sebab di sebalik kesalahan mengklasifikasi kulit dan bukan kulit dengan menggunakan model Pembelajaran Bermakna (DL) yang berbeza, ruang warna dan parameter pengoptimuman yang berbeza. Terdapat tiga masalah yang dijelaskan dalam literatur akademik, iaitu masalah yang berkaitan dengan data (cth: seakan-akan tona kulit), jumlah data (cth: jumlah data yang besar memerlukan sumber komputer yang banyak), dan masalah teknikal (cth: mengoptimumkan parameter). Dua artikel mengenai DL mengenai pengesanan kulit tidak membahas masalah yang disebutkan itu secara meluas. Asas bagi DL ialah set data latihan dan kualiti latihan berdasarkan pada kualiti input data. Pembinaan set data ini adalah terdiri daripada 17 juta tampalan untuk mengatasi masalah yang dijelaskan iaitu set data yang sistematik untuk pelbagai tona kulit dengan gambaran (seakan-akan tona kulit). Set data ditukar menjadi ruang warna yang berbeza dengan pelbagai label yang mencirikan senario yang berbeza, dan menjalankan DL yang berbeza. YCbCr dan CNN yang digunakan dalam eksperimen menunjukkan prestasi yang tinggi dalam klasifikasi kelas binari dan berbilang kelas. Klasifikasi binari kulit dan seakan-akan kulit menghasilkan 98% dan klasifikasi pelbagai kelas masing-masing menghasilkan 84% dan 69% bagi empat dan lima kelas. Tambahan pula, klasifikasi binari antara warna kulit dan seakan-akan tona kulit (cth: tona kulit hitam dan tona seakan-akan kulit hitam) menghasilkan 97%, 81%, 60% dan 51% untuk warna hitam, coklat, medium dan cerah. Eksperimen ini menujukkan bahawa warna kulit yang lebih gelap memberikan ketepatan klasifikasi yang lebih baik diikuti dengan mengoptimumkan parameter (Lapisan Tersembunyi, Neuron, Aktivasi-Fungsi, Pengoptimal, Pemula, Input Data, dan Saiz Data). Penanda aras menggunakan hibrid CNN dan RNN dapat meningkatkan ketepatan sehingga 99% dan 98%, berbanding 97% untuk SAE dan 91% seperti yang dilaporkan dalam jurnal. Implikasi bagi mengkaji senario kulit yang berbeza adalah untuk menganalisis sebab-sebab di sebalik pertindihan antara kulit dan pengecaman tona kulit. Kajian ini berpotensi dan membuka hala tuju ke arah peningkatan pembangunan pengesan kulit versi umum dan menggunakannya dengan aplikasi yang berbeza.

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LIST OF EQUATIONS

LIST OF ABBREVIATIONS

AI	Artificial Intelligence
ML	Machine Learning
DL	Deep Learning
ANNs	Artificial Neural Networks
DNNs	Deep Neural Networks
CNNs	Convolutional Neural Networks
RNNs	Recurrent Neural Networks
LSTM	Long Short Term Memory Networks
SAEs	Stacked Auto Encoders
CSV	Comma-Separated Values
ROI	Region Of Interest

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter present research is conducted in the area of skin detection. Skin detection is currently used in various applications especially that involved identification of human skin and to differentiate between skin and non-skin using computer technology and sets of techniques and datasets (Yadav & Nain, 2016). Many researches have been done to come with the best techniques especially skin detector and specific skin detection methods that can accurately identify the skin and non-skin, and at the same time reduce the computational cost, increase the processing speed and better in performance (S. Naji, Jalab, & Kareem, 2019).

Skin detection researches being done to be applied in various applications. Among the applications are human computer interaction, image filtering, computer vision, surveillance, medical diagnosis, military, anti-pornography and human tracking (Moallem, Mousavi, & Monadjemi, 2011). The computer systems designed as detector will able to select skin regions from images being input and compare with the one in the databases, depending on a variety of applications that identifies them.

As for example for medical diagnosis (Gao et al., 2013), the affected skin of the actual patient will be captured using capture device. The specialist will use the detector machine to compare the image captured with the one in the databases to provide certain kind of diagnosis result that enable the medical specialist to determine the possible illness and prescribe specific medicine for that illness (Mahmoodi & Sayedi, 2016). In most high end offices, biometric device is being used as authentication for entering restricted areas or even as attendance to the working place (Jo et al., 2017). In new smartphone, skin detection and fingerprint recognition is used as password to access the phone for valid users (Labati, Genovese, Piuri, & Scotti, 2019). In image filtering such as anti-pornography, skin detection is used to determine the websites that show illicit materials so the authority can block the websites from viewing especially for under age citizens. Parents can use this application to filter what their children can access in the internet (Perez et al., 2017).

		
Authentication	Face detection	Diagnosis skin

Figure 1.1. Type of Skin Detection Applications

The applications of skin detection can be anywhere, including the recent development in Internet of Things, Smart City, Smart Home/ Office, and anything that involved artificial intelligence such as expert system, business intelligence, machine learning and deep learning, in which widely researched and applied in some developed country.

In medical field, skin detection can be capitalized to speed up the diagnosis of illnesses so the doctors and the hospital can provide better services to the patient. In most airports, skin detection is used by the immigration to match the travellers against their passport and citizenship details. Airports also use biometric devices to allow specific staff to enter restricted areas such as entrance to the aircraft and borders.

1.2 Research Background

Various researches have been done in skin detection and among the specific area the researchers focus on are in the area of skin detection modelling and skin detection application (Omanovic, Buza, & Besic, 2014). Skin detection is a significant step for a wide range of research related to image processing and computer vision, several methods have already been proposed to come up with best accuracy of classification skin and non-skin.

Skin detection is performed as an initial step in most human-related image processing applications (Zhou, Jiang, & Lin, 2016) . The detected of the skin regions are usually processed based on the different application such as face detection, hand detection, gesture recognition, video surveillance applications, skin disease and web content filtering (e.g., pornographic filters). The performance of these applications is significantly affected by the accuracy of the skin detection step. All these application relay on the process of finding skin region or skin pixels in images or video.

Detection of human skin and skin tone itself considering as main area of many researcher attention in recent years (M. Islam, Watters, & Yearwood, 2011). Skin tone has been chosen for many skin detection applications due to its high speed processing as well as good detection performance. Recent challenges faced by researchers in skin tone detection include choice of colour space and creating skin model to detect the skin regions effectively.

1.3 Problem Statement

Skin detector is traditional classification problem which has been investigated in academic literature. It has several potential applications including, medical applications (e.g. skin cancer or other dermatology diseases) (Esteva et al., 2017), surveillance applications (e.g. face recognitions) (Hussain & Al-Bayati, 2019), contain analysis (e.g. pornography detection) (M. S. Farooq et al., 2019),and other applications. Despite the large number of articles published recently, issues related to skin detectors are yet to be addressed (MOHAMMED, Lv, & Islam, 2019) (He et al., 2019) . These problems are classified into seven category:

- **Skin Tones:** Skin tone is the surface skin colour determined by the amount of melanin in the skin. There is a wide-range of skin tones (i.e. from white to black) which significantly overlap with non-skin tones, while good skin detector ought to have the capabilities to identify skin tones under different conditions. However, this task is challenging due to several factors, includes but not limited to variation in pigment melanin, differences in illumination and differences in colour range among different ethnicity/geographic areas (A. R. Islam, Alammari, & Buckles, 2019) (Song, Wu, Xi, Park, & Cho, 2017) (Yas, Zaidan, Zaidan, Rahmatullah, & Karim, 2018). *Therefore, skin and non-skin dataset should consider this variety to guarantee the reliability and validity of the developed skin detector.*

- **Pixel and Patches:** Pixel is the smallest portion of image which consist of one or more than one byte to represent the colour level, while patch is a group pixels determined by a square matrix of two by two pixels or bigger. Despite the complex modules utilized/developed to classify skin and non-skin at the pixels level, there are the lack of studies to predict pixels as groups. It is hard to determine whether a single pixel is skin or non-skin without considering the context around this particular pixel. Several approaches introduce pixel wise threshold for different colour spaces, however, there is lack of multi-purpose skin detection method (Kolkur, Kalbande, Shimpi, Bapat, & Jatakia, 2017) (Roy, Mohanty, & Sahay, 2017) (S. Naji et al., 2019). *As a consequence, reliable patch wise skin detector is needed for different applications.*

- **Skin-Like:** Skin-Like is an object colour fall into human skin tones. The overlap between skin patches and skin like textual patches misleads the learning process which result misclassification. Wood, soil, hair, sand, complex background and graphics are among those skin like problems highlighted in the academic literature ((Hwang, Kim, & Cho, 2017b; Kim, Hwang, & Cho, 2017) (Zuo, Fan, Blasch, & Ling, 2017) (Al-Mohair, Saleh, & Suandi, 2015) (Shoyaib, Abdullah-Al-Wadud, & Chae, 2012) (Zaidan et al., 2014b). *To overcome this issue, there are several element to be considered including dataset representation (i.e. representative number from each colour tone), replace pixel-wise data with patches, increase skin-like for non-skin patches and balance the number of patches from each skin tone and its skin-like patches (i.e. skin-like for each skin tone)*

- **Computational Power and Resources:** To run or deploy deep learning approach on a large amount of data requires resources and computational power (Sahu, Yu, & Qin, 2018) (Lee, Jang, & Kim, 2016) and reliable skin detector modulation is not an exclusion. This due to the amount of training, testing and validation data. A reliable skin detector provides value to make different applications more reliable (M. A. Farooq, Azhar, & Raza, 2016). The higher reliability, the lower time complexity for obtaining output images, the lower error rate, the better skin detector (Zaidan et al., 2014a). *Therefore, high computing device consist of large memory and superior computing components such as GPU/CPU to facilitate large scale experiments is required to run different experiment scenarios*.

- **Datasets Challenges:** Despite the large number of datasets utilized/developed in the academic literature (See table 2.5 , Chapter Two), yet there is lack of information on what basis this dataset is designed, does it cover all skin tones, is it balance, does it include skin like in the none-skin portion. To the best of our knowledge, such well-described dataset is not reported in academic literature (within the scope our systematic literature review). *Therefore, development of systematic dataset can answer several questions about skin detector accuracy.*

- **Colour Space:** Colour space is the system utilizes a particular colour model to translate the colour into a number. From definition, there are several colour representation reported in the literature review. Few studies explore the differences between these colour spaces with respect to the classification accuracy. Studies such as (Zaidan et al., 2019), (Golhani, Balasundram, Vadamalai, & Pradhan, 2018), (Hamuda, Mc Ginley, Glavin, & Jones, 2017) discuss the impact of changing colour space associated with the accuracy however, no study extended this comparison to patches wise skin detector with deep learning. On the other hand, different studies suggested different colour space resulted from their comparison, in particular, *YUV* colour space (Al-Tairi, Rahmat, Saripan, & Sulaiman, 2014) , *CbCr* colour space (Ungureanu, Javidnia, Costache, & Corcoran, 2016a), *YCBCr* colour space (Lionnie & Alaydrus, 2017), *HSV* colour space (Shaik, Ganesan, Kalist, Sathish, & Jenitha, 2015b) *hybrid* colour space (Oghaz, Maarof, Zainal, Rohani, & Yaghoubyan, 2015). *It is safe to say confidently that, the best colour space benchmarking required more investigation. Colour space selection proved to have impact on the* *classification accuracy which also deserve experiment to select the best colour representation in the dataset*.

- **Machine Learning Related Challenges:** Machine learning related challenges refers to the challenges of setting up the parameters and modulating the machine through optimizing its parameters, dataset, training, testing, evaluation and validation process. This process requires time, resources, qualified datasets, and parameters optimization. Not to mention the number of available models of deep learning. According to (R. Zhao et al., 2019), training a high-accuracy model requires trying hundreds of configurations of hyper-parameters to search for the optimal configuration. Apart from the scenarios, the execution time of a single scenario required long time (in some cases, the process take weeks) due the number of parameters, and layers of the deep learning architecture (Vinayakumar et al., 2019), while the volume of data required to achieve high accuracy is relatively large (B. Dong & Wang, 2016) . *Therefore, parameter optimization and representative scenarios with multiple runs is required to reduce the training time and to identify the optimal parameters.*

Out of the reviewed articles, there are only two articles utilized deep learning to classify skin/non-skin (Zuo et al., 2017) (You Lei, Yuan, Wang, Wenhu, & Bo, 2016). These articles did not address the mentioned challenges and have not intensively explore the skin detector model using deep machine learning. This research is an attempt to study patch based skin detector under different circumstances mentioned in the research methodology and address the mentioned challenges in the problem statement.

1.4 Research Objectives

The research objectives if this research are as follows:

1. To investigate the existing skin detection approaches and highlight their weaknesses.
2. To design and develop systematic dataset for multiple skin tones and race.
3. To modulate skin detection model based on deep learning with different aspects (i.e. skin or non-skin and different skin tones).
4. To analysis misclassifications of skin and non-skin towards, identify the reasons behind those misclassifications.
5. To evaluate and benchmark the develop skin detector and skin dataset with academic literature.

1.5 Research Questions

- Q1. What are the skin detection approaches have being conducted in last 10 years?
- Q2. What is the research gap and problem in existing skin detector models?
- Q3. Is the utilized skin datasets are systematically represented the skin tones and its skin like?
- Q4. Which colour space is suitable for deep learning based skin detector technique?
- Q5 Does deep learning has consistency to develop generic and dynamic multi skin detection techniques?

- Q6. What is the reason behind the misclassifications in skin detection techniques?
- Q7. What is the differences between our works with previous studies?

1.6 The Link between Objectives and Research Questions

Research questions are framed to provide guidance to the research in table 1-1.

The table below showing the connections between objectives and research questions.

Table 1.1.
The Link between Objectives and Research Questions.

Objectives	Research Questions
To investigate the existing skin detection approaches and highlight their weaknesses.	Q1. What are the skin detection approaches have being conducted in last 10 years? Q2. What is the research gap and problem in existing skin detector models?
To design and develop systematic dataset for multiple skin tones and race.	Q3. Is the utilized systematic skin dataset clear represented of skin tones? Q4. Which colour space is suitable for deep learning based skin detector technique?
To develop skin detection model based on deep learning to classify skin or non-skin on different skin tones.	Q5 Does deep learning has consistency to develop generic and dynamic multi skin to skin detection techniques?
To analysis misclassifications of skin and non-skin towards, identify the reasons behind those misclassifications.	Q6 what is the reason behind the misclassifications in skin detection techniques?
To evaluate and benchmark the develop skin detector and skin dataset with academic literature.	Q7. What is the differences between our works with previous studies?

1.7 Organization of Research

This study composed of six chapters (see the figure 1.2 below). Structure of study, the background of research, research problem, research questions, research objective, relationship between research questions and the links between research objective with research problem, provided in chapter one. The remaining of this research are organized as follows:

Chapter Two: *Literature Review***,** This chapter introduces the systematic literature reviewed with the focus of skin detection approach. This chapter adopted the systematic review approach to investigate the academic literature with the scope of skin detection. The purpose of this systematic literature review is to identify the gaps pertaining skin detection techniques and to build appropriate taxonomy for the state of art. Furthermore, the challenges, motivation and recommendations behind the research on skin detection is also discussed.

Chapter Three: *Research Methodology*, in this chapter shows the sequence of research methodology phases, starting from the first phase preliminary study flowed by creating a systematic dataset of different human skin tones and skin-like followed by modelling phase of deep learning selections, then analysing phase, in this phase of research to come up with the reasons behind misclassification between human skin tones and skin-like, the overlapping between skin and non-skin. Lastly, the evaluation and benchmarking phase and how the phases can be connected to the objectives and research questions and explain each of these phases briefly in the next sections.

Chapter Four: *Dataset,* this chapter presents the steps of creating systematic dataset consist of skin and non-skin images. The first step downloading images of human skin and non-skin form internet provider services. Followed by human expert to classify the images into different range of tone (i.e. for both skin and skin like). Followed by region of interest cropping and applying the windowing technique to generate the patches, lastly, convert it into different colour spaces and labelling.

Chapter Five: *Experimental Results,* in this chapter different experimental scenario have been used, start from chosen the best colour space, the input of different colour space and experimental figure out the best colour space accuracy. Followed by which deep learning model is prober to classify (skin and non-skin) associated with higher accuracy. The following task is to optimize the best parameters of the classification which eventually, improving the accuracy. Upon the completion of the previous experiment, the validation process take a place to identify the best module with optimal parameters. Last but not least, examine the differences between this works the identified benchmarks.

Chapter Six: *Research Summary*, in this chapter, the objectives achievements, followed by future directions and conclusion of the research work are presented and details.

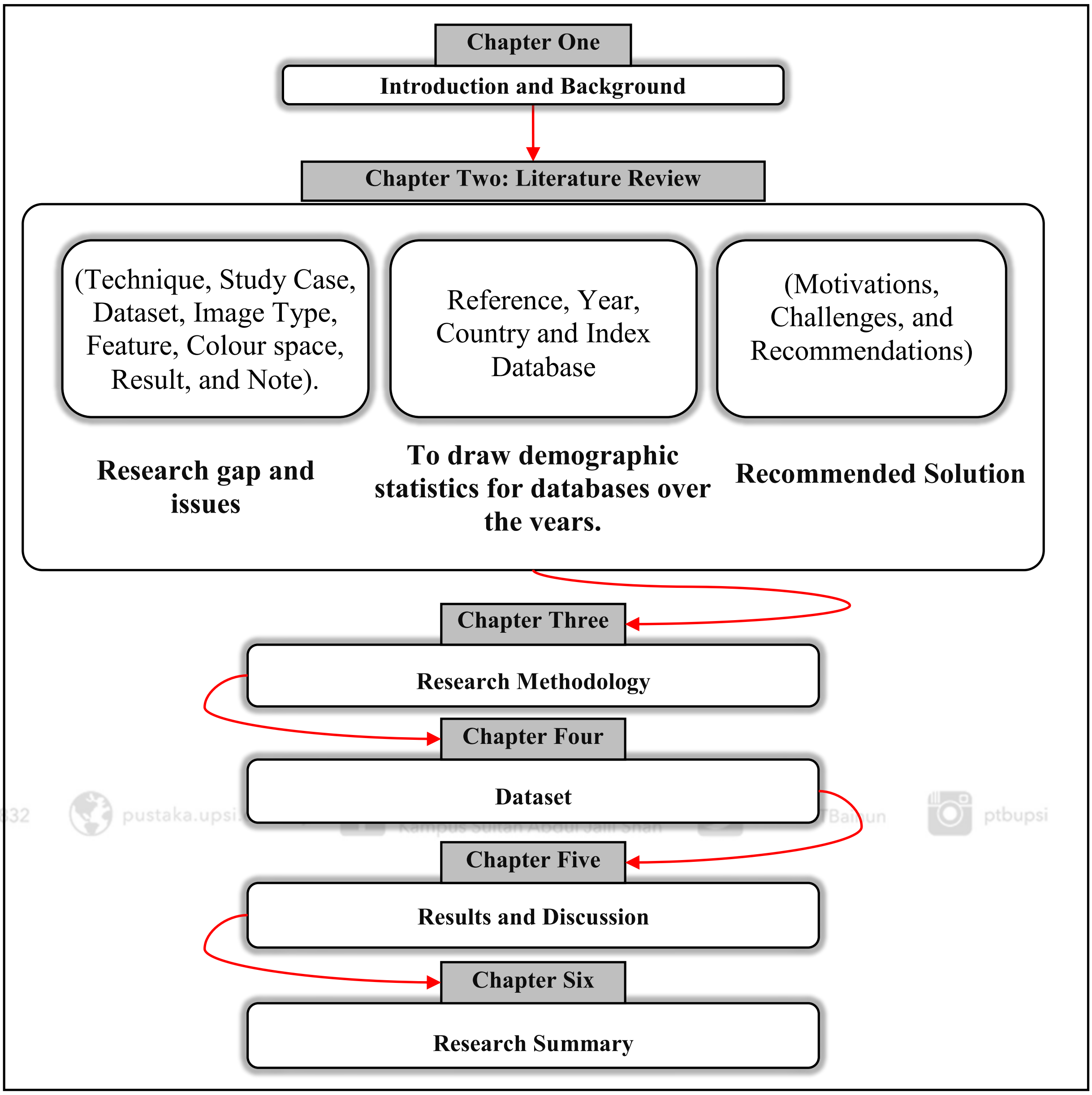

Figure 1.2. Organization of Research