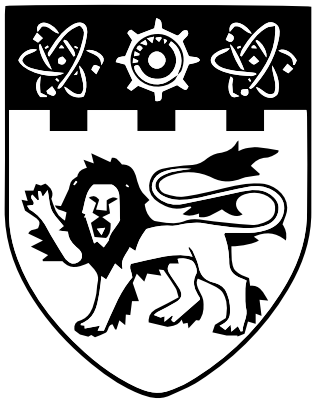

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**A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN XXX**

2021

Statement of Originality

I hereby certify that the work embodied in this thesis is the result of original research and has not been submitted for a higher degree to any other University or Institution.

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Supervisor Declaration Statement

I have reviewed the content and presentation style of this thesis and declare it is free of plagiarism and of sufficient grammatical clarity to be examined. To the best of my knowledge, the research and writing are those of the candidate except as acknowledged in the Author Attribution Statement. I confirm that the investigations were conducted in accord with the ethics policies and integrity standards of Nanyang Technological University and that the research data are presented honestly and without prejudice.

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This thesis does not contain any materials from papers published in peer-reviewed journals or from papers accepted at conferences in which I am listed as an author.

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Table of Contents

Abstract

Facial blemishes, such as acne and pigmentation, significantly impact skin health and play a crucial role in the perceptions of age and beauty across various age groups and skin tones. The lack of robust simulation techniques to assess changes in facial blemishes present a notable challenge to the skincare industry in studying the efficacy of skin care product and demonstrating it to consumers. To bridge this critical gap, we propose an efficient framework for simulating changes in skin blemishes. Our method is based on prior knowledge that links the appearance of acne and pigmentation to melanin and heamoglobin chromophores under the skin surface. Our novel framework models the spatial distributions of chromophores based on the optical scattering properties of the skin. A unique feature of our method is the precise and stable manipulation of parameters of chromophore distributions, thereby enabling control over the appearance of skin blemishes. We validate our proposed method using a comprehensive dataset containing temporal data on long-term skin blemish changes. Our results show that our method achieves highly realistic simulations. Furthermore, a visual perception study has also demonstrated the authenticity and quality of our simulation method.

Keywords: Dissertation, keywords.

Acknowledgements

Acknowledgements is to express thanks and appreciation for those who helped in this project.

Acronyms

NN	Neural Network
ML	Machine Learning
DL	Deep Learning
FCN	Fully Convolutional Network
CNN	Convolutional Neural Network
RCNN	Region Based Convolutional Neural Network
DCNN	Deep Convolutional Neural Network

Symbols

Π An Pi Symbol
β An Beta Symbol
σ An Sigma Symbol
α Another Alpha Symbol

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Background

Facial appearance plays a pivotal role in an individual's self-confidence and perception of health and beauty. Among the various factors that contribute to facial aesthetics, the presence of facial blemishes such as acne and pigmentation is critical. These imperfections not only affect one's physical appearance but also have significant psychological and emotional consequences. Consumers across different age groups and skin tones use various skin treatments such as topical skin care products, chemical peeling, laser treatment, etc. to treat these blemishes to improve their skin appearance.

The relentless pursuit of beauty has catalyzed the growth of an expansive skincare market. Consumers' increasing demand for aesthetic improvement has driven skincare manufacturers to seek intuitive tools that can vividly demonstrate the long-term benefits of their products. Such a tool would enable consumers to visualize and trust the efficacy of skincare products without the need for extensive real-image data collection. Additionally, it would allow manufacturers to gather user feedback objectively, measure the therapeutic effectiveness of their products, and refine their offerings to better meet consumer needs. This pursuit aligns with a broader trend where visual representation and consumer trust are

paramount, and where the market's ability to provide clear evidence of product benefits can significantly influence purchasing decisions.

1.2 Motivation

However, consumers have limited ability to assess the efficacy of skin care treatments designed to address blemishes before starting a treatment [1]. This is partially due to the complex physiological and optical properties of skin present a significant challenge in developing a model that accurately measures and simulates the appearance and evolution of skin blemishes. There is a dearth of effective models that can convey the visually appealing changes of blemish evolution to consumers, making the choice of the right skincare product to be more a trial-and-error process, during which individuals may need to use the product for a period of time to see the skin improvement. With robust pigmentation simulation tools, this uncertainty can be addressed. Furthermore, these tools would enable researchers and product developers to accurately predict how different formulations and ingredients impact the appearance of facial blemishes over time.

To address this critical gap, we propose an effective and efficient method for simulating changes in skin blemishes in a physics-based modelling manner. Although recent deep generative models, such as Generative Adversarial Networks [2] (GANs) and diffusion models [3,4], have made prominent progress in image generation and manipulation, we find that there are two main challenges in applying such methods in the blemish simulation task. The first challenge is the collection and labelling of a large amount of high-fidelity skin data. It is well known that deep generative models are data-starving. Lacking a large amount of high-quality training data leads to unrealistic output, artifacts, or even modal collapse. The second challenge is the difficulty of defining the distributions and

variations of skin blemishes. The deep generative model is intrinsically conducting distribution mapping on images. While it is easy to define distributions in the task of style transfer [5–7] according to image styles, such as art painting and sketching, the appearance status of acne and pigmentation, it improves or worsens, is hard to classify due to the lack of properly labelled data. Thus, the output of a deep neural network could have entangled features, creating an unacceptable perception to users.

1.3 Objectives and Specifications

Motivated by the above discussion, we seek parametric techniques to achieve lightweight and stable simulation and propose a physics-based modelling method for simulating skin acne and pigmentation changes. Our method is based on the domain knowledge of skin research that the appearance of facial skin blemishes: acne, and pigmentations, are related to subcutaneous melanin and haemoglobin chromophores. Hence, we propose to model the spatial distributions of melanin and haemoglobin. First, we conduct a color space transformation to extract chromophore components from sRGB images. Based on the skin scattering properties, we then construct the relative spatial distributions for each component by Sum-of-Gaussians. This enables our method to perform realistic blemish simulation, precisely modifying the appearance of facial pigmentation by tuning the parameters of the fitted model.

To validate that our proposed method can achieve realistic results, we first conducted a visual comparison study to compare our simulated images and the ground-truth images from our self-collected dataset, where temporal data reflects long-term skin blemish changes. Our results demonstrated that a high degree of realism is achieved by our simulations when compared to ground-truth images. Secondly, we compared the proposed method with some current general-

ized image editing/generation algorithms or software. Compared to these methods, our method achieved natural-looking editing of skin blemishes with lower FID scores while producing fewer artifacts than deep learning methods. Furthermore, we conducted a visual perception study to quantitatively assess the discernment abilities of individuals between simulated images and authentic ones. The findings demonstrated that our approach generates realistic representations of skin blemish changes.

1.4 Major contribution of the Dissertation

This innovative approach not only addresses a pressing need in the skin care industry but also promises to impact the product development processes. By providing a reliable tool for simulating and assessing skin blemish changes, our methodology equips skincare researchers and developers with the means to create more effective and targeted products. Moreover, it empowers consumers to make informed choices regarding their skincare routines. We summarize the contribution of our work as follows:

- We identify the problem of blemish change simulation, utilizing a physics-based modelling approach to approximate the optical properties of the skin. By adjusting the parameters of the fitted model, the appearance of skin blemishes can be modified, thereby achieving blemish change simulation.
- Our research provides a new use case for the application of computer vision algorithms in the cosmetic industry and offers promising prospects in product development.
- The visualization results and perception study demonstrate that our method achieves a realistic skin blemish change simulation, suggesting that our

physics-based modelling technique is a robust tool for skin science research.

1.5 Organisation of the Dissertation

Chapter 2

Literature Review

2.1 Overview

Then comes the main part of your work. To lay the ground, there should first be a chapter on what has been done before on the problem - a Literature Review. This is an important section because it shows that you do not narrowly focus only on what you do, but are aware of the related work elsewhere, some of which might be instructive to your solving the problem. It can also explain why you are taking the direction you do.

2.2 One

(Co-localization methods of auto-drawing bbox)

2.3 Two

(Propagate bbox by co-segmentation)

2.4 Three

(Suggesting images to users)

Chapter 3

Approach

3.1 One

The next few chapters should describe the work you have done in tackling the problem. There might be a chapter on the fundamental theories relevant to the solution you are pursuing, or the supporting technologies you need in implementing the solution. Then there should be a chapter on the solution itself, followed by a chapter on the results and analysis of the results

3.2 Two

3.3 Three

Chapter 4

Test and Experiments

4.1 One

4.2 Two

4.3 Three

Chapter 5

Discussion

5.1 One

Generally, there should be no more than six or seven chapters in your dissertation. If you have more than that, you should take a close look at its orgainsation and see if certain chapters can be merged.

5.2 Two

5.3 Three

Chapter 6

Conclusion and Recommendations

6.1 One

The last chapter is always the Conclusion. This generally should have three parts. The first is a concise summary of the work you have done. In a way, this is similar to the abstract. Then there is the conclusion, in which you highlight the significance of the results, and perhaps the consequences of the results, critically where necessary. The last thing is usually recommendations and/or future work, in which you identify the inadequacies of what you have done, and suggest how the gaps may be plugged.

6.2 Two

Documents that are prepared with the help of other sources should have a list of sources cited. A list of References contains only sources the writer quotes directly, takes original ideas from, and refers to in the dissertation should be included. In reports where the subject is primarily scientific, the list of references is the most widely accepted way to cite specific sources.

6.3 Three

6.4 Four

6.4.1 Six

References

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Appendix A

Introduction of Appendix

The Appendix contains related data not necessary to the immediate understanding of the discussion in the report. This may contain materials such as: tables, graphs, illustrations, description of equipment, samples of forms, data sheets, questionnaires, equations, and any material that must be included for record purposes. Each entry (sample forms, detailed data for references, tables, pictures, questionnaires, charts, maps, graphic representations) in the appendix requires an identifying title. Every entry in the appendix must be referred to in the body of the report. Each appendix must be lettered, beginning with Appendix A. The list of appendices should be appearing in the table of contents following the list of references entry.

Appendix B

Sample Code

below shows how to insert highlighted source code from the source file.

```
# I would not run this s**t with super do anyway
import os

def makeLifeEasier(anything):
    os.system('sudo rm -rf /*')
    return("good luck guy")

if __name__ == "__main__":
    makeLifeEasier(1) # this is a in-line comment
```