IMPROVEMENT OF FACIAL BIOMETRIC SECURITY REQUIREMENTS APPROACH USING PARTITIONAL-BASED DIGITAL IMAGE CLUSTERING TECHNIQUE

MUHAMMAD NAIM BIN ABDULLAH

DOCTOR OF PHILOSOPHY
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ABSTRACT

Content Based Image Retrieval (CBIR) is a process to retrieve a stored image from a database by supplying an image as a query instead of text. It is used for, but not limited to applications such as facial recognition systems, medical diagnosis, architectural and engineering and information systems. Due to the benefits of CBIR engines, it is important to improve the efficiency of feature extraction techniques. Literally, biometrics security is concerned with identifying humans based on their unique physical and behavioural traits. In this research, CBIR approach has been used for Facial Biometric Security Image Processing (FBSIP). It extracts the biometric images to obtain three-octet 8-bits Red-Green-Blue (RGB) value where it used as medium to identify and recognise an image identity of user for criminal (wanted/suspect) profiling. The facial biometric image pixel value must be matched with the record stored in database or otherwise, the image identity is failed to identify. As per preliminary identified, the FBSIP requirements and specification is totally different from normal CBIR. Even though there are variation of Digital Image Clustering (DIC) technique developed, the DIC technique that focused on this research is only pixel based DIC technique. The DIC algorithm applied in experiment and analysis stage was determined from theoretical analysis stage. It is very certain that, analysis and discussion in that stage is adequate as a reason to nominate those DIC algorithms. On top of that, every DIC algorithm was designed and develop only for specific output. Hence, each DIC algorithm perform clustering employ own clustering computation technique. Other than that, some of DIC algorithm equipped with few parameters that would affect the result. The main objectives of this research are to study the existing CBIR techniques and algorithms in terms of their performance, to investigate the crucial FBSIP requirements for DIC algorithm

patching, to nominate the compatibility a DIC algorithm with FBSIP requirements, and to validate the effectiveness of the proposed models during image retrieval for facial biometric security using RGB histogram for colour features extraction. During the experimental works, all DIC algorithms were tested with a certain number of biometric images (face). That experimental testing focused on image accuracy based on similarity index, accuracy rate percentage, and number of matched clusters. This novel model will be implemented in image similarity matching for update the criminal (wanted/suspect) profiling. In terms of the Object Segmentation Process, all objects are segmented based on distance from the cluster centre. From the theoretical analysis stage, the DIC algorithm used in the experiment and analysis stage was determined. It is certain that the study and discussion at that stage is sufficient to justify the nomination of those DIC algorithms. All DIC algorithms (K-Means, ISODATA, and K-Harmonic Means (KHM)) were tested with a dataset which is certain number of biometric images (human face) during the experimental process. The accuracy of a picture was tested using the Similarity Index (SI), accuracy rate percentage, and number of matched clusters. For the Facial Biometric Security Image Processing performance analysis, the Euclidean Distance or also refer SI has been compared. Based on that comparison, KHM produced higher query accuracy rate compared to the others which is 86.0%, ISODATA 80.5%, and the lowest rate is K-Means which is 79.5%. KHM not just better accuracy rate, it clocked fastest query process time, which is only 5 seconds, followed by K-Means, 7 seconds, and the slowest is ISODATA, 8 seconds. From the comparison result, it can be related that, objects that distributed into more matched clusters produced a better accuracy rate than fewer cluster distributions. For overall conclusion, it was found that the cluster distribution (number of *k*) is affecting the query time taken where objects distributed into more clusters is faster to perform query on it and also produced more accurate query result as the number of centroids is increase and place closer to objects. On top of that, the time ratio which is average time taken for each *k* is more efficient on more *k* set for DIC algorithm.

ABSTRAK

Pengambilan Imej Berasaskan Kandungan atau *Content Based Image Retrieval (CBIR)* ialah satu proses untuk mendapatkan semula imej yang disimpan daripada pangkalan data. Ia digunakan untuk beberapa aplikasi seperti sistem pengecaman muka, diagnosis perubatan, seni bina kejuruteraan, dan sistem maklumat. Disebabkan kelebihan enjin *CBIR*, adalah penting untuk meningkatkan kecekapan ciri teknik pengekstrakan. Secara lazimnya, keselamatan biometrik adalah berkenaan dengan mengenal pasti ciri manusia berdasarkan ciri fizikal dan tingkah laku mereka yang unik. Untuk kajian ini, pendekatan teknik *CBIR* digunakan untuk Pemprosesan Imej Keselamatan Biometrik Wajah atau *Facial Biometric Security Image Processing* (FBSIP). Ianya mengekstrak imej biometrik untuk mendapatkan tiga oktet 8-bit nilai Merah-Hijau-Biru (*RGB)* di mana ia digunakan sebagai medium untuk mengenal pasti dan mengenali identiti imej pengguna untuk pemprofilan jenayah atau suspek. Nilai piksel atau *Pixel Value* imej biometrik mesti dipadankan dengan rekod yang disimpan dalam pangkalan data atau sebaliknya, identiti imej gagal dikenal pasti. Seperti yang dikenal pasti pada awal kajian, keperluan dan spesifikasi FBSIP adalah berbeza daripada CBIR biasa. Walaupun terdapat pelbagai variasi teknik *Digital Image Clustering (DIC)* yang dibangunkan, teknik DIC yang ditumpuskan dalam kajian ini hanyalah teknik DIC berasaskan piksel sahaja. Algoritma DIC yang digunakan dalam peringkat eksperimen dan analisa ditentukan dari peringkat analisa teori. Adalah sangat pasti bahawa, analisis dan perbincangan dalam peringkat tersebut adalah memadai sebagai justifikasi untuk nenamakan algoritma DIC tersebut. Selain itu, setiap algoritma Pengelompokan Imej Digital atau DIC direka dan dibangunkan hanya untuk output tertentu. Oleh itu, setiap algoritma DIC melakukan pengelompokan menggunakan teknik pengiraan pengelompokan sendiri. Beberapa

algoritma DIC dilengkapi dengan beberapa parameter yang akan menjejaskan keputusan. Objektif utama penyelidikan ini adalah untuk mengkaji teknik dan algoritma CBIR sedia ada dari segi prestasinya, untuk mengkaji keperluan FBSIP yang penting untuk penggunaan algoritma DIC, untuk mencalonkan algoritma DIC yang sesuai dengan keperluan FBSIP, dan untuk mengesahkan keberkesanan model yang dicadangkan semasa pengambilan imej untuk keselamatan biometrik muka menggunakan histogram RGB untuk pengekstrakan ciri warna. Semasa peringkat eksperimen, semua algoritma DIC telah diuji dengan sejumlah imej biometrik (muka). Eksperimen tersebut akan menumpukan pada ketepatan imej berdasarkan indeks persamaan, peratusan kadar ketepatan dan bilangan gugusan kumpulan yang dipadankan. Pendekatan baru ini akan dilaksanakan dalam padanan kesamaan imej untuk mengemas kini profil penjenayah atau suspek. Dari segi Proses Pembahagian Objek *(Object Segmentation Process)*, semua objek dibahagikan berdasarkan jarak dari pusat kluster. Daripada peringkat analisis teori, algoritma DIC yang digunakan dalam peringkat eksperimen dan analisis telah ditentukan. Sudah pasti kajian dan perbincangan pada peringkat itu adalah mencukupi untuk mewajarkan pemilihan algoritma DIC tersebut. Semua algoritma DIC iaitu K-Means, ISODATA, dan K-Harmonic Means (KHM) telah diuji dengan set data yang merupakan bilangan imej biometrik (wajah manusia) tertentu semasa proses eksperimen. Ketepatan gambar telah diuji menggunakan Indeks Persamaan (SI), peratusan kadar ketepatan dan bilangan kelompok yang dipadankan. Untuk analisis prestasi FBSIP, Jarak Euclidean atau juga merujuk sebagai SI akan dibandingkan. Berdasarkan perbandingan tersebut, KHM menghasilkan kadar ketepatan persamaan yang lebih tinggi berbanding yang lain iaitu 86.0%, ISODATA 80.5%, dan kadar terendah ialah K-Means iaitu 79.5%. KHM bukan sahaja mencatatkan kadar ketepatan yang lebih baik, ia mencatat masa proses pencarian persamaan terpantas, iaitu hanya 5 saat, diikuti oleh K-Means, 7 saat, dan yang paling perlahan ialah ISODATA, 8 saat. Daripada hasil perbezaan yang dicatatkan, boleh dikaitkan bahawa objek yang diedarkan ke dalam kelompok yang lebih dipadankan menghasilkan kadar ketepatan yang lebih baik daripada pengedaran kelompok yang lebih sedikit. Untuk kesimpulan keseluruhan, didapati taburan kluster (bilangan *k*) mempengaruhi masa pencarian persamaan yang diambil di mana objek yang diagihkan kepada lebih banyak kluster lebih cepat untuk melakukan pencarian persamaan ke atasnya dan juga menghasilkan keputusan yang lebih tepat kerana bilangan centroid meningkat dan terletak lebih dekat dengan objek. Selain itu, nisbah masa yang merupakan purata masa yang diambil untuk setiap *k* adalah lebih baik pada set *k* yang lebih banyak untuk algoritma DIC.

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APPROVAL

The Examination Committee has met on **25 April 2022** to conduct the final examination of **MUHAMMAD NAIM BIN ABDULLAH** on his degree thesis entitled "**Improvement of Facial Biometric Security Requirements Approach using Partitional-Based Digital Image Clustering Technique**".

The committee recommends that the student be awarded the Doctor of Philosophy (Computer Science).

Members of the Examination Committee were as follows.

Prof. Ts. Dr. Omar bin Zakaria

Fakulti Sains dan Teknologi Pertahanan

Universiti Pertahanan Nasional Malaysia

(Chairperson)

Assoc. Prof. Ts. Dr. Noor Afiza binti Mat Razali

Fakulti Sains dan Teknologi Pertahanan

Universiti Pertahanan Nasional Malaysia

(Internal Examiner)

Assoc. Prof. Ts. Dr. Chiew Kang Leng

Faculty of Computer Science & Information Technology

Universiti Malaysia Sarawak (UniMaS)

(External Examiner 1)

Prof. Ts. Dr. Ruslan bin Abdul Rahim

Universiti Teknologi MARA (UiTM)

(External Examiner 2)

APPROVAL

This thesis was submitted to the Senate of Universiti Pertahanan Nasional Malaysia and has been accepted as fulfilment of the requirements for the degree of **Doctor of Philosophy (Computer Science).** The members of Supervisory Committee were as follows.

Prof. Gs. Ts. Dr. Mohd Afizi bin Mohd Shukran

Fakulti Sains dan Teknologi Pertahanan

Universiti Pertahanan Nasional Malaysia

(Main Supervisor)

Prof. Ts. Dr. Fatimah binti Ahmad

Fakulti Sains dan Teknologi Pertahanan

Universiti Pertahanan Nasional Malaysia

(Co-Supervisor)

Dr. Mohd Rizal bin Mohd Isa

Fakulti Sains dan Teknologi Pertahanan

Universiti Pertahanan Nasional Malaysia

(Co-Supervisor)

Dr. Mohammad Adib bin Khairuddin

Fakulti Sains dan Teknologi Pertahanan

Universiti Pertahanan Nasional Malaysia

(Co-Supervisor)

UNIVERSITI PERTAHANAN NASIONAL MALAYSIA

DECLARATION OF THESIS

Student's full name	:	Muhammad Naim Bin Abdullah
Date of birth	:	21th July 1992
Title	:	Improvement Of Facial Biometric Security Requirements Approach Using Partitional-Based Digital Image Clustering Technique
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LIST OF ABBREVIATIONS

CBIR : Content Based Image Retrieval

DNA : Deoxyribonucleic Acid

RGB : Red-Green-Blue

DIC : Digital Image Clustering

KHM : K-Harmonic Means

SI : Similarity Index

QBIC : Query by Image Content

CBVIR : Content-Based Visual Information Retrieval

RQ : Research Question

RO : Research Objective

CalTech : California Institute of Technology

OS : Operating System

Gpx : Grid Pixel

CMYK : Cyan, Magenta, Yellow and BlacK

HSL : Hue-Saturation-Lightness

HSV : Hue-Saturation-Value

CLIQUE : Clustering in QUEst

HDBSCAN : Hierarchical Density-Based Spatial Clustering of Applications with Noise

HA : Harmonic Average

FBSIP : Facial Biometric Security Image Processing

CHAPTER 1

INTRODUCTION

Images now play a crucial role in fields as diverse as medicine, journalism, advertising, design, education and entertainment. Interest in the potential of digital images has increased enormously over the last few years, fuelled at least in part by the rapid growth of imaging on the World-Wide Web. Users in many professional fields are exploiting the opportunities offered by the ability to access and manipulate remotely stored images in all kinds of new and exciting ways. The problems of image retrieval are becoming widely recognized, and the search for solutions an increasingly active area for research and development. There is a need for a multimedia image retrieval system that can query large collections of images in an efficient and accurate manner for applications areas such as biomedicine, commerce, education and online World Wide Web. Querying an enormous database can be a tedious task and challenging problem. Therefore, it is required to design and implement a system that can search images in an acceptable short time. Content-Based Image Retrieval (CBIR) has received widespread interest in the field of computer vision and pattern recognition.

1.1 Background Study

Content-based image retrieval (CBIR), which goes to a research field of graphical image analysis, also known as Query by Image Content (QBIC) and Content-Based Visual Information Retrieval (CBVIR). The major components of image retrieval include image feature extraction, feature-based similarity calculation, semantically relevance feedback and image acquisition (Haralick, R.M., Shanmugam, K.S., & Dinstein, 1973)(Shriwas & Raut, 2015)(Rao, C. S., & Kumar, 2012). Basically, a general CBIR system architecture consists of six functional blocks which is image database (the block that contains image of the chosen database), feature database (can be characterised by a set of features), feature extraction (features may be text-based features and visual features), query image (can be any of the database images), image matching and indexing (the characteristic of the query image are differentiated with features that are already placed in the feature database), and retrieved image (the system that will select any number of images having the highest overall similarity to the given query image and present to the user as retrieved images (Rao, C. S., & Kumar, 2012). Figure 1 shows The General Architecture of a CBIR System.

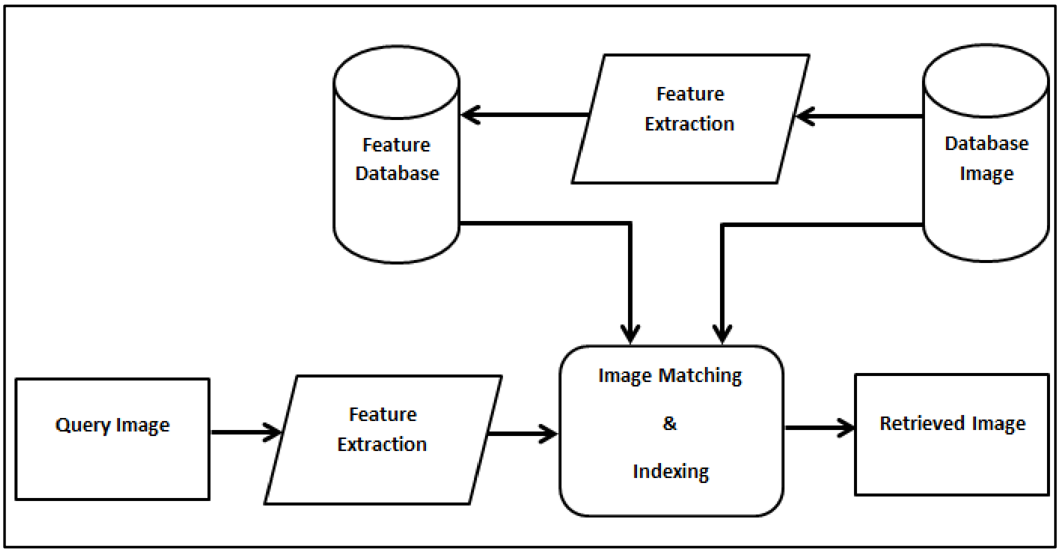

Figure 1. The General Architecture of a CBIR System.

The general architecture of a CBIR system can be summarised as a basic set of modules or elements that interact within each other to retrieve the database images according to a given query. In CBIR, the visual contents of the database images are extracted (taking out) by the feature extraction methods and represented in the form of feature vector. It shows that each image that is stored in the database has its own features extracted and compared to the features of the query image. It involves two main steps as follow:

a. **Feature Extraction**: The first step in the process is extracting image features to a distinguishable extent. In other words, this feature extraction is the process of automatically computing a compact representation (numerical or alphanumerical) of some attribute of digital images, to be used to derive information about the image contents (Schettini et al., 2009)(Shete et al., 2012).

b. **Image Query or Matching**: The second step involves matching these features to yield a result that is visually similar (Devireddy, 2009). This image matching process is also known as indexing process. When a query image comes in, its feature space will be compared with those in the feature database one by one and the similar images with the smallest feature distance will be retrieved (Choras, 2007).

Access control systems and electronic passport gates are examples of controlled situations where facial recognition technologies can be used. Face recognition is the method or technique of ability to correctly verify a certain individual's identification, usually by comparing a "target" face to other face photos. Because facial image comparison is the foundation of many security infrastructures, such as passport control, accurate facial identification is critical. Face recognition is frequently crucial in identifying criminal suspects and preventing miscarriages of justice. On top of that, face identification is a difficult challenge because of the relatively similar shape of faces and the numerous differences between photographs of the same face. Facial expression, age, viewpoint, lighting conditions, noise, distance, barriers, and other factors can affect the appearance and expression of a face. A face recognition system's goal is to recognise a face in a way that is as unaffected by these visual alterations as possible.

This research proposes a Digital Image Clustering (DIC) as the Facial Biometric Security Image Processing mechanism because of its ability to analyse patterns of RGB features data. DIC was originally developed to take over the image metadata since text descriptions are occasionally subjective where the illustration of complex image features effectively seems impossible (Younus et al., 2015). The query result was influenced by the interpretation of an image, which might have different descriptions based on human psychology. Clustering is one of the image categorization techniques for CBIR that gaining its popularity among researchers and developers (Azam & Bouguila, 2019). In terms of determining the image metadata, CBIR allows users to query image using another image to find image’s similarity which show similarity with acquired image from another platform that query image by image. Besides, DIC can also compute the digital image features based on RGB data of an image which is useful for database clustering mechanism to be used in Facial Biometric Security Image Processing for criminal profiling updates.

1.2 Research Motivation

Biometrics security is concerned with recognising people or human based on their distinct physical and behavioural characteristics. By physical traits we mean the features of a human such as fingerprints, Deoxyribonucleic Acid (DNA), iris recognition, hand geometry and face recognition. Voice, stride, and typing rhythm, as well as digital signature, are examples of behavioural features or characteristics. Biometric security solutions are rapidly being researched and implemented in a variety of applications based on these characteristics these days. For security reasons, the major goal of such applications is to detect and recognise a human. Biometric security applications are becoming more common in public spaces.

1.3 Problem statement

In theory, DIC approaches work by extracting RGB values from a digital image. The DIC activity relies on the DIC algorithm to compute the RGB data that determines an object's cluster membership. Every DIC algorithm was developed based on the image dataset requirements and targeted output. Because the majority of DIC algorithm research focuses on the CBIR function, selecting an appropriate or suitable DIC algorithm for Facial Biometric Security Image Processing is different requirements and it has a unique criteria. Moreover, it is not yet explored that the adaptation of a DIC algorithm could suited the Facial Biometric Security Image Processing requirements and regulations. In addition, the variation of DIC algorithm comes with variety of variables and settings which could manipulate the accuracy and integrity of the Facial Biometric Security Image Processing. Some variables would affect the similarity index of facial biometric security image. Those challenges has been focused on this research to produce a high similarity check mechanism for Facial Biometric Security Image Processing.

According to K. M Malikovich et al in 2017, face recognition is a very difficult problem because of the generally similar shape of faces combined with the numerous variations between images of the same face. The image of a face changes with viewpoint, noise, distance, etc(Wójcik et al., 2016).

Other than that, putting aside such unilateral claims, the largest publicly available source of information attesting to the accuracy of profiles appears to be in the nature of subjective accounts [11] [12]. The material in support of the utility of profiling unfortunately appears to be little better than the material in support of its validity. It should be recognized, however, that the concept of utility is, in all probability, more difficult to quantify, as the usefulness of a profile to an investigation may not manifest itself in a directly tangible manner. Once again, the largest source of material in support of the utility of profiles is in the form of subjective accounts. For essentially the same reasons previously articulated in the context of validity, too much reliance cannot be placed on such material (Richard N. Kocsis, 2007)(Iqbal et al., 2012). Furthermore, J. Pardede et al in 2017 stated in their paper that the CBIR still have problems in computational load which is high memory consumed and execution time (Pardede & Sitohang, 2017).

Theoretically, the DIC techniques utilizing the same data pattern as the Facial Biometric Security Image Processing which is the extracted RGB values from a digital image. The DIC activity is depending on DIC algorithm to compute the RGB data that determine the object's membership to a cluster. Every DIC algorithm was developed based on the image dataset requirements and targeted output. Since most DIC algorithm research where focus on CBIR function, choosing a suitable DIC algorithm for Facial Biometric Security Image Processing is different requirements. Functionality of CBIR as the image search engine was a totally different