FEATURE EXTRACTION AND SELECTION ALGORITHM FOR CHAIN CODE REPRESENTATION OF HANDWRITTEN CHARACTER

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A thesis submitted in fulfillment of the

requirements for the award of the degree of

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This thesis is dedicated to:

My beloved Mama and Papa

My lovely fiancé Juhari Othman

My sisters (Devi, Deni, Ria, Rika, Dina)

Thank you for always being there for me, supporting me and encouraging me to be the best that I can be

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ABSTRACT

Isolated characters, especially Latin characters, usually contain many branches on their characters' nodes that causes difficulties to decide which direction would a traverse continues. Furthermore, a revisit to previous visited nodes is often required in order to visit all the nodes in one continuous route. In this thesis, some techniques to solve problems for Handwritten Character Recognition (HCR) involving isolated characters are proposed. HCR consists of three stages which are pre-processing, feature extraction and classification. In the pre-processing, thinning algorithm was applied to remove the redundancies of pixel in character binary image. In the feature extraction, Freeman Chain Code (FCC) was used as data representation that uses 8-neighbourhood directions labelled as 1 to 8. However, the FCC representation is dependent on the route length and branches of the characters' node. The larger the number of branches, which is common for isolated characters, the longer the time required for the extraction. Here, a FCC extraction based on Heuristic Randomized-based algorithm was proposed to reduce the route length and computational time. Based on the experiment, it was demonstrated that the proposed FCC extraction is superior in terms of producing the shortest route length with minimum computational time, compared to Enumeration-based algorithm, Genetic Algorithm and Ant Colony Optimization. In this thesis, features vector extracted using the FCC extraction was used as input to the classification. There were 69 features used, 64 features were from the chain codes and 5 features were from original image. Support Vector Machine (SVM) and Artificial Neural Network (ANN) were chosen as classifier in the classification of image characters. The performance of ANN is better than SVM in terms of accuracy. The accuracy of ANN on sample data from the National Institute of Standards and Technology database reached more than 96% for all upper-case and lower-case, more than 98% for all upper-case, lower-case and characters, and more than 90% for digits only.

ABSTRAK

Aksara terasing, terutamanya aksara Latin, biasanya mengandungi banyak cabang pada nod aksara mereka yang menyebabkan kesukaran untuk menentukan arah mana penjelajahan akan diteruskan. Tambahan lagi, lawatan semula ke nod yang telah dilawati sebelumnya selalunya diperlukan untuk membolehkan lawatan ke semua nod dalam satu laluan berterusan. Dalam tesis ini, beberapa teknik untuk menyelesaikan masalah bagi Pengecaman Aksara Tulisan Tangan (HCR) yang melibatkan aksara terasing dicadangkan. HCR mengandungi tiga peringkat iaitu prapemprosesan, pengekstrakan ciri dan pengkelasan. Dalam prapemprosesan, algoritma penipisan digunakan untuk menyingkirkan lebihan piksel dalam imej binari aksara. Dalam pengekstrakan ciri, Kod Rantai Freeman (FCC) digunakan sebagai perwakilan data yang menggunakan arah 8-kejiranan berlabel 1 hingga 8. Namun begitu, perwakilan FCC bergantung kepada panjang laluan dan cabang bagi nod aksara. Semakin besar bilangan cabang, yang memang biasa bagi aksara terasing, semakin panjang masa yang diperlukan bagi pengekstrakan. Di sini, pengekstrakan FCC berasaskan algoritma Heuristik Berasaskan-Rawak dicadangkan untuk mengurangkan panjang laluan dan masa pengiraan. Berdasarkan eksperimen, keputusan menunjukkan bahawa pengekstrakan FCC adalah lebih baik dari segi menghasilkan jarak laluan terpendek dengan masa pengiraan minimum, berbanding dengan algoritma berasaskan-Perhitungan, Algoritma Genetik dan Pengoptimuman Koloni Semut. Dalam tesis ini, ciri-ciri vektor yang diekstrak menggunakan pengekstrakan FCC digunakan sebagai input kepada pengkelasan. Terdapat 69 ciri-ciri yang digunakan, 64 ciri-ciri ialah daripada kod rantai dan 5 ciri-ciri ialah daripada imej asal. Mesin Sokongan Vektor (SVM) dan Rangkaian Neural Buatan (ANN) dipilih sebagai pengkelas untuk pengkelasan aksara imej. Pencapaian ANN adalah lebih baik berbanding SVM dari segi ketepatan. Ketepatan ANN untuk data sampel dari pangkalan data *National Institute of Standards and Technology* mencapai lebih dari 96% untuk semua huruf besar dan kecil, melebihi 98% untuk semua huruf besar, huruf kecil dan nombor, dan melebihi 90% untuk nombor sahaja.

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LIST OF ABBREVIATIONS

ACA	-	Ant Colony Algorithm
ACO	-	Ant Colony Optimization
AHS	-	Arabic Heuristic Segmentation
AI	-	Artificial Intelligence
ANN	-	Artificial Neural Network
ART	-	Adaptive Resonance Theory
BP	-	Back Propagation
C_VCC	-	Compressed Vertex Chain Code
CC	-	Chain Code
CEDAR	-	Centre of Excellence for Document Analysis and Recognition
DIGRAPH	-	Directed Graph
E_VCC	-	Extended Vertex Chain Code
EC	-	Evolutionary Computing
EHS	-	Enhanced Heuristic Segmentation
ERM	-	Empirical Risk Minimization
FCC	-	Freeman Chain Code
FQI	-	Feature Quality Index
GA	-	Genetic Algorithm
HCR	-	Handwritten Character Recognition
HEM	-	Heuristics Extraction Method
HIT-MW	-	Harbin Institute of Technology-Multiple Writers
HMM	-	Hidden Markov Model
IFHCDB	-	Isolated Farsi/Arabic Handwritten Character Database
INDCENPARMI	-	Indian Centre for Pattern Recognition and Machine Intelligence
LIBSVM	-	Library Support Vector Machine

MATLAB	-	Matrix Laboratory
MIS	-	Multiple Image Set
MLP	-	Multi Layer Perceptron
NIST	-	National Institute of Standards and Technology
NSV	-	Number Support Vector
OCR	-	Optical Character Recognition
PCA	-	Principal Component Analysis
PCC	-	Primitives Chain Code
PDE	-	Partial Differential Equation
PR	-	Pattern Recognition
PSO	-	Particle Swarm Optimization
PSP	-	Prospective Segmentation Points
QP	-	Quadratic Programming
RBF	-	Radial Basis Function
RIMES	-	Reconnaissance et Indexation de données Manuscrites et de fac similÉS/Recognition and Indexing of Handwritten Documents And Faxes
SD-19	-	Special Database-19
SLP	-	Single Layer Perceptron
SLT	-	Statistical Learning Theory
SOM	-	Self Organizing Map
SRM	-	Structural Risk Minimization
SSE	-	Sum-Square Error
SV	-	Support Vector
SVM	-	Support Vector Machine
TBI	-	Thinned Binary Image
VC	-	Vapnik Chervonenkis
VCC	-	Vertex Chain Code
VL_VCC	-	Variable Length Vertex Chain Code

LIST OF SYMBOLS

n	-	Number of population
ρ	-	Mutation rate / evaporation rate
eC	-	Total edge count
τ_{ij}	-	Pheromone value is a tendency to continue the walk from edge i to edge j
ofv_k	-	Objective Function Value for Ant Solution k
t	-	Kernel Function Type
c	-	Cost Parameter
γ	-	Gamma in the Kernel Function
v	-	Number of Fold Cross-Validation
S_1	-	Hidden Layer
S_2	-	Output Layer

LIST OF REFERENCES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Handwriting recognition is defined as the transformation of a language into symbolic representation from its visual marks (Plamondon and Srihari, 2000). The goal of handwriting recognition is to interpret input where it can be recognition of handwritten sentences, words or characters. There are two types of handwriting recognition: off-line and on-line recognition. Off-line recognition is a system that accepts its image input from a digital scanner or camera while the on-line recognition is a system that accepts input from online devices (i.e. Personal Digital Assistant) and computed the relationship between points to extract the features in real time. Off-line recognition is more complex and need further research works compared to its on-line counterpart. Tay (2002) proposed the problems and difficulties of the handwriting recognition task can be classified into four categories, which are nature of handwriting signals, handwriting styles, writer dependency and vocabulary sizes

Character recognition is a part of the handwriting recognition problem which can be in the handwritten or printed format. Recognition of handwritten character by computer is a difficult problem. Optical Character Recognition (OCR) is a machine to automatically recognize characters through an optical mechanism. The goal of OCR is to identify and analyse input character. The research in OCR has been going for more than 50 years but the goal of this area is still out of reach.

Handwritten Character Recognition (HCR) is a part of OCR. Moreover, the achievements by the researchers are differed based on existence of specific case in each database used. Different databases make the handling differ in the solution of the recognition characters because of the variation and complexity of data in each database. Even though research in this area is extensive, further research is not necessarily in improving the percentage of accuracy but also in attempting to reduce complexity of its pre-processing techniques, its classifier and its post-processing (Suliman *et al.,* 2008). Many of the successful commercialized HCR have been applied in many applications such as automation of reading bank cheque numbers, postcode on envelopes, recognition of addresses, document analysis and verification of signatures.

In general there are three stages in character recognition that are pre-processing, feature extraction and classification. Therefore, it is obvious to take careful design for all of three stages. This thesis concentrates on all these three stages. First stage is pre-processing, thinning algorithm is applied and used on databases from two sources namely Centre of Excellence for Document Analysis and Recognition (CEDAR) and National Institute of Standards and Technology (NIST). CEDAR database is taken from (Engkamat, 2005) where neural network approach is applied in the thinning process. On the other hand, NIST database used Matrix Laboratory (MATLAB) Image Processing toolbox for similar purpose. In second stage is the feature extraction, to select or invent features that allow effective and efficient recognition of patterns (Cheriet *et al.,* 2007). As in many practical problems, it is often not easy to find those with most effective features (Zhaoqi and Xuegong, 2000). Two important problems before building the feature extraction that must be known that are feature extraction and feature selection. Feature extraction phase is related with which extraction technique will be used against the image character. There are many extraction techniques available such as moment, histogram, direction features, image registration, Hough transform, line-based representation, Fourier descriptors, shape approximation, topological features and linear transforms. In the other hand, the aim for feature selection phase is to find the most relevant features to improve the classification accuracy. The third stage is classification, where the character images classification is performed.

Shape approximation technique in feature extraction stage, particularly chain code has been widely used to encode the boundary line because of its simplicity and low storage requirement (Neuhoff and Castor, 1985). Chain Code (CC) representation gives the boundary of character image where the codes represent the direction of where is the location of the next pixel from current point. Freeman Chain Code (FCC) is selected as representation and identification of image characters because it is easy for isolated character based on outer boundary representation. Isolated characters means an individual (single) character, important to be done before character recognition step. An FCC extraction technique that uses 8-neighbourhood direction labelled as 1 to 8 is applied.

Isolated characters, especially Latin characters, usually contain branches on each character node, which causes difficulty to decide which direction would the traverse continues. Moreover, a revisit to previous visited node is often needed to visit all the nodes. One continuous route is needed to solve such problems, which cover all the nodes of the image. Thus, FCC extraction techniques via Heuristics and Meta-heuristics techniques are proposed. Heuristics techniques comprise of Randomized-based and Enumeration-based algorithms while Meta-heuristic techniques are including Genetic Algorithm (GA) and Ant Colony Optimization (ACO). Knowing that the use of heuristic and meta-heuristics techniques to construct FCC is not widely explored and the existence of the length problem in representing and recognition characters of FCC, they motivate this thesis. These techniques enable us to extract and recognize such difficult characters in relatively shorter computational time and shorter route length.

Handwritten Latin characters are selected as object in this experiment. In Latin language, there are many pairs of characters which are ambiguous for human and machines (i.e. U-V, C-G, F-P, M-N, D-O). From two proposed techniques that are heuristic and meta-heuristic, randomized-based algorithm from heuristic is selected for the experiment in feature extraction and classification using NIST database. In reality, both techniques are almost similar in their performance; minutely differ in terms of route length and computation time.

Feature vector is built from five features from image properties and sixty four features from extracted FCC (8 FCC division x 8 directional code frequency per division = 64 features) which totalled to 69 features. Support Vector Machine (SVM) and Artificial Neural Network (ANN) are chosen for the classification stage in order to classify the image characters.

1.2 Problem Background

An automated character recognition system is a solution that can interpret characters automatically. The automatic recognition of characters can be extremely useful where it is necessary to process large volume of handwritten characters. HCR can be classified into three stages, which are pre-processing, feature extraction and classification. Pre-processing is involving operation to produce a clean character image and can be used directly and efficiently by the feature extraction. In feature extraction, effective and efficient features are to be selected for use in classification stage. The last stage is the classification that is the end of HCR where image character is being recognized. The success rate of the system is depending on the entire stages.

Feature extraction is intended to produce several characteristics, which can be used to differentiate an image label with other image labels and to find a subset of features that will maximize the effectiveness of recognition or maximize the efficiency of the process (by minimizing the number of features), or both, done with or without the involvement of a classifier. In order to carry out such important task, FCC as image character's feature will be used to guess the image label. FCC construction using one continuous route has not widely explored such a method would enable us to extract and recognize such difficult characters and to find approximate solutions for FCC generation along with minimizing its length in relatively shorter computational time with shorter route length.

This thesis proposed two techniques to generate FCC namely heuristic and meta-heuristic. The encouragement of them is motivated by following considerations:

i. The starting node for the FCC construction influences its length. In addition, a handwritten character often has several branches, and this makes it difficult to decide where it should go on direction. Moreover, a revisit to the previous visited nodes is often needed to visit all the nodes. These difficulties in handling several branches have motivated the use of heuristic and meta-heuristic techniques.
ii. The performance of the recognition stage depends on the data input provided from the previous stages. The input data for the classification stage (in this case is the FCC) must correctly represent and distinguish each character. Since a handwritten character can be represented with several FCCs, the techniques must have the ability to provide such results. In order to achieve this, Heuristic and Meta-heuristics are used to generate the FCC.

To sum up, the research question of this thesis can be stated as:

i. How to minimize the length of FCC using heuristic and meta-heuristic techniques?
ii. What is the route length and computation time of FCC in the representation of image character?
iii. What is the efficiency of FCC in terms of accuracy in SVM and ANN in a single classification session?

1.3 Problem Statement

There are three subjects considered to drive this thesis. They are the HCR problem and its related research area such as graph theory; the chain code scheme, mainly the FCC and its code generator from various sources; and HCR classification and its related features. In HCR problem, the problem of off-line character is difficult than on-line character because the different people have different handwriting styles. So, off-line character is the priority in this thesis, especially for Latin handwritten character.

1.4 Objective

The main objective of this thesis are shown below:

i. To develop Heuristic and Meta-Heuristic algorithm in extracting FCC.
ii. To identify and select feature vectors based on FCC and image character properties.
iii. To develop classifier for handwritten character based on feature vectors.
iv. To propose the new framework in HCR based on the chain code representation.

1.5 Scope

In order to achieve the objective of this thesis, it is important to identify the scope, which covers the following aspect:

i. Applying the established thinning algorithm in pre-processing stage and representing the Thinned Binary Image (TBI) using FCC.
ii. In pre-processing stage, upper-case Latin characters are taken from CEDAR using Engkamat proposed method while MATLAB toolbox is applied to NIST Special Database-19 (SD-19) database for the same thinning step.

iii. In feature extraction and classification stages, data are derived from NIST dataset and consists of upper-case, lower-case, letter (mixture of upper-case/lower-case), digit and all characters (mixture of letter/digit).

iv. In feature extraction stage, the heuristic techniques are randomized-based and enumeration-based algorithms while meta-heuristic techniques are GA and ACO.

v. In classification stage, the techniques are SVM and ANN.

vi. Performance measurement in order to calculate of FCC is route length and computation time.

vii. Performance measurement in classification is the accuracy.

1.6 Thesis Organization

There are eight chapters in the thesis. Chapter 1 presents the introduction of the thesis, problem background, problem statement, objectives, scope, thesis organization and followed by work contribution. Chapter 2 appraises the literature review. It discusses introduction, HCR, handwriting style and database, pre-processing in HCR, feature extraction and selection, classification and summary. Chapter 3 presents research methodology used to build up this thesis. This chapter presents the research framework, problem identification and specification, data definition and collection, pre-processing and techniques selection, development of FCC extraction algorithms, feature identification and classification algorithm, validation and result analysis, implementation and summary. Chapter 4 is the Heuristic FCC extraction algorithm. It describes the structure of the algorithms and its data structure, the Randomized-based algorithm, Enumeration-based algorithm and accompanied by the summary. Chapter 5 is the Meta-heuristic FCC extraction algorithm that presents the structure of the algorithms and its data structure, Genetic Algorithm, Ant Colony Optimization, result of the generating the FCC and followed by the summary. Chapter 6 is the identification of features and development of classifier. It discuss introduction, feature vector identification and selection, SVM, ANN and followed by the summary. Chapter 7 is result analysis and validation. It explained the dataset and parameter setting used for pre-processing, feature

extraction and classification stages. Then, continue with result of pre-processing, result of FCC extraction algorithm that are Heuristic and Meta-heuristic, result of classification algorithm are SVM and ANN, evaluation of proposed algorithm and finally summary. Chapter 8 is the conclusion and future work. This chapter illustrates our summary, benefit of thesis, contribution of thesis, conclusion and the suggestion for possible future work.

1.7 Contribution

The main contribution of this thesis is the developments of HCR in two stages: feature extraction and classification. In feature extraction, two techniques used that are heuristic and meta-heuristic techniques are built to generate FCC with the aim to find a continuous route (which is complicated in case of Latin character) that covers all the nodes of the image. Heuristic technique are consisted of randomized-based and the enumeration algorithm while GA and ACO implementation are contained in meta-heuristic technique. In classification, feature vector is image content properties and FCC character extracted using randomized-based algorithm for input classification with the vector length of 69 features. Two classifiers based on each SVM and ANN is built with the priority to the recognition accuracy. The best of recognizer and classifier of handwritten character based on FCC representation is presented. Lastly, a new framework based on the chain code representation is proposed. The framework has included all stages in HCR and been tested on two standard handwriting image databases.

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