BIOMIMETIC PATTERN RECOGNITION FOR WRITER IDENTIFICATION USING GEOMETRICAL MOMENT FUNCTIONS

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Dedicated to:

My parents H. Sahmin Hanan and Hj. Nurhayati Kemis
My brother Jumadi, S.E., Kasnadi and my sister Misba, S.Kep.
My parents–in–law Drs. H. Adnan Rais and Cholidjah
My brother–in–law Ir. Tri Yulisman Eka Putra, M.M., Yulius Agung, S.E.,
Abdul Hadi, S.E., Drs. Muhammad Suharni, M.A., Agusman Irawan, A.Md.
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My children Mardhatillah, Aisyah Munawwarah, Husnul Khatimah
Muhammad Ihsan Dzikrullah and Muhammad Ikram Dzulqarnain

Thank you for your prayers, supporting and understanding

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ABSTRACT

Writer identification (WI) based on handwriting has a great significance in many real world applications, such as crime suspect, identification in forensic science, in the court of justice where one must come to a conclusion about the authenticity of a document, and authorship determination of historical manuscripts. WI emphasizes on identifying the authorship of handwriting while ignoring the connotation of the words in the documents. The samples of WI included in the training sample sets have no prior knowledge between the same classes of samples. While biomimetic pattern recognition (BPR) has unique characteristics of accepting the samples which means the difference between two samples of the same class must be gradually changed. Unlike classical WI procedure, BPR uses the concept of cognition in which when new feature of handwriting samples are fed to the classifier, only these samples will be trained accordingly. Therefore, this study focused on the concept of BPR based on the principle of homology-continuity (PHC), hyper sausage neuron network (HSNN), and three weight neuron network (TWNN). PHC is the prior knowledge to be applied into the distribution of sample data in BPR. While, HSNN's coverage in high dimensional space with feature space for covering the distribution area of the sampling points in the same class constructed a sausage shape, TWNN made triangle shape. The identification process of the samples in HSNN and TWNN coverage depends on the proposed threshold values. This study found that the results of the proposed methods were better in identifying the authorship of handwriting with an accuracy of more than 95% using various features of geometrical moment functions.

ABSTRAK

Pengenalpastian penulis (PP) berdasarkan tulisan tangan mempunyai kepentingan yang besar dalam aplikasi sebenar seperti suspek jenayah, pengenalpastian dalam sains forensik, dalam mahkamah keadilan iaitu seorang individu mesti menjurus kepada ketulenan dokumen berkaitan, penentuan hakmilik pengarang manuskrip bersejarah, dan sebagainya. PP menekankan tentang pengenalpastian hakmilik pengarang tulisan tangan dengan memencilkan makna perkataan tersebut dalam dokumen berkaitan. Sampel PP yang terdapat dalam set sampel latihan tidak mempunyai pra-pengetahuan di antara kelas sampel yang sama. Manakala, Pola Pencaman Biomimetik (BPR) mempunyai ciri-ciri unik penerimaan iaitu perbezaan antara dua sampel bagi kelas yang sama akan berubah secara bertahap-tahap. Tidak seperti prosedur tradisi PP, BPR menggunakan konsep kognisi iaitu apabila fitur baru sampel tulisan tangan disuap kepada pengelas, hanya sampel baru saja yang akan dilatih. Oleh yang demikian, kajian ini tertumpu kepada konsep BPR berdasarkan prinsip selajar-homogen (PHC), jaringan hiper neuron sosej (HSNN) dan jaringan neuron tiga pemberat (TWNN). PHC adalah pengetahuan sejarah yang akan digunakan dalam sampel taburan titik bagi BPR. Manakala, liputan HSNN dalam ruang dimensi yang tinggi dengan ruang fitur untuk meliputi kawasan taburan bagi titik pensampelan dalam kelas yang sama membina bentuk sosej, TWNN mempunyai bentuk segitiga. Proses pengenalpastian sampel dalam liputan HSNN dan TWNN bergantung kepada nilai ambang yang dicadangkan. Hasil kajian mendapati bahawa kaedah cadangan memberikan keputusan yang baik dalam mengenalpasti hakmilik pengarang tulisan tangan dengan nilai ketepatan lebih dari 95% menggunakan pelbagai fitur fungsi momen geometri.

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LIST OF ABBREVIATIONS

AsMI	-	Aspect Moment Invariants
AUMI	-	Aspect United Moment Invariants
BPNN	-	Back Propagation Neuron Network
GMI	-	Geometrical Moment Invariants
HSN	-	Hyper Sausage Neuron
HSNN	-	Hyper Sausage Neural Network
TWN	-	Three Weight Neuron
TWNN	-	Three Weight Neuron Network
UMI	-	United Moment Invariants
WAMI	-	Weighted Aspect Moment Invariants
WCM	-	Weighted Central Moments
WI	-	Writer Identification
WUMI	-	Weighted United Moment Invariants
ZAMI	-	Zernike Aspect Moment Invariants
ZAUMI	-	Zernike Aspect United Moment Invariants
ZMI	-	Zernike Moment Invariants
ZUMI	-	Zernike United Moment Invariants

LIST OF SYMBOLS

μ_{pq}	=	Central Moment
m_{pq}	=	Moment
$\iint$	=	Double Integration
d	=	Number of Features
m	=	Number of Neuron
n	=	Number of Samples
$f(x,y)$	=	Level of Background
dx, dy	=	Differentiation of Variable
$\bar{x}, \bar{y}$	=	Average of Data
$\sum$	=	Summation of Data
η_{pq}	=	Scaling Factor of Moment Invariant
η'_{pq}	=	Discrete Scaling
η''_{pq}	=	Boundary Scaling
$\phi_1 - \phi_7$	=	Features Values of Geometric Moment
$ZM_1 - ZM_6$	=	Features Values of Zernike Moment
$\theta_1 - \theta_8$	=	Features Values of United Moment
Th	=	Existing Threshold
Th_1	=	First Proposed Threshold
Th_2	=	Second Proposed Threshold

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CHAPTER I

INTRODUCTION

1.1 Overview

Writer identification is an important study topic in pattern recognition domain. Writer identification has a great significant in many real world applications, such as crime suspect, identification in forensic science, in the court of justice where one must come to a conclusion about the authenticity of a document and writer determination of historical manuscripts.

Many researchers have developed several methods in handwriting analysis to find the best solution to identify the authorship of handwriting based on Wavelet-Based Generalized Gaussian Density Algorithm (Zhenyu *et al*., 2005a), Hidden Markov Model (Schlapbach and Bunke, 2007; Huaigu *et al*., 2011), Bayesian Classifier (Siddiqi and Vincent, 2007), Gaussian Mixture Model (Schlapbach *et al*., 2008; Kırlı and Gülmezoglu, 2011), Support Vector Machine (SVM) Classifier (Santana *et al*., 2008; Chanda *et al*., 2010; Chanda *et al*., 2012), and Normal Density Discriminant Function (NDDF) Classifier (Kırlı and Gülmezoglu, 2011). These techniques are based on statistical pattern recognition (SPR). SPR considers all available information of samples in training set, and no prior knowledge exists

between the same classes of samples. SPR needs to separate the samples to classify them. In contrast, Biomimetic Pattern Recognition (BPR), proposed by Shou-jue in 2002, practices the continuity in feature space of any one of the certain class of samples as the prior knowledge and describe on the cognition process (Shou-jue and Xingtao, 2004). The concept of cognition, instead of classification, is much closer to the classification function of human being than SPR (Shou-jue and Xingtao, 2004). Therefore, the aim of BPR is being the best covering of samples in the feature space instead of the best separating, emphasized by SPR.

Writer identification system uses geometrical moment functions to extract features based on handwriting word images. In this study, it was applied several geometrical invariant functions, namely: Geometrical Moment Invariants (Hu, 1962), Zernike Moments (Teague, 1980), Aspect Moment Invariants (Feng and Keane, 1994), United Moment Invariants (Yinan *et al.*, 2003), Aspect United Moment Invariants (Muda *et al.*, 2008), Weighted Aspect Moment Invariant and Weighted United Moment Invariants (Pamungkas and Shamsuddin, 2009), Zernike Aspect Moment Invariant (Bakar and Shamsuddin, 2009), Zernike United Moment Invariants (Bakar *et al*., 2011) and Zernike Aspect United Moment Invariant (Bakar, 2011).

1.2 Background of the Problem

Writer identification is divided into two categories: on-line and off-line writer identification (Said *et al*., 2000). Off-line writer identification is based on the use of computer image processing and pattern recognition technique (Srihari *et al*., 2001a; Said *et al*., 2000). There are two groups of off-line approaches, namely: text-dependent and text-independent (Said *et al*., 2000). Text-dependent methods require the writers to write the same texts and text-independent methods do not match the same characters but extract writing style features from the handwriting images that

considered as different textures (Zhenyu *et al.*, 2005a). The problem of writer identification is in identifying a writer among a set of N candidates. Therefore, the system must learn a set of handwriting samples of each individual candidate.

Research in writer identification has found significant interest in recent years due to its forensic applicability. A writer identification system performs a one-to-many search in a large database with handwriting samples of known writer and returns a likely list of candidates (Bulacu and Schomaker, 2007). This represents a special case of image retrieval, where the process is based on features capturing handwriting individuality. The hit list is further scrutinized by forensic expert who makes final decision regarding the identity of authorship of questioned handwriting samples.

The problem of writer identification frequently arises in the court of justice where one must come to a conclusion about authenticity of a document. It is also posed in several institutes which analyze texts of former writers, and are interested in the genetics of these texts, identification of varies writers who took part in drafting of a manuscript or who made corrections. The current significant results in the field of handwriting recognition made it possible to bring today first significant answer to this particular problem.

Nowadays, many studies focus on statistical decision model to identify the authorship of handwriting. Pattern classification is used to determine the pattern without using prior knowledge of the relationship between the samples in the same class. Human recognizes objects individually by finding the commonalities between objects in the same class. It assumed that the sample points of the same class in the feature space would be continuous and recognizable characters. Therefore, the recognition of a particular object class, analysis and cognition of the "shape" of the infinite set of points formed by all objects in the feature space are important.

Handwriting can be manually analyzed by a handwriting analysis expert to observe the uniqueness and characteristic features from the writer, but this process needs lot of times. Several researchers developed tools or computer applications to replace the task of expert in analyzing the questioned handwriting document (Srihari *et al*., 2006; Bensefia *et al*., 2005; Pervouchine *et al*., 2005).

Many previous works have been done in order to classify the authorship of handwriting where they focus on: 1) Template Matching technique such as: Pattern Matching (Wirotius *et al*., 2003), K-Nearest Neighbor (Zhang *et al*., 2003; Kırlı and Gülmezoglu, 2011),Weighted Euclidean Distance (Zhenyu *et al*., 2005a; Somaya Al-Ma'adeed *et al*., 2008; Wei *et al*., 2009), and X^2 Distance (Bulacu and Schomaker, 2007; Shahabi and Rahmati, 2009; Ghiasi and Safabakhsh, 2010); 2) Neural Network Pattern Classification such as: Multi-Layer Perceptron (Ram and Moghaddam, 2009), and SOM cluster (Marinai *et al*., 2010); 3) Statistical Pattern Classification such as: Wavelet-Based Generalized Gaussian Density Algorithm (Zhenyu *et al*., 2005a), Bayesian Classifier (Siddiqi and Vincent, 2007), Gaussian Mixture Model (Schlapbach *et al*., 2008; Kırlı and Gülmezoglu, 2011), SVM Classifier (Santana *et al*., 2008; Chanda *et al*., 2010; Chanda *et al*., 2012), NDDF Classifier (Kırlı and Gülmezoglu, 2011), Hidden Markov Model (Schlapbach and Bunke, 2007; Huaigu *et al*., 2011).

All pattern recognition techniques for writer identification believe all available information of samples is included in the training sample sets, and no prior knowledge exists between the same classes of samples. In contrast, BPR has an idea of understanding when two objects in the same classes of samples belong to the same class, it must be at least one gradual change course between these two objects and all objects in this gradual change course belong to the same class. It is called the principle of homology-continuity (PHC) (Shou-jue and Xingtao, 2004; Qin *et. al*., 2005; Lili and Shou-jue, 2009). Therefore, goal of BPR is the best covering of samples in feature space then the best separating of samples in SPR.

In addition, when a new class of handwriting samples is added into a handwriting identification system based on the concept of cognition in BPR, it does not train all samples but only new samples do (Zhi-hai *et al*., 2003; You-zheng *et al*., 2010). This method is different with classic SPR which needs to train the whole system. Therefore, BPR method has less training time then SPR method.

Furthermore, many applied researches of BPR had been successfully in object recognition (Shou-jue *et al*., 2005), face recognition (Guliang and Shou-jue, 2005; Chengan *et al*., 2007), clustering DNA microarray data (Wenming and Shou-jue, 2005), off-line handwritten Chinese characters recognition (Jian-ping *et al*., 2006), multispectral images recognition (Wenming and Hao, 2009), text classifier (Ji-bin *et al*., 2009), iris recognition (Junying *et al*., 2009; Yikui *et al*., 2010), moving object recognition (Li *et al*., 2010), motor imagery EEG recognition (Xu and Wu, 2010), head recognition (Xiaping and Jianfu, 2011), system on programmable chip (Xinyi and Xiaopeng, 2012).

1.3 Statement of the Problem

Nowadays, many previous studies have focused on template matching technique, neural network pattern classification and statistical pattern classification to identify the authorship of questioned handwriting. Pattern classification is not employing the prior knowledge of relationship between samples in the same class. Therefore, recognition of a particular object class, analysis and cognition of the "shape" of the infinite set of points formed by all objects in feature space are important.

Thus, the proposed of this study used BPR method (biomimetic classifier) to identify the authorship of questioned handwriting samples. The biomimetic classifier based on hyper sausage neuron network (HSNN) and three weight neuron network (TWNN).

The research question of this study can be stated as follows:

How efficient is biomimetic pattern recognition in identifying the authorship of handwriting using several geometrical moment functions?

1.4 Purpose of the Study

The purposes of the study identified the authorship of questioned handwriting based on BPR method using HSNN and TWNN. The influences of several geometrical moment functions on writer identification problems were presented and analyzed. In addition, this study proposed two thresholds and applied them into HSNN and TWNN to improve the performance of writer identification.

1.5 Objectives of the Study

The aims of study were to propose BPR method to identify the authorship of questioned handwriting which can improve the term of identification performance.

The objectives of this study have been identified as stated below:

1. To develop BPR with several geometrical moment functions for writer identification.
2. To design new thresholds of BPR for faster writer identification.
3. To investigate the effectiveness of proposed BPR algorithm in writer identification.

1.6 Scope of the Study

The scope of this study includes the following:

1. The standard database of 40 writers (2421 images data) was from IAM database (Marti and Bunke, 2002).
2. This study used the existing features extraction for handwriting images.
3. This study focused on global feature extraction and in this context, several geometrical moment functions were implemented.
4. Omni-directional cognitive text did not study.
5. Java programming and Matlab were used as programming tool.

1.7 Theoretical Framework

In general, pattern recognition has three phases that shown in Fig. 1.1 which were pre-processing, feature extraction and classification (Bensefia *et al*., 2002).

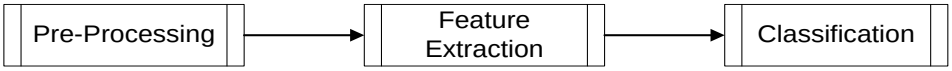

Figure 1.1: Framework of the SPR for Writer Identification

This study adopted this framework which focused on feature extraction and classification, and omitted the pre-processing. According to Schlapbach and Bunke (2007) that pre-processing can decrease the performance of writer identification while it advances the handwriting identification. In this study, BPR was developed with multi weight neuron network to implement in the classification task, that each connection between two nodes in an artificial neuron network (ANN) using double weight called HSNN and TWNN for three weights in each connection between two nodes.

1.8 Importance of the Research

This study proposed technique to identify the authorship of questioned handwriting based on BPR method using hyper sausage neuron network and three weight neuron network. In addition, proposed thresholds were used to faster the writer identification stage. The effectiveness of proposed BPR method was an alternative to determine the authorship of questioned handwriting samples.

1.9 Contributions of the Study

The contributions of the study were a framework of BPR method to determine the writer identification, HSNN and TWNN, which was used as a procedure to identify the authorship of handwriting. Two proposed thresholds for HSNN and TWNN were applied to accelerate the process of writer identification. The authorship of questioned handwriting samples were effectively identified by the proposed BPR method.

1.10 Significant of the Study

This study analyzed the performance of HSNN and TWNN to identify the authorship of questioned handwriting samples. This study showed that HSNN and TWNN were used to solve difficult problems in writer identification effectively, and the influence using several geometrical moment functions and thresholds for writer identification.

1.11 Organization of the Thesis

This study was organized into six chapters as stated in below. Chapter 1 consists of the study background of handwriting for writer identification, geometrical moment functions and biomimetic pattern recognition. The objective, purpose, scope and importance of study were purposed.

Chapter 2 described handwriting analysis, geometrical moment functions and pattern recognitions. Handwriting analysis consists of on-line and off-line writer identification, handwriting recognition and identification, writer verification and identification, text-dependent and text-independent, and individuality of handwriting. A brief basic of geometrical moment functions was studied such as geometrical moment invariants (GMI), Zernike moment invariants (ZMI), aspect moment invariants (AsMI), weighted central moment (WCM), and united moment invariants (UMI). Furthermore, the several integration moment functions were discussed, namely: aspect united moment invariants (AUMI), weighted aspect moment invariants (WAMI), weighted united moment invariants (WUMI), Zernike aspect moment invariants (ZAMI), Zernike united moment invariants (ZUMI), and Zernike aspect united moment invariants (ZAUMI). Pattern recognition consists of statistical pattern recognition (SPR) and biomimetic pattern recognition (BPR). In BPR concept were discussed the principle of homology-continuity (PHC), high dimensional geometry shape (HDGS), multi weight neuron network (MWNN), and existing thresholds.

Chapter 3 consists of justification problem, situation and concept, data representation, biomimetic training and testing procedure, performance measurement procedure, and development tools.

Chapter 4 developed the proposed biomimetic classifier to identify the authorship of handwriting. Experiment and analysis of the result were discussed in Chapter 5, and finally, Chapter 6 was for conclusion and future work.

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