UNIVERSITI PUTRA MALAYSIA

HIGHER ORDER CENTRALISED SCALE-INVARIANTS FOR UNCONSTRAINED ISOLATED HANDWRITTEN DIGITS

SITI MARIYAM HJ. SHAMSUDDIN

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By

SITI MARIYAM HJ. SHAMSUDDIN

Thesis Submitted in Fulfilment of the Requirements for the Degree of Doctor of Philosophy in the Faculty of Computer Science and Information Technology Universiti Putra Malaysia

May 2000

Dedicated to my husband; Abdul Jamal,

my daughter; Salihah Nadiah,

my parents and family

Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfilment of the requirements for the degree of Doctor of Philosophy.

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Chairman : Md. Nasir Sulaiman, Ph. D.

Faculty : Computer Science and Information Technology

The works presented in this thesis are mainly involved in the study of global analysis of feature extractions. These include invariant moments for unequal scaling in x and y directions for handwritten digits, proposed method on scale-invariants and shearing invariants for unconstrained isolated handwritten digits. Classifications using Backpropagation model with its improved learning strategies are implemented in this study. Clustering technique with Self Organising Map (SOM) and dimension reduction with Principal Component Analysis (PCA) on proposed invariant moments are also highlighted in this thesis.

In feature extraction, a proposed improved formulation on scale-invariant moments is given mainly for unconstrained handwritten digits based on regular moments technique. Several types of features including algebraic and geometric invariants are also discussed.

A computational comparison of these features found that the proposed method is superior than the existing feature techniques for unconstrained isolated handwritten digits.

A proposed method on invariant moments with shearing parameters is also discussed. The formulation of this invariant shearing moments have been tested on unconstrained isolated handwritten digits. It is found that the proposed shearing moment invariants give good results for images which involved shearing parameters.

In character recognition, an improved error signal for hidden layer of backpropagation is proposed based on sigmoid activation function of $1/(1+e^{-2x})$. The proposed method is able to achieve a higher recognition rate compared to a standard backpropagation and Kalman's backpropagation.

PCA is used in this study to reduce the dimension complexity of the proposed moments scale-invariants. The results show that the convergence rates of the proposed scale-invariants are better after reduction process using PCA. This implies that the PCA is an alternative approach for dimension reduction of the moment invariants by using less variables for classification purposes. The results show that the memory storage can be saved by reducing the dimension of the moment invariants before sending them to the classifier. In addition, classifications of unconstrained isolated handwritten digits are extended using clustering technique with SOM methodology. The results of the study show that the clustering of the proposed moments scale-invariants is better visualised with SOM.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah.

PERINGKAT YANG LEBIH TINGGI SKALA TERPUSAT TAKBERUBAH BAGI DIGIT TUNGGAL TULISAN TANGAN TANPA KEKANGAN

Oleh

SITI MARIYAM HJ. SHAMSUDDIN

Mei 2000

Pengerusi : Md. Nasir Sulaiman, Ph. D.

Fakulti : Sains Komputer dan Teknologi Maklumat

Kerja-kerja yang dibentangkan di dalam tesis ini melibatkan kajian pengekstrakan fitur analisis sejagat. Ini termasuk momen takberubah bagi pengskalaan tak sekata pada arah x dan y untuk digit tulisan tangan, kaedah cadangan bagi skala takberubah dan herotan takberubah untuk digit tunggal tulisan tangan tanpa kekangan. Pengkelasan menggunakan model rambatan balik beserta dengan strategi pembelajaran pembaikan dilaksanakan di dalam kajian ini. Teknik kelompok menggunakan Peta Swa-Organisasi (SOM) dan penurunan dimensi menggunakan Analisis Komponen Utama (PCA) terhadap momen takberubah juga diketengahkan di dalam tesis ini.

Dalam pengekstrakan fitur, satu rumus pembaikan terhadap momen skala takberubah dicadangkan untuk digit tulisan tangan tanpa kekangan berdasarkan kepada teknik momen biasa. Pelbagai jenis fitur termasuk aljabar takberubah dan geometri takberubah juga

dibincangkan. Perbandingan perhitungan bagi kesemua fitur ini menunjukkan bahawa kaedah yang dicadangkan adalah lebih baik daripada teknik fitur yang sedia ada bagi digit tunggal tulisan tangan tanpa kekangan.

Satu kaedah cadangan terhadap momen takberubah dengan parameter herotan juga dibincangkan. Rumus terhadap momen herotan takberubah telah diuji terhadap digit tunggal tulisan tangan tanpa kekangan. Didapati bahawa momen herotan takberubah yang dicadangkan memberikan keputusan yang baik bagi imej yang melibatkan parameter herotan.

Dalam pengecaman aksara, satu kaedah isyarat ralat yang telah diperbaiki untuk aras tersembunyi pada rambatan balik dicadangkan berdasarkan fungsi keaktifan sigmoid $1/1+e^{-2x}$. Kaedah yang dicadangkan berupaya memberi kadar pengecaman yang lebih tinggi berbanding dengan rambatan balik piawai dan rambatan balik Kalman.

PCA digunakan dalam kajian ini untuk mengurangkan kesukaran dimensi terhadap momen skala takberubah yang dicadangkan. Hasil yang diperolehi menunjukkan bahawa kadar penumpuan terhadap momen skala takberubah yand dicadangkan adalah lebih baik selepas proses penurunan menggunakan *PCA*. Ini memberi implikasi bahawa kaedah PCA merupakan satu pendekatan alternatif untuk penurunan dimensi bagi momen takberubah dengan menggunakan sedikit pembolehubah bagi tujuan pengkelasan. Keputusan menunjukkan bahawa storan ingatan boleh dijimatkan dengan menurunkan dimensi momen takberubah sebelum dihantar kepada penkgelas. Tambahan pula, pengkelasan terhadap digit tunggal tulisan tangan tanpa kekangan diperluaskan lagi menggunakan teknik

kelompok dengan kaedah SOM. Hasil kajian mendapati bahawa pengkelompokan terhadap momen skala takberubah yang dicadangkan memberi paparan yang lebih baik menggunakan SOM.

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Siti Mariyam Hj. Shamsuddin

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LIST OF ABBREVIATIONS

MLP	Multilayer Perceptron
NZMI	Normalized Zernike Moment Invariants
CSM	Contour Sequence Moments
PCA	Principal Component Analysis
ANNs	Artificial Neural Networks
ADALINE	Adaptive Linear Elements
MADALINE	Multiple Adaptive Linear Elements
LMS	Least Mean Square
BP	Backpropagation
MSE	Mean Square Error
MLSE	Mean Log Square Error
SOM	Self Organising Map
BMU	Best Matching Unit

CHAPTER I

INTRODUCTION

Background

Pattern recognition is an essential part of any high-level image analysis system. The goal of a typical computer vision system is to analyse images of a given scene and recognise the content of the scene. Most of the structures involve four processes when dealing with pattern recognition (Khotanzad and Jiin-Her Lu, 1990).

Handwritten digits recognition has been the focus of considerable research during the last four decades. Scientists and engineers with interests in image processing and pattern recognition have developed various approaches to these problems (Mori *et. al*, 1992). In general, these methods fall into two main categories : global analysis and structural analysis. Global analysis methods use global features of the digits such as characteristic of moment invariants and Fourier descriptors in conjunction with statistical classification methods. While in structural analysis, local features such as loops, endpoints, junctions and their relationships are used in a syntactical classification approach.

Hu [1962] presented in his historical paper on the use of moment invariants in 2-D pattern recognition. He generated a set of moments based on combinations of algebraic invariants. These moments, which are invariant under changes of position,

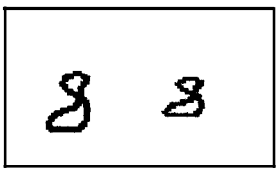

Figure 1 : Digit 8 with Different Scaling

As such, Feng [1994] has generated an aspect invariant moments for images of unequal scaling by forming moment invariants which are independent of the different scalings in the x and y directions as shown below :

$$\eta_{pq} = \frac{\mu_{00}^{\frac{p+1}{2}+1}}{\mu_{20}^{\frac{p+1}{2}} \mu_{02}^{\frac{q+1}{2}}} \mu_{pq}.$$

The experiments on handwritten and handprinted digits show that an aspect invariant moments together with MLP network required only 473 training iterations for convergence and the recognition rate increased to 98.9%. This moments eliminates the need for size normalisation of the unconstrained digits, and their dynamic range remains constant with moment order.

Raveendran *et. al* [1997] presents an alternative formulation of moment invariants based on regular moments. These moments are meant for images of unequal scaling and shifted to the x and y directions and is given as :

$$\tilde{\gamma} = \frac{\tilde{\eta}_{pq}}{\tilde{\eta}_{p+1,q+1}} \qquad \text{for } p,q = 0,1,2,3.....$$

where

$$\tilde{\eta}_{pq} = \left(\frac{\beta}{\alpha}\right)^{\frac{q-p}{2}} \eta_{pq},$$

in which,

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^{\frac{p+q}{2}+1}}$$

According to Raveendran, no assumption was made regarding the values that α or β may assume. These invariants are invariant to equally/unequally scaled, translation and reflection.

Problem Statement

To date, the author finds out that only two contributions (Raveendran *et. al*, 1997; Feng Pan and Mike Keane, 1994) have been done on the reformulation of the regular moments for extracting the features of the handwritten digits. Both approaches considered the use of the moments norm of higher order, but did not use the higher order centralised invariants in the formulation of the moments norm. Thus in this study, the explorations of using higher order centralised moments are

considered for unconstrained isolated handwritten digits of unequal scaling using regular moments.

Objectives of the Research

The objective of this study is to explore the use of higher order centralised scale-invariants in the formulation of the regular moments for scale and translation invarianceness. These include generating feature extraction methodologies which involve geometric moment invariants, aspect invariant moments that leads to an improved scale-invariants with higher order centralized moments. Other objectives include :

- Embedding proposed scale-invariants into Hu's moment invariants which are invariants to translation, scaling and rotation.

- Shearing moment invariants for unconstrained isolated handwritten digits.

- An improved error signal of hidden layer for backpropagation model in the classification phase by introducing a gain factor κ in sigmoid activation function, $1/1+e^{-\kappa x}$.

Contributions of the Research

Major contributions described in this thesis are listed below :

1. Improved scale-invariants using higher order centralised moments for unconstrained isolated handwritten digits, and embodiment of an improved scale-invariants into Hu's moment invariants which are invariants to translation, scaling and rotation.

2. An improved error signal of backpropagation model in the classification phase.

3. Shearing moment invariants for unconstrained isolated handwritten digits.

4. PCA as a method of invariants complexity reduction.

5. SOM technique as an alternative method on clustering proposed invariants.

Organisation of the Thesis

This thesis is organised in accordance with the standard structure of thesis and dissertations at Universiti Putra Malaysia. The thesis has six chapters, including this introductory chapter which covers the background information that leads to an idea of furthering in detail the concept of feature extraction techniques such as

moment invariants for unequal scaling in x and y direction for solving unconstrained isolated handwritten digits.

Chapter II – *Feature Extraction Methods* give brief surveys on the achievements of the previous works, the applications of handwritten digits recognition, and an introduction of the regular moment invariant formulations. It also deals with the preprocessing techniques, which involve image acquisition, image filtering techniques and image thresholding. Feature extraction methods using moment invariants are also discussed for unconstrained isolated handwritten digits which leads to the proposed invariants and shearing invariants for digits of unequal scaling, and will be discussed in chapter IV. Technique of Principal Component Analysis (PCA) is also discussed in this chapter to reduce the dimension of the proposed invariants.

Chapter III – *Neural Network Recognition Methods* discuss neural network classifier which involves standard backpropagation, Kalman's backpropagation and proposed backpropagation for classifying unconstrained isolated handwritten digits with its learning strategies. This chapter also discusses on clustering technique using Self Organising Map (SOM) to cluster the proposed invariants.

Chapter IV – *Methodologies of the Proposed Methods* give detail explanations of the proposed methods on scale-invariants, shearing invariants and backpropagation model.