

DOCTORAL THESIS

Feature extraction in pattern recognition and document analysis by fractal and wavelet

Tao, Yu

Date of Award:
2001

[Link to publication](#)

General rights

Copyright and intellectual property rights for the publications made accessible in HKBU Scholars are retained by the authors and/or other copyright owners. In addition to the restrictions prescribed by the Copyright Ordinance of Hong Kong, all users and readers must also observe the following terms of use:

- Users may download and print one copy of any publication from HKBU Scholars for the purpose of private study or research
- Users cannot further distribute the material or use it for any profit-making activity or commercial gain
- To share publications in HKBU Scholars with others, users are welcome to freely distribute the permanent URL assigned to the publication

Feature Extraction in Pattern Recognition
and Document Analysis by Fractal and Wavelet

TAO Yu

A thesis submitted in partial fulfillment of the requirements
for the degree of
Doctor of Philosophy

April 2001

Hong Kong Baptist University

Abstract

This work addresses several issues in the topic of feature extraction based on fractal and wavelet including the theory and experiments for pattern recognition and document analysis. We are investigating the utility of several emerging techniques to extract the feature from regions of the image. These methods include utilizing fractal features to enhance pattern discrimination, central projection transform to describe the shape of a region, and wavelet features to aid in segmentation and boundary identification. Use of these new techniques has yielded very promising results.

In particular, the new method of feature extraction reduces the dimensionality of a two-dimensional pattern by way of a central projection method, and thereafter, performs Daubechies' wavelet transform on the derived one-dimensional pattern to generate a set of wavelet transform sub-patterns, namely, curves that are non-self-intersecting. The divider dimensions are readily computed from the resulting non-self-intersecting curve. These divider dimensions constitute a new feature vector for the original two-dimensional pattern, defined using the curves' fractal dimensions. Once these feature vectors have been captured, we can compare them to the training set by calculating the Euclidean Distance between the different feature vectors. The smallest distance will be selected for matching and classifying.

Variance in orientation is one of the common intrinsic uncertainties in pattern recognition. To solve this problem, a novel method of feature extraction with rotation invariant property is presented in this thesis. One of the main contributions of this study is that a rotation invariant signature of two-dimensional contours based on the fractal theory is proposed. The rotation invariant signature is a measure of the fractal dimensions, which is rotation invariant based on a series of central projection transform (CPT) groups. As the CPT is applied to a two-dimensional object, a unique

contour is obtained. In the unfolding processing, this contour is further spread into a central projection unfolded curve, which can be viewed as a periodic function due to the different orientations of the pattern. We consider the unfolded curves to be non-empty and bounded sets in \mathbb{R}^n , and the box computing dimension is applied to them. It has been proved that the box computing dimensions of the central projection unfolded curves of a rotated pattern are equal to each other, i.e. the central projection unfolded curves with respect to the box computing dimension are rotation invariant.

In this study, a new approach based on modified fractal signature (MFS) and modified fractal feature (MFF) for script classification and handwritten signature verification is also developed in this thesis. The modified fractal signature approach has been chosen to extract the geometric structure of the document image. The upper and bottom layers are used to segment the document image into small blocks. Then, according to the modified fractal feature algorithm described in this thesis, the MFF value of every block is obtained. The MFF will be used in the identification and classification of a selected set of document images with good results.

Contents

Declaration	i
Abstract	ii
Acknowledgements	iv
Table of Contents	v
List of Tables	ix
List of Figures	x
List of Symbols	xiv
List of Abbreviation	xv
1 Introduction	1
1.1 Background to the Research	1
1.2 Contributions of this Thesis	3
1.3 Outline of this Thesis	4
2 Feature Extraction in Pattern Recognition	6
2.1 Methodology	6
2.2 Feature Extraction	8
2.3 General Approaches to Feature Extraction	10
2.3.1 Nature of the Feature	11
2.3.2 Feature Reduction	11
2.3.3 The Guidelines of Feature Extraction	14
2.3.4 Feature Extraction Schemes	15
2.4 Related Feature Extraction Methods	18
2.4.1 Entropy Minimization	18
2.4.2 Fractal	24

2.4.3	Wavelet	26
3	Theories of Fractal and Wavelet	30
3.1	Basic Concepts of Fractal Theory	30
3.1.1	Definitions of Fractals	30
3.1.2	Hausdorff Dimension	32
3.1.3	Box Computing Dimension	36
3.1.4	Minkowski Dimension	42
3.2	Basic Concepts of Wavelet Transform	45
3.2.1	Continuous Wavelet Transform	46
3.2.2	Basic Concept of Multiresolution Analysis	47
3.2.3	Mathematical Definitions of Multiresolution Analysis	48
4	Central Projection Transform (CPT)	52
4.1	Basic Definitions of CPT	52
4.2	Properties of CPT	57
4.3	Parallel Algorithm for CPT	58
4.4	Contour Unfolding	60
5	Information Distribution of the Central Projection Method for Chinese Character Recognition	62
5.1	Introduction	62
5.2	Analysis of the Information Content of Chinese Characters	65
5.3	Analysis of Information Content Based on Central Projection	68
5.4	Experiments	73
5.5	Conclusions	74
6	Combination of Fractal and Wavelet for Feature Extraction	76
6.1	Introduction	76
6.2	Dimensionality Reduction Based on Central Projection	77
6.2.1	The Traditional Projection Operation	77
6.2.2	The Central Projection Transform (CPT)	78
6.3	Multiresolution Analysis and Wavelet Decomposition	79
6.3.1	Construction of 1-D Orthonormal Wavelet Basis	80
6.3.2	Sub-Pattern Produce by Wavelet Decomposition	81

6.4	Computing Divider Dimension of 1-D Patterns	85
6.5	Experiments	86
6.5.1	Experimental Procedure	87
6.5.2	Traditional Fourier Descriptors	89
6.5.3	The Weighted Euclidean Distance (WED) Classifier	89
6.5.4	Experimental Results	90
6.6	Conclusions	93
7	Implementation of Rotation Invariant by Fractal and CPT	97
7.1	Introduction	97
7.2	Feature Extraction with Rotation Invariant Property	98
7.2.1	Rotations	98
7.2.2	Rotation Invariants	100
7.2.3	Rotation Invariant of discrete Images	103
7.3	Rotation Invariants in Invariant Pattern Recognition	107
7.3.1	Boundary Curvature	108
7.3.2	Fourier Descriptors	109
7.3.3	Zernik Moments	109
7.3.4	Neural Networks	110
7.4	Rotation Invariance Based on Box Computing Dimension	111
7.4.1	Estimation of the 1-D Fractal Dimension	111
7.4.2	Rotation Invariant Signature (RIS)	113
7.5	RIS Algorithm	121
7.5.1	Preprocessing	121
7.5.2	CPT Operation	122
7.5.3	Estimating the BCD	124
7.5.4	The Extraction of Feature with Rotation Invariant Property	125
7.6	Experiments	127
7.6.1	Experimental Procedure	127
7.6.2	Experimental Results	130
7.7	Conclusions	134

8	Extraction of Feature from Documents by Fractal Dimension	135
8.1	Introduction	135
8.2	Document Analysis Based on Fractal Feature	138
8.2.1	δ -Parallel Bodies	139
8.2.2	Blanket Technique to Extract Fractal Feature	143
8.3	Algorithm	146
8.3.1	Extracting Geometric Structure From Document Image	146
8.3.2	Modified Fractal Feature	149
8.4	Experiments	152
8.4.1	Preprocessing	152
8.4.2	Classification of Oriental and Euramerican Scripts	153
8.4.3	Handwritten Signature Verification	156
8.5	Conclusions	159
9	Conclusions and Further Work	163
	Bibliography	165
	Publications	173
	Curriculum Vitae	176