

TABLE OF CONTENTS

| CHAPTER | TITLE | PAGE |
|---------|-------------------------------|----------|
| | DECLARATION | ii |
| | DEDICATION | iii |
| | ACKNOWLEDGEMENTS | iv |
| | ABSTRACT | v |
| | ABSTRAK | vi |
| | TABLE OF CONTENTS | vii |
| | LIST OF TABLES | xi |
| | LIST OF FIGURES | xiii |
| | LIST OF ABBREVIATIONS | xv |
| | LIST OF APPENDICES | xvi |
| 1 | INTRODUCTION | 1 |
| | 1.1 Introduction | 1 |
| | 1.2 Problem Background | 3 |
| | 1.3 Problem Statement | 4 |
| | 1.4 Importance of the Study | 4 |
| | 1.5 Objectives of the Project | 5 |
| | 1.6 Scopes of the Project | 6 |
| | 1.7 Summary | 6 |

| | | |
|----------|---|-----------|
| 2 | LITERATURE REVIEW | 7 |
| 2.1 | Introduction | 7 |
| 2.2 | Moment Invariants | 9 |
| 2.2.1 | Zernike Moment Invariant | 11 |
| 2.2.2 | Legendre Moment Invariant | 13 |
| 2.2.3 | Tchebichef Moment Invariant | 15 |
| 2.3 | Implementation of Moment Invariant in Pattern Recognition Applications | 16 |
| 2.3.1 | Face Recognition | 17 |
| 2.3.2 | Optical Character Recognition | 18 |
| 2.3.3 | Other Pattern Recognition Applications | 19 |
| 2.4 | Artificial Neural Networks | 21 |
| 2.4.1 | General Regression Neural Networks | 21 |
| 2.5 | Neural Networks Implementation | 24 |
| 2.6 | Summary | 25 |
| | | |
| 3 | METHODOLOGY | 26 |
| 3.1 | Introduction | 26 |
| 3.2 | Research Framework | 27 |
| 3.3 | Software Requirement | 28 |
| 3.4 | Image Source | 28 |
| 3.5 | Image Pre-processing | 29 |
| 3.6 | Feature Extraction | 30 |
| 3.6.1 | ZMI Algorithm | 31 |
| 3.6.2 | LMI Algorithm | 33 |
| 3.6.3 | TMI Algorithm | 34 |
| 3.7 | Intra-class Analysis | 35 |
| 3.8 | Inter-class Analysis | 37 |
| 3.9 | Data Pre-processing | 38 |
| 3.10 | Classification by Neural Networks | 39 |
| 3.11 | Inter-class Analysis | 40 |
| 3.12 | Summary | 42 |

| | | |
|----------|---|-----------|
| 4 | IMPLEMENTATION, COMPARISON OF RESULTS AND DISCUSSION | 43 |
| 4.1 | Introduction | 43 |
| 4.2 | Leaf Images | 44 |
| 4.3 | Result of Intra-class Analysis | 46 |
| 4.3.1 | Absolute Error | 48 |
| 4.3.2 | Percentage Absolute Error (PAE) | 50 |
| 4.3.3 | Percentage Min Absolute Error 1 (PMAE1) | 52 |
| 4.3.4 | Percentage Min Absolute Error 2 (PMAE2) | 53 |
| 4.3.5 | Total Percentage Mean Absolute Error (TPMAE) | 54 |
| 4.4 | Result of Inter-class Analysis | 55 |
| 4.4.1 | Comparison Based On Value of Feature Vectors | 55 |
| 4.4.2 | Comparison Based On Computational Time | 58 |
| 4.5 | Analysis of Feature Extraction Results | 59 |
| 4.6 | Classification Phase | 59 |
| 4.6.1 | Data Preparation | 60 |
| 4.6.2 | GRNN Spread Parameters Declaration | 60 |
| 4.7 | Classification Results of GRNN Classifier | 61 |
| 4.8 | Summary | 64 |
| 5 | DISCUSSION AND CONCLUSION | 65 |
| 5.1 | Introduction | 65 |
| 5.2 | Discussion of Results | 65 |
| 5.3 | Problems and Limitations of Research | 67 |
| 5.4 | Recommendation for Future Works | 67 |
| 5.5 | Conclusion | 68 |

| | |
|-----------------------|----------------|
| REFERENCES | 70 |
| APPENDICES A-H | 75 - 96 |

LIST OF TABLES

| TABLE NO. | TITLE | PAGE |
|------------------|---|-------------|
| 2.1 | List of face recognition applications that use moment invariants | 17 |
| 2.2 | List of OCR applications that use moment Invariants | 19 |
| 2.3 | List of other pattern recognition applications that use moment invariants | 20 |
| 2.4 | List of applications that use neural networks as classifier | 24 |
| 3.1 | The value of scaling and rotation factors | 30 |
| 4.1 | List of image name | 44 |
| 4.2 | Scaling and rotation factors of image A1 | 46 |
| 4.3 | Value of feature vectors using ZMI | 47 |
| 4.4 | Value of feature vectors using LMI | 47 |
| 4.5 | Value of feature vectors using TMI | 48 |
| 4.6 | Absolute Error for ZMI | 49 |
| 4.7 | Absolute Error for LMI | 49 |
| 4.8 | Absolute Error for TMI | 50 |
| 4.9 | PAE for image A1 with rotate factor of 10° | 51 |
| 4.10 | TPMAE of different moments for image A1 | 54 |

| | | |
|------|---|----|
| 4.11 | Value of feature vectors of four images for ZMI | 56 |
| 4.12 | Value of feature vectors of four images for LMI | 56 |
| 4.13 | Value of feature vectors of four images for TMI | 56 |
| 4.14 | Computational time taken in seconds | 58 |
| 4.15 | GRNN result for each spread parameters | 62 |

LIST OF FIGURES

| FIGURE NO. | TITLE | PAGE |
|-------------------|--|-------------|
| 2.1 | GRNN architecture | 23 |
| 3.1 | Process involve in research framework | 27 |
| 3.2 | Algorithm of Basic_GMI() computation | 32 |
| 3.3 | Algorithm of ZMI computation | 32 |
| 3.4 | Algorithm of Norm() computation | 33 |
| 3.5 | Algorithm of LMI computation | 34 |
| 3.6 | Algorithm of TMI computation | 35 |
| 3.7 | Process of training, validation and testing phase in neural network | 40 |
| 4.1 | Leaf images | 44 |
| 4.2 | An image A1 with its various rotations and scaling factor | 45 |
| 4.3 | PAE graph for image A1 with rotate factor of 10° | 51 |
| 4.4 | PMAE1 graph for image A1 with image variation | 52 |
| 4.5 | PMAE2 graph for image A1 with different dimension | 53 |
| 4.6 | TPMAE graph of different moments for image A1 | 54 |
| 4.7 | Comparison value of feature vectors based on leaf class | 57 |

| | | |
|------|--|----|
| 4.8 | Comparison value of feature vectors based on leaf class for original image | 57 |
| 4.9 | k-fold partition of the dataset | 60 |
| 4.10 | Graph of PCC versus spread parameter value | 63 |
| 4.11 | Graph of time average versus spread parameter value | 63 |

LIST OF ABBREVIATIONS

| | | |
|--------------|---|---|
| AE | – | Absolute Error |
| ANN | – | Artificial Neural Network |
| BPN | – | Back-propagation Neural Network |
| GMI | – | Geometric Moment Invariant |
| GRNN | – | General Regression Neural Network |
| IEC | – | Invariant Error Computation |
| <i>k</i> -NN | – | <i>k</i> -nearest neighbor |
| LMI | – | Legendre Moment Invariant |
| MLPN | – | Multilayer Perceptron Neural Network |
| MMC | – | Moving Median Centers |
| NCC | – | Number of Correct Classification |
| OCR | – | Optical Character Recognition |
| PAE | – | Percentage Absolute Error |
| PCA | – | Principal Components Analysis |
| PCC | – | Percentage of Correct Classification |
| PMAE1 | – | Percentage of Mean Absolute Error 1 |
| PNN | – | Probabilistic Neural Network |
| RBFNN | – | Radial Basis Function Neural Network |
| RBPNN | – | Radial Basis Probabilistic Neural Network |
| TIFF | – | Tagged Image File Format |
| TMI | – | Tchebichef Moment Invariant |
| ZMI | – | Zernike Moment Invariant |

LIST OF APPENDICES

| APPENDIX | TITLE | PAGE |
|-----------------|---------------------------------|-------------|
| A | Project 1 Gantt Chart | 75 |
| B | Project 2 Gantt Chart | 77 |
| C | Original Leaf Images | 79 |
| D | Binary Leaf Images | 81 |
| E | Image References | 83 |
| F | Value of Feature Vectors By ZMI | 85 |
| G | Value of Feature Vectors By LMI | 89 |
| H | Value of Feature Vectors By TMI | 93 |