



**Graduate Mechatronics Engineering Program
School of Engineering**

**Online Video - Based Arabic Handwriting
Recognition System**

**Thesis for Master of Science in Mechatronics
Engineering**

Submitted by:
Husamudin Hajjaj

Supervised By

Dr. Khaled Assaleh
Dr. Tamer Shanableh

May, 30, 2007

ACKNOWLEDGEMENTS

I'm grateful to my supervisors Dr. Khaled Assaleh and Dr. Tamer Shanableh for their skillful, support and guidance throughout my study. Their encouragement and effort resulted in achieving great results. Also, I appreciate their patience with me.

I wish to acknowledge my sincere gratitude to Dr. Mohammad Al-Jarrah, director of mechatronics graduate program, for his kind support.

Also, I acknowledge Eng. Samer Akoom for his efforts in revising the English language of the thesis.

Last but not least, I would like to thank my family and friends for their endless love and support.

ABSTRACT

In the recent years, handwriting recognition systems started to have a major role in the new technology such as computers, mobile phones and hand-held devices to enhance the interaction between humans and these systems. With this in mind, non-Arabic handwriting recognition systems plot far distances compared to their Arabic counterparts. This is surprising given that the Arabic language is spoken by Arabs in over 20 countries and roughly associated with the geographic region of the Middle East and North Africa. Nevertheless it is also spoken as a second language by the people of several Asian countries in which Islam is the principal religion (e.g. Indonesia). Moreover, languages such as Farsi, Urdu, Malay, and some West African languages have adopted the Arabic alphabet for writing.

Another fact is that most of Arabic contributions focused on off-line systems while a few proposed methods were introduced for on-line handwriting recognition in the last two decades. Therefore, on-line Arabic systems still have reduced accuracy and user-friendliness compared to non-Arabic counterparts. Although non-Arabic systems started to include video processing in the recognition process, Arabic ones have not used them yet.

This thesis proposes a unique method that will extract features from live-video frames, which describe the hand movements during writing a letter. The extraction of the dynamic features from row images is achieved by using Temporal and Spatial analysis and classifying the letters using KNN and HMM classifiers.

The experiment results shows a promising recognition rate of 99.11% using KNN classifier and 96.43% using HMM one.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS.....	ii
ABSTRACT.....	iii
LIST OF FIGURES.....	vii
LIST OF TABLES.....	ix
CHAPTER 1 INTRODUCTION.....	10
1.1 Handwriting Recognition Systems (HR Recognition).....	10
1.2 Online & Offline operation mode	10
1.3 Recognition System User Dependence	11
1.4 Constraints on Arabic Handwriting Style	11
1.4.1 Letter Connectivity	11
1.4.2 Dots effects	12
1.4.3 Overlapping property	12
1.4.4 Shape Variability	13
1.4.5 Fonts Variability	13
1.5 On-line Arabic Handwriting Review	14
1.6 Video Based Handwriting Recognition Systems Review	16
1.7 Thesis Organization.....	18
CHAPTER 2 METHODOLOGY.....	20
CHAPTER 3 DATABASE COLLECTION.....	23
3.1 Instrumentation.....	23
3.1.1 System Setup.....	23
3.1.2 Video Settings.....	24
3.1.2.1 Capturing Resolution:.....	24
3.1.2.2 Frame Rate:.....	24
3.1.2.3 Triggering Rate:.....	25

3.2.3	Capturing Conditions	26
3.2.3.1	Lighting:	26
3.2.3.2	Camera's Position:.....	26
3.2.3.3	Writing Style:	26
3.2.3.4	Database size:	26
3.2	Letter's Movements Analysis.....	27
3.2.1	Flattened – Base movements	27
3.2.2	Half - Circular movements.....	27
3.2.3	Narrow - Angled movements.....	28
3.2.4	Elliptic – Started movements	29
3.2.5	Saw-toothed movements	29
3.2.6	Arc movements	30
3.2.7	Linear movements.....	31
3.2.8	Flattened with Tiny circle movements.....	31
3.2.9	Reverse L movements.....	32
3.2.10	Full Circular movements.....	33
3.2.11	Multi - Curved movements	33
CHAPTER 4	FEATURE EXTRACTION.....	34
4.1.	Temporal Analysis	34
4.2	Spatial Analysis.....	37
4.2.1	Image alignment via principle component analysis (PCA)	37
4.2.2	Discrete Cosine Transformation	37
4.2.3	ADs Projection.....	38
4.2.4	Walsh - Hadamard Transform	38
4.3	Feature Extraction Schemes	39
4.3.1	Absolute Accumulative Differences	39
4.3.2	Polar Accumulative Differences	39

4.3.3	Vectorized Accumulative Differences	40
4.3.4	1-D Projected Accumulative Differences	40
4.3.5	2-D Projected Accumulative Differences	41
4.3.6	Two-tier weighted Accumulative Differences:.....	41
4.3.7	Walsh – Hadamard (WH):	42
CHAPTER 5 CLASSIFICATION		43
5.1	KNN Classifiers.	43
5.1.1	Leave N out estimation	43
5.1.2	Classification Evaluation	44
5.2	HMM Classifier.....	45
5.2.1	Letter modeling using HMM	45
5.2.1.1	Hidden States Probability A :	45
5.2.1.2	Observable States Probability B :	46
5.2.1.3	Initial states probability π :	47
5.2.2	The learning process:	47
5.2.2.1	Forward Processing:	48
5.2.2.2	Backward Processing:.....	48
5.2.2.3	Parallel Processing:.....	48
5.2.3	The Validating process:	50
5.2.4	The evaluation method:.....	50
CHAPTER 6 EXPERIMENTAL RESULTS		51
6.1	KNN Classification	51
6.2	HMM Classification.....	59
6.3	Conclusion.....	61
REFERENCES.....		62
APPENDIX.....		64

LIST OF FIGURES

Figure	page
Figure 1-1 One motion includes 3 letters	11
Figure 1-2 15 Primary letters	12
Figure 1-3 example of words with possible dotting ambiguity	12
Figure 1-4 Overlapped letters	12
Figure 1-5 Different letter shapes for different locations in the word	13
Figure 1-6 Two different Fonts, Traditional and Roq'aa	13
Figure 1-7 Video processing enhances the recognition process	17
Figure 2-1 System Overviews	20
Figure 2-2 Flatted – based letters	21
Figure 2-3 On-line Video-based handwriting recognition system	21
Figure 3-1 System's Setup	23
Figure 3-2 Unique frames captured from the hand movements	25
Figure 3-3 Flatted – based letters	27
Figure 3-4 Half – Circular movements	28
Figure 3-5 Narrow – Angled movements	28
Figure 3-6 Elliptic – Started movements	29
Figure 3-7 Saw- Toothed movements	30
Figure 3-8 Arc movements	30
Figure 3-9 Linear movements	31
Figure 3-10 Flatted with Tiny circle movements	32
Figure 3-11 Reverse - L movements	32
Figure 3-12 Full Circular movements	33
Figure 3-13 Multi – Curved movements	33
Figure 4-1 (a) Hand movements for letter ح , (b) Absolute AD, (c) Positive AD, (d) Negative AD	36
Figure 4-2 (a) Absolute AD for letter ع with tilted handwriting angle, (b) with correct handwriting angle, (c) PCA is applied	38
Figure 4-3 Absolute AD	39
Figure 4-4 <i>Polar ADs</i>	40
Figure 4-5 <i>Vector ADs</i>	40
Figure 4-6 1D - Projected ADs	41

Figure 4-7 2D – Projected ADs	41
Figure 4-8 Two-tier weighted Accumulative Differences	42
Figure 4-9 WH Transform Scheme	42
Figure 5-1 Leave Tow Out confusion matrix	44
Figure 5-2 Hidden states for writing letter ب	46
Figure 5-3 Hidden Markov Chains for letter ب	46
Figure 5-4 Baum – Welsh Algorithm	47
Figure 5-5 HMM Recognizer	50
Figure 6-1 Zonal Cutoffs and classifier's recognition rate	51
Figure 6-2 Image Size and recognition rate	52
Figure 6-3 Threshold and recognition rate	53
Figure 6-4 Confusion Matrix for the Polar ADs for user 1	55
Figure 6-5 Confusion Matrix for the Polar ADs for user 2	56
Figure 6-6 Performance of two-tier weighted ADs for user 1	57
Figure 6-7 Performance of two-tier weighted ADs for user 2	58
Figure A-1 Example of writing letter (ع) for user 1	64
Figure A-2 Example of writing letter (و) for user 1	65
Figure A-3 Example of writing letter (ص) for user 2	65
Figure A-4 Example of writing letter (ج) for user 2	66

LIST OF TABLES

Table	page
Table 1-1 Results of the Previous Work	16
Table 6-1 Recognition rate of different ADs schemes	56