

TABLE OF CONTENTS

CANDIDATE'S DECLARATION	<i>ii</i>
ABSTRACT	<i>iii-vi</i>
DEDICATION	<i>vii</i>
ACKNOWLEDGEMENTS	<i>viii-xi</i>
TABLE OF CONTENTS	<i>xii-xvii</i>
LIST OF FIGURES	<i>xviii-xxi</i>
LIST OF TABLES	<i>xxii-xxiii</i>
LIST OF RELATED PUBLICATIONS	<i>xxiv-xxv</i>
LIST OF STTP/FDP/SEMINARS/TALKS/WEBINARS.....	<i>xxvi-xxviii</i>
LIST OF ABBREVIATIONS	<i>xxix-xxxiii</i>
CHAPTER 1: INTRODUCTION	1-34
1.1 OVERVIEW	1-2
1.2 HANDWRITTEN WORD RECOGNITION	2-6
1.2.1 Online Handwritten Word Recognition	3
1.2.2 Offline Handwritten Word Recognition	3-6
1.2.2.1 Segmentation Based or Analytical Approach...	4-5
1.2.2.2 Segmentation Free or Holistic Approach	5-6
1.2.2.3 Hybrid Approach.....	6
1.3 APPLICATIONS AND CHALLENGES	6-10
1.3.1 Applications of Handwritten Word Recognition	6-7
1.3.2 Challenges of Handwritten Word Recognition	7-10
1.4 PROS AND CONS	10-13
1.4.1 Pros of Handwritten Word Recognition.....	11-12
1.4.2 Cons of Handwritten Word Recognition.....	12-13
1.5 OVERVIEW OF DEVANAGARI SCRIPT	13-14
1.6 PHASES OF AN OFFLINE HANDWRITTEN WORD RECOGNITION SYSTEM.....	14-30
1.6.1 Data Collection	14
1.6.2 Image Acquisition and Digitization	14-15
1.6.3 Pre-processing	15-17

1.6.4	Segmentation	17
1.6.5	Feature Extraction	17-18
1.6.5.1	Statistical Feature Extraction	17-18
1.6.5.2	Structural Feature Extraction	18
1.6.5.3	Deep Feature Extraction	18
1.6.6	Classification	18-28
1.6.6.1	Decision Tree (DT)	19-20
1.6.6.2	Extreme Learning Machine (ELM)	21-22
1.6.6.3	Gaussian Naive Based (Gaussian NB)	22
1.6.6.4	K-Nearest Neighbor (KNN)	22-24
1.6.6.5	Multi-Layer Perceptron (MLP)	24
1.6.6.6	Naive Bayes (NB)	24-25
1.6.6.7	Random Forest (RF)	25-26
1.6.6.8	Support Vector Machine (SVM)	26-27
1.6.6.9	Extreme Gradient Boosting (XGBoost)	27-28
1.6.7	Performance Evaluation	28-30
1.6.7.1	Recognition Accuracy (RA)	28
1.6.7.2	Precision (PR)	29
1.6.7.3	Recall (RL)	29
1.6.7.4	F1-Score (FS)	29
1.6.7.5	False Acceptance Rate (FAR)	29-30
1.6.7.6	False Rejection Rate (FRR)	30
1.6.7.7	Matthew's Correlation Coefficient (MCC)	30
1.6.7.8	Area Under the Curve (AUC)	30
1.7	OBJECTIVES OF THE PROPOSED WORK	31
1.7.1	Assumptions.....	31
1.8	MAJOR CONTRIBUTIONS AND ACHIEVEMENTS.....	31-32
1.9	ORGANIZATION OF THE THESIS.....	32-33
CHAPTER 2: HISTORICAL PERSPECTIVE	35-70	
2.1	OVERVIEW.....	35-36
2.2	LITERATURE REVIEW	36-64
2.2.1	Based on Methods Considered	36-45
2.2.1.1	Feature Extraction Methods	36-40

2.2.1.2	Classification Methods	40-44
2.2.1.3	Deep Learning Methods	44-45
2.2.2	Based on Recognition Considered	45-64
2.2.2.1	Numeral/Digit Recognition.....	46-47
2.2.2.2	Word/Text Recognition	47-54
2.2.2.3	Isolated Character Recognition	54-61
2.2.2.4	Script Recognition	61-64
2.3	COMPARATIVE STUDY	64-68
2.3.1	Research Gaps	66-67
2.3.2	Deep Learning based Approaches and Research Challenges.....	67-68
2.4	DISCUSSION	68-69
CHAPTER 3: DATA COLLECTION, DIGITIZATION AND PRE-PROCESSING		71-82
3.1	DATA COLLECTION	71-73
3.2	DIGITIZATION	73
3.3	PRE-PROCESSING	73-74
3.4	PERFORMANCE ANALYSIS OF THINNING ALGORITHMS FOR OFFLINE HANDWRITTEN DEVANAGARI WORDS	74-82
3.4.1	Overview of Thinning Algorithms	74-75
3.4.1.1	A Brief Overview of [ZSu] Algorithm	74
3.4.1.2	A Brief Overview of [GHa] Algorithm	74-75
3.4.1.3	A Brief Overview of [LKC] Algorithm	75
3.4.2	Performance Metrics	75-77
3.4.2.1	Reduction Rate (RR)	75-76
3.4.2.2	Sensitivity Measurement (SM)	76
3.4.2.3	Thinness Measurement (TM)	76-77
3.4.2.4	Mean Opinion Score (MoS)	77
3.4.3	Performance Analysis and Discussion	77-82
3.5	CHAPTER SUMMARY	82
CHAPTER 4: OFFLINE HANDWRITTEN DEVANAGARI WORD RECOGNITION SYSTEM BASED ON GRADIENT AND STRUCTURAL FEATURES		83-94

4.1	INTRODUCTION.....	83-84
4.2	FEATURE EXTRACTION TECHNIQUES	84-87
4.2.1	Gradient-based Features	85-86
4.2.2	Structural-based Features	86-87
4.3	CLASSIFICATION TECHNIQUES.....	87
4.4	EXPERIMENTAL RESULTS AND DISCUSSION	88-92
4.4.1	System Performance based on Recognition Accuracy (%)	88-89
4.4.2	System Performance based on FAR (%).....	89-90
4.4.3	System Performance based on FRR (%).....	90-91
4.4.4	System Performance based on Precision (%).....	91-92
4.5	ANALYSIS BASED ON EXPERIMENT RESULTS	93
4.6	CHAPTER SUMMARY	93-94
CHAPTER 5: RECOGNITION SCHEME FOR OFFLINE HANDWRITTEN DEVANAGARI WORDS BASED ON MAJORITY VOTING METHODOLOGY.....		95-112
5.1	INTRODUCTION.....	95-96
5.2	FEATURE EXTRACTION TECHNIQUES	96-100
5.2.1	Intersection & Open-End Point-based Features	96-97
5.2.2	Elliptical-based Features	97-99
5.2.3	Arnold Transform-based Features.....	99-100
5.3	MAJORITY VOTING METHODOLOGY.....	100-101
5.4	EXPERIMENTAL RESULTS AND DISCUSSION.....	101-109
5.4.1	Performance Analysis based on Recognition Accuracy (%)	102-103
5.4.2	Performance Analysis based on FAR (%).....	103
5.4.3	Performance Analysis based on FRR (%).....	104-105
5.4.4	Performance Analysis based on Precision (%).....	105-106
5.4.5	Performance Analysis based on F1-Score (%).....	106-107
5.4.6	Performance Analysis based on MCC	107-108
5.4.7	Performance Analysis based on AUC (%).....	108-109
5.5	COMPARISON WITH THE STATE-OF-THE-ART METHODS AND SYNTACTIC ANALYSIS	110-111
5.6	CHAPTER SUMMARY	111-112

CHAPTER 6: OFFLINE HANDWRITTEN DEVANAGARI WORD RECOGNITION SYSTEM USING ADAPTIVE BOOSTING APPROACH.....	113-128
6.1 INTRODUCTION.....	113
6.2 FEATURE EXTRACTION TECHNIQUES	114-117
6.2.1 Uniform Zoning-based Features	114-115
6.2.2 Peak Extent-based Features	115-116
6.2.3 Gabor Filter-based Features	116-117
6.3 ADAPTIVE BOOSTING (ADABOOST) APPROACH	117-118
6.4 EXPERIMENTAL RESULTS AND DISCUSSION	118-122
6.4.1 Recognition Results in terms of Recognition Accuracy (%)	119
6.4.2 Recognition Results in terms of FAR (%).....	119-120
6.4.3 Recognition Results in terms of FRR (%).....	120-121
6.4.4 Recognition Results in terms of F1-Score (%).....	121
6.4.5 Recognition Results in terms of AUC (%).....	121-122
6.5 COMPARISON WITH THE STATE-OF-THE-ART WORK AND SYNTACTIC ANALYSIS	122-126
6.6 CHAPTER SUMMARY	126-127
CHAPTER 7: RECOGNITION OF OFFLINE HANDWRITTEN DEVANAGARI WORDS USING GRADIENT BOOSTED DECISION TREE (GBDT) APPROACH	129-146
7.1 INTRODUCTION.....	129
7.2 FEATURE EXTRACTION TECHNIQUES	130-133
7.2.1 Uniform Zoning-based Features	130-131
7.2.2 Diagonal-based Features	131-132
7.2.3 Centroid-based Features	133
7.3 GRADIENT BOOSTED DECISION TREE (GBDT) APPROACH	134
7.4 EXPERIMENTAL RESULTS AND DISCUSSION	134-141
7.4.1 System Performance based on Recognition Accuracy (%)..	135-136
7.4.2 System Performance based on FAR (%).....	136-137
7.4.3 System Performance based on FRR (%).....	137-138
7.4.4 System Performance based on F1-Score (%).....	138-139
7.4.5 System Performance based on MCC	139-140

7.4.6	System Performance based on AUC (%).....	140-141
7.5	COMPARISON WITH THE STATE-OF-THE-ART WORK AND SYNTACTIC ANALYSIS	141-145
7.6	CHAPTER SUMMARY	145-146
CHAPTER 8: VGG16: AN EFFICIENT APPROACH FOR OFFLINE HANDWRITTEN DEVANAGARI WORD RECOGNITION USING DEEP FEATURES AND XGBOOST.....		147-160
8.1	INTRODUCTION.....	147-148
8.2	VGG16 AS FEATURE EXTRACTOR	148-149
8.3	XGBOOST (EXTREME GRADIENT BOOSTING) APPROACH.	149
8.4	EXPERIMENTAL RESULTS AND DISCUSSION.....	149-155
8.4.1	Performance Analysis based on Recognition Accuracy (%)	150-151
8.4.2	Performance Analysis based on Precision (%).....	151-152
8.4.3	Performance Analysis based on Recall (%).....	152-153
8.4.4	Performance Analysis based on F1-Score (%).....	153-154
8.4.5	Performance Analysis based on AUC (%).....	154-155
8.5	COMPARISON WITH THE STATE-OF-THE-ART WORK AND SYNTACTIC ANALYSIS	155-158
8.6	CHAPTER SUMMARY	158-159
CHAPTER 9: CONCLUSIONS AND FUTURE DIRECTIONS.....		161-168
9.1	OVERVIEW	161-162
9.2	BRIEF CONTRIBUTIONS OF THE WORK	162-166
9.3	MAJOR CONCLUSIONS	166
9.4	FUTURE SCOPE OF THE WORK	166-167
REFERENCES		169-182
APPENDIX-I: DATABASE COLLECTION FORM		183