

CONTENTS

| | |
|---|------------|
| Abstract | v |
| Resum | vii |
| Resumen | ix |
| Contents | xi |
| 1 Introduction | 1 |
| 1.1 Scientific Goals | 2 |
| 1.2 Document Structure | 3 |
| Bibliography | 5 |
| 2 Preliminaries | 7 |
| 2.1 Handwritten Text Recognition | 8 |
| 2.2 Preprocess Methods | 10 |
| 2.2.1 Slant Correction | 10 |
| 2.2.2 Vertical Size Normalization | 11 |
| 2.2.3 Otsu's Method | 11 |
| 2.3 n -gram Models | 12 |
| 2.4 EM Algorithm | 14 |
| 2.5 Evaluation Metrics | 15 |
| Bibliography | 17 |
| 3 Databases | 19 |
| 3.1 CENPARMI Arabic cheque database | 20 |
| 3.2 IAM Handwriting Database | 22 |
| 3.2.1 IAM word dataset | 24 |
| 3.2.2 IAM line dataset | 24 |

| | | |
|----------|--|-----------|
| 3.3 | IFN/ENIT - database | 25 |
| 3.4 | RIMES database | 27 |
| 3.5 | GERMANA database | 28 |
| 3.6 | RODRIGO database | 29 |
| | Bibliography | 33 |
| 4 | Bernoulli Hidden Markov Models | 35 |
| 4.1 | Introduction | 36 |
| 4.2 | HMMs | 36 |
| 4.2.1 | Parameter Estimation | 37 |
| 4.2.2 | Search for the Most Likely State Transition Sequence | 40 |
| 4.3 | Bernoulli Hidden Markov Model (BHMM) | 40 |
| 4.4 | Experiments | 42 |
| 4.5 | Concluding Remarks | 43 |
| | Bibliography | 47 |
| 5 | Embedded Bernoulli Mixture HMMs | 49 |
| 5.1 | Introduction | 50 |
| 5.2 | Embedded BHMMs | 51 |
| 5.3 | Bernoulli Mixture | 51 |
| 5.4 | Embedded Bernoulli Mixture HMMs | 52 |
| 5.5 | BHMM-based Handwriting Word Recognition | 53 |
| 5.5.1 | The Forward Algorithm | 55 |
| 5.5.2 | The Backward Algorithm | 56 |
| 5.5.3 | The Viterbi Algorithm | 56 |
| 5.6 | Maximum Likelihood Parameter Estimation | 59 |
| 5.7 | Windowed BHMMs | 60 |
| 5.8 | Experiments | 62 |
| 5.8.1 | Embedded BHMMs | 62 |
| 5.8.2 | Embedded Bernoulli mixture HMMs | 64 |
| 5.8.3 | Windowed BHMMs | 65 |
| 5.8.4 | Window Repositioning | 69 |
| 5.8.5 | More Results on IAM | 70 |
| 5.8.6 | Results on RIMES | 72 |
| 5.9 | Concluding Remarks | 72 |
| | Bibliography | 75 |
| 6 | Bernoulli HMMs for Continuous HTR | 77 |
| 6.1 | Introduction | 78 |
| 6.2 | BHMM-based Continuous HTR | 78 |
| 6.2.1 | Embedding BHMMs into LM States | 79 |
| 6.2.2 | Embedding BHMMs into LM Edges | 81 |
| 6.2.3 | Pruning Techniques | 84 |
| 6.2.4 | Constrained Search | 84 |
| 6.3 | Experiments | 85 |

| | | |
|----------|---|------------|
| 6.3.1 | The IAM Database | 85 |
| 6.3.2 | The Germana Database | 86 |
| 6.3.3 | The Rodrigo Database | 88 |
| 6.3.4 | Results on Printed Arabic Text | 90 |
| 6.4 | Concluding Remarks | 92 |
| | Bibliography | 93 |
| 7 | Mixture Multi-class Logistic Regression Models for Binary Images | 95 |
| 7.1 | Introduction | 96 |
| 7.2 | Bernoulli Mixture Classifier | 97 |
| 7.3 | Mixture of Multi-class Logistic Regression | 99 |
| 7.4 | Equivalence Between Classifiers | 100 |
| 7.4.1 | From Generative to Discriminative Parameters | 100 |
| 7.4.2 | From Discriminative to Generative Parameters | 101 |
| 7.5 | Experiments | 103 |
| 7.5.1 | Experiments with One Mixture Component per Class | 104 |
| 7.5.2 | Experiments with Several Mixture Components per Class | 107 |
| 7.6 | Concluding Remarks | 109 |
| | Bibliography | 115 |
| 8 | Discriminative BHMM Classifier | 117 |
| 8.1 | Introduction | 118 |
| 8.2 | Log-linear HMM for Binary Data | 118 |
| 8.2.1 | BHMM Inspired Log-linear Model | 119 |
| 8.2.2 | Discriminative Classifier | 121 |
| 8.2.3 | Feature Functions | 122 |
| 8.3 | Equivalence Between BHMMs and LLHMMs | 123 |
| 8.3.1 | From Generative to Discriminative Parameters | 123 |
| 8.3.2 | From Discriminative to Generative Parameters | 123 |
| 8.4 | LLHMM Parameter Estimation | 127 |
| 8.4.1 | γ -MMI Criterion | 128 |
| 8.4.2 | The Power Approximation | 129 |
| 8.4.3 | Error Rate Criterion | 130 |
| 8.4.4 | Regularization | 130 |
| 8.5 | Experiments | 131 |
| 8.5.1 | Database and Experimental Setup | 131 |
| 8.5.2 | Experiments | 132 |
| 8.6 | Concluding Remarks and Future Work | 136 |
| | Bibliography | 141 |
| 9 | Conclusions | 143 |
| 9.1 | Summary | 144 |
| 9.2 | Scientific Publications | 146 |

| | | |
|----------|--|------------|
| A | Notes on Discriminative BHMMs | 151 |
| A.1 | Discriminative to Generative Transition Probabilities | 151 |
| A.2 | Efficient LLHMM Parameter Estimation | 152 |
| A.2.1 | The Forward Algorithm | 152 |
| A.2.2 | The Backward Algorithm | 153 |
| A.2.3 | Example of Parameter Estimation Using Forward-Backward | 153 |
| | List of Figures | 157 |
| | List of Tables | 161 |