

Contents

Certificate	ii
Declaration by the Candidate	iii
Copyright Transfer Certificate	iv
Acknowledgements	v
Preface	vii
Contents	xii
List of Figures	xvii
List of Tables	xxi
Abbreviations	xxiii
1 Introduction	1
1.1 Animal Biometrics	1
1.1.1 Animal Biometrics: Fingerprints, Visual appearance, and Bio- metric characteristics	2
1.1.2 Interdisciplinary Relevance: Animal Biometrics	5
1.1.3 Advantages of Animal Biometrics	6
1.2 Cattle Recognition System	8
1.2.1 Major Component of Cattle Recognition System	10
1.2.2 Performance Statistics	12
1.2.3 Operation Modes	13

1.2.3.1	Identification Mode	13
1.2.3.2	Verification Mode	14
1.2.4	Distributions of Match Score	15
1.2.5	Measurement of System Errors	16
1.3	Classical Animal Identification Methodology	19
1.4	Motivation	22
1.5	Objective of the Thesis	23
1.6	Major Contributions	24
1.7	Thesis Organization	25
2	Related Work and State-of-the-Art	29
2.1	Animal Biometrics	29
2.1.1	Animal Biometrics Based Recognition System	31
2.1.2	Component of Animal Biometrics-based Recognition System	32
2.1.3	Data Acquisition and Data Pre-processing	34
2.1.4	Extraction and Representation of Features	34
2.1.5	Matching of biometric Features	35
2.2	Classical Cattle Identification Methodology	37
2.2.1	Permanent Identification Methodology	38
2.2.2	Semi-permanent Identification Methodology	41
2.2.3	Temporary Identification Methodology	43
2.3	Cattle Biometric Identifiers	47
2.3.1	Retinal Vascular Patterns	47
2.3.2	Iris Patterns	51
2.4	Cattle Identification Based on Muzzle Print Images	52
2.4.1	Muzzle Print Images	53
2.4.2	Short Review on Identification and Monitoring of Cattle Based on Patents	61
2.5	Research objectives	65
3	Recognition of Cattle using Face Images	67
3.1	Introduction	67
3.1.1	Motivation	71
3.2	Database Preparation and Description	74
3.3	Proposed Cattle Recognition System (CRS)	77
3.3.1	Sensor Module (Data Acquisition Phase)	81
3.3.2	Preprocessing and Enhancement	81
3.3.3	Feature Extraction and Matching	82
3.4	Experimental Result and Discussion	84
3.4.1	Performance Evaluation	84
3.4.1.1	Principal Component Analysis	86
3.4.1.2	Linear Discriminant Analysis	88

3.4.1.3	Independent Component Analysis	90
3.4.1.4	Candid Covariance Free-Incremental-PCA	92
3.4.1.5	Incremental-Linear Discriminant Analysis	92
3.4.2	Experimental Protocol and Analysis	93
3.5	Summary	102
4	Automatic Identification of Cattle based on Muzzle Point Pattern	105
4.1	Introduction	106
4.2	Motivation	110
4.3	Material and Methods	113
4.3.1	Database Preparation and Description	113
4.4	Proposed Approach	114
4.4.1	Pre-processing of Muzzle Point Image	116
4.4.2	Segmentation of Muzzle Point Image	117
4.4.2.1	Minima Selection and Region Merging	120
4.5	Feature Extraction and Matching	122
4.5.1	Encoding of Texture Features of Muzzle Point Images	123
4.6	Classification	127
4.6.1	K-nearest neighbour (K-NN) Classifier	127
4.6.2	Fuzzy K-Nearest Neighbour Classifier	127
4.6.3	Radial Basis Function Neural Network Classifier	128
4.6.4	Decision Tree Classifier	128
4.6.5	Gaussian Mixture Model Classifier	128
4.6.6	Probabilistic Neural Network Classifier	129
4.6.7	Multilayer Perceptron Classifier	129
4.6.8	Naïve Bayes Classifier	129
4.7	Classifier Tuning Strategy	130
4.7.1	Statistical Analysis	131
4.7.2	Performance Evaluation	132
4.8	Experimental Results and Discussion	137
4.8.1	Experimental Analysis	139
4.8.2	Recognition of Muzzle Point Images under Different Rotations	141
4.8.3	Recognition of Muzzle Point Image of Cattle between Different Occlusion	143
4.9	Discussion	144
4.10	Summary	149
5	A Muzzle Point Pattern based Techniques for Individual Cattle Identification	151
5.1	Introduction	151
5.1.1	Motivation	152
5.2	Proposed Muzzle Point Pattern based Recognition Approach	153
5.2.1	Pre-processing of Muzzle Point Image Pattern	155

5.3	Feature Extraction and Matching Approach	157
5.4	Chi-square based Matching of Muzzle Point Images	157
5.5	Experimental Results and Discussion	160
5.5.1	Database Preparation and Description	160
5.5.2	Algorithms for Performance Evaluation	163
5.5.3	Appearance-based Feature Extraction and Representation technique	163
5.5.4	Texture Feature Descriptor Techniques	165
5.5.5	Speeded Up Robust Features	166
5.5.5.1	SURF Descriptor	168
5.5.5.2	Local Binary Pattern	169
5.5.6	Experimental Evaluation	172
5.6	Summary	177
6	Deep Learning Framework for Recognition of Cattle Using Muzzle Point Image Pattern	179
6.1	Introduction	179
6.2	Proposed System	182
6.2.1	Convolution Layer	185
6.2.1.1	Local Receptive Fields	187
6.2.1.2	Shared and Biases Weights	189
6.2.1.3	Pooling Layers	190
6.2.1.4	Fully Connection Layer	191
6.2.1.5	Rectified Linear Unit (ReLU)	192
6.2.1.6	Computation of Reconstruction Error	193
6.2.2	Restricted Boltzmann Machine	194
6.2.3	Deep Belief Network	195
6.2.4	Stacked Denoising Autoencoder	196
6.3	Experimental Results and Discussion	201
6.3.1	Algorithms For Performance Evaluation	201
6.3.2	Experiment Protocol and Experimental Evaluation	202
6.3.3	Experimental-2: Existing Handcrafted Texture Feature and Representation Method	208
6.3.4	Experimental-3 Appearance based Face Recognition and Representation Method	211
6.4	Comparison to the state-of-the-art	214
6.5	Summary	220
7	Conclusion and Future Scope of The Thesis	223
7.1	Concluding Remarks	223
7.1.1	Future Scope of This Thesis	227
8	Research Publications	231