Chapter 7

Conclusion and Future Scope of The Thesis

7.1 Concluding Remarks

This thesis has studied the problem of traditional animal identification system and livestock framework based systems for recognition of individual cattle using standard approaches. This thesis attempts to design and develop an automatic recognition system for recognition of individual cattle based on face images and muzzle point features of cattle which simultaneously provides strong security guarantees along with acceptable performance metrics for identification of individual cattle.

More specifically speaking, four different recognition frameworks based systems for identification of individual cattle based on face and muzzle point image pattern have been developed. An underlying objective of first work is to validate the prepared database for the face image of cattle using proposed cattle recognition system using computer vision and pattern recognition approaches. The validation and testing phase of face image database

facilities in formally analyzing the extracted set of features for face images of cattle of identification of individual cattle.

This research demonstrated a current state of the art based approach for recognition of cattle based on face images in the emerging research field of animal biometrics and computer vision. In the computer vision based methods, Independent Component Analysis (ICA) algorithm yielded the recognition accuracy of 86.95% at the starting level of Gaussian smoothing of face image database. The PCA-LiBSVM and ICA-LiBSVM face recognition approaches provided the recognition accuracy of 95.62% and 95.87% respectively. Experimental results on cattle face database of 5000 face images (*e.g.*, 500 subjects $\times 10$ image of each subject) illustrated that recognition of individual cattle based on face images is feasible.

In the second objective of this thesis, a novel hybrid texture feature based extraction and classification approach are proposed for identification of individual cattle based texture feature of muzzle point images of cattle. The proposed approach worked on following stages: data acquisition, pre-processing and enhancement of captured muzzle point images, segmentation, extraction and classification of extracted features.

The extracted texture features of muzzle point features are validated by using Analysis of variance (ANOVA) technique to measure the value of (F) and (p) parameter for validating the statistical significance of extracted texture features. The statistical models used to analyze the differences among classes means of muzzle point features and their associated procedures. After that, statistically, significant features are classified by various classification models to recognize individual cattle.

The proposed approach operates on the texture feature vectors obtained from the 5000

images of muzzle pattern using eight texture feature based descriptor methods and performed the classification and recognition of cattle breeds. The proposed approach provided the recognition accuracies of 94.50%, and 96.74% by classifying the extracted texture features of muzzle point images by applying K-NN, and Fuzzy-K-NN classification techniques. This research work illustrates the current state-of-the–art approaches for the recognition, and classification of individual cattle.

The next task of in this thesis pertains to the identification of cattle based on the fusion of extracted texture feature of muzzle point features. The proposed recognition algorithm uses the texture feature descriptor techniques, such as Speeded-up Robust Features (SURF) and Local Binary Pattern (LBP) for the extraction of features of muzzle point images at different smoothed levels of Gaussian pyramid. The feature descriptors acquired at each Gaussian smoothed level are combined using fusion weighted sum rule method. In this experiment, the performance of the proposed algorithm is computed with five-time random cross-validation of the muzzle point pattern database of cattle. The average rank-1 accuracy is observed to be 93:87% for identification of individual cattle. After performance evaluations of feature texture descriptors, and appearance-based face recognition, representations algorithms based on the muzzle point features, it is concluded that each cattle is uniquely recognized based on muzzle point features of cattle.

The fourth work in this thesis focuses on the recognition of cattle using deep learning recognition system based on muzzle point features. The proposed recognition framework is applied to learn the extracted feature for better representations using hybrid deep learning model. The hybrid deep learning model ensures the generated representations of features on the different layers are more robust and suitable for recognition and verification of individual cattle.

The proposed recognition system consists of two components: (1) A deep mixture model to find the accurate correspondence features between muzzle point image patterns and (2)

Convolution Neural Network (CNN), Deep Belief Network (DBN) and Stacked Denoising Autoencoder (SDAE) based deep learning based fusion approach for extraction and encoding of the extracted features of muzzle point image pattern database.

The deep learning approach is applied to learn a discriminatory feature representation of muzzle images with limited training dataset. With the proposed deep learning approaches, such as CNN, SDEA and DBN provided identification accuracy of 75.98%, 88.46%, and 95.99%, respectively. The handcrafted texture features based representation algorithms are also utilized for evaluations of experimental results. The Local Binary Pattern (LBP) and Circular-LBP (CLBP) texture feature descriptor based techniques provide the rank-1 identification accuracy of 16.80$\pm$ 0.80% to and 26.97$\pm$1.20%, respectively with four muzzle point images as gallery image per subject (cattle).

In case of appearance based feature extraction and representation approaches, such as principal components analysis is used to perform the dimensionality reduction of extracted features. The direct Kernel- Linear Discriminant Analysis (KLDA) provided the 15.89$\pm$1.7% to 29.97$\pm$1.13% identification accuracy. The learnt feature descriptor techniques, such as Vector of Locally Aggregated Descriptors (VLAD) +LDA+OSS and VLAD+LDA+SVM techniques given 45.98$\pm$1.5% to 59.64$\pm$1.12% and 50.76$\pm$1.6 % to 67.98$\pm$1.17% identification accuracy, respectively. Based on observation, we conclude that deep belief network deep learning approach provides better identification accuracy for recognition of individual cattle. Hence it can be concluded that the DBN based deep learning framework is the right choice for recognition purpose.

Finally, we conclude that proposed cattle recognition system can be applied to solve the problem of missed or swapped animals, verification of false insurance claims and reallocation at slaughterhouses of cattle by applying based on face and muzzle point features. An exhaustive set of experiments performed on the face image and muzzle point image

pattern database revealed that our proposed schemes outperform a current state-of-the-art based approach for recognition of individual cattle.

After performance evaluations of different classification and recognition algorithms of individual cattle based on muzzle image pattern database, we hereby conclude that various multidisciplinary researchers, scientists, and developers have yet to explore the level of animal monitoring, tracking, registration, control and outbreak of critical diseases of animal by recognizing individual animal.

7.1.1 Future Scope of This Thesis

The proposed methods proved to be accurate and fulfilling the objectives with which this entire work was initiated. However, there are some prospective future directions in which this thesis wok can conveniently to be widened. These are enlisted point-wise as follows:

- **Extension of Prepared Database:** The future research work will put emphasis on increasing the size of muzzle point pattern database. The database will be enhanced, and different conditions will be considered while the acquisition of muzzle point images for each cattle (subjects): low illumination, blurriness, and pose variations as image covariates in the muzzle point image database. We are currently working on preparing an animal biometric-based recognition system for the verification of false insurance claims of various valuable animal, registration, and health monitoring process using their animal biometric characteristics.

- **Design of Multi-modal Fusion based Recognition System:** To obtained significant impact, more proliferation, and broad applicability of animal biometrics requires being widened. The multi-modal animal biometrics-based recognition systems can be developed for the robust and enhancement of recognition accuracy

of species or individual animal using their prominent biometric characteristics and generic visual features.

Although addressed to some extent in this thesis, it is the requirement to design and develop multi-modal cattle recognition system using fusion techniques to improve the identification and verification rate to mitigate the properties such as low false rejection rates (FRR), False Acceptance Rate (FAR) and computational complexity. Therefore, it is essential to develop a generalized framework for finding the accurate results by fusion of the different set of biometric features (face image and muzzle point feature) of cattle.

We would like to increase the performance of the proposed system; the muzzle point features can be fused with that of facial images of cattle for particular biometric recognition system in real-time.

- **Real-time Animal Biometrics-based Recognition Systems:** With the proliferation of animal biometrics based recognition systems, design and implementation of new cattle recognition system can be expected in the future to monitor and perform the accurate identification of cattle in real time scenario. Therefore, a robust cattle monitoring system based on proposed muzzle point recognition algorithms that can execute the verification of false insurance of claims of cattle and provide better recognition accuracy in the real-time scenario.

- **Incorporating new ideas:** A contemporary security concept extensively limits the attainable objective of the resulting animal biometrics-based recognition systems. Consequently, innovative techniques must be analyzed and investigated for utilizing in biometric template protection of muzzle point image pattern and face image of cattle.

  The captured images of cattle are transferred from the smartphone of users (*e.g.*, owners, parentages, and others) to servers of cattle recognition system using the

Internet or wireless communication network for the verification of false insurance of claims and recognition of individual cattle.

For instance, digital watermarking methods can be used to protect the privacy of biometric feature of muzzle point pattern and face images of animals by hiding them into a cover multimedia object in the process of insurance of individual cattle .Investigations into the feasibility of such concept are an exciting prospect.

- **Adaptable Techniques:** Most application based framework will have at least two versions in the near future: mobile (*e.g.*, smart devices, such as smartphone, smart watch, smart tablet and digital camera) and fog computation. Cattle recognition using animal biometrics-based recognition systems based on primary biometric features is emerging field of computer vision, pattern recognition, and animal biometrics. While the mobile version will be suited for aspects such as low computational complexity and low storage requirement, the cloud models will be required for computation of biometric features and retrieval of other relevant information for real verification rates and strong resilience against any attacks on biometric templates. As such, the current biometric template protection framework should be adaptable according to the needs and requirements of the underlying application and uses.

- **Development of New Framework and Efficient Solutions:**

  The complexity of the system design challenges ahead calls for a new breed of biologically knowledgeable scientists, multidisciplinary researchers, engineers, and technically motivated biologists. These should be cross-disciplinary experts who have the faithful understanding of the target species or individual animals and its habitat, as well as implement the technical tools and simulation systems, efficient algorithms that form the basis for practical engineering solutions. The future will determine whether cattle biometrics can live up to its guarantee of revolutionizing

the way we look at the morphological, phenotype and biometric feature characteristics of the animals.