PREFACE

This thesis represents a culmination of work and better learning that has taken place in the last couple of years. The idea of this thesis began when I met Dr. Sanjay Kumar Singh, (Associate Professor), Department of Computer Science and Engineering, I.I.T (B.H.U.) during research interaction.

I had an opportunity to discuss the major issues related to my research work. He appreciated my coherent set of ideas. He suggested me to design and develop some novel findings for the recognition and verification of animals based on their primary discriminatory biometric features using computer vision, pattern recognition, image processing and animal biometric based approaches.

When I met again with Dr. Sanjay Kumar Singh, then I shared findings of my novel research with him. He was very pleased to know that I continued my research work to identify and verify individual cattle based on their biometric identifiers. I used the face image and muzzle point (nose) image pattern as primary biometrics to identify and verify individual cattle.

In the available literature, classical animal recognition methodologies are mainly ear-tags, freeze-branding, ear-tattoos, ear-tips or notches, embedding of microchips, and hot iron in the animal body for identification and tracking. These classical identification are invasive approaches for the recognition and verification of individual cattle. Moreover, the classical animal recognition-based approaches are more susceptible to massive vulnerability of loss and illegibility. It always lead to more security issues for the protection of cattle or other animals, as reported in various surveys.

In the classical animal recognition systems, there is more probability of registration and identification of animal using ear-tags, RFID based techniques and embedded microchips

for identification and tracking of individual cattle. However, ear-tags are damaged, lost, or stolen easily. The duplication and forge of the labeled unique number in the ear tags can be done easily. Therefore, classical animal recognition methodology is unable to cater a competent level of security to individual cattle. The classical animal recognition methodologies also fail to provide a required level of registration, identification of missed and swapped cattle, reallocation of livestock, and verification of false insurance claims. The classical animal recognition systems are limited in public domain due to the enormous amount of manpower requirements, high cost and vulnerability of loss. This loss occurs due to duplication, fraudulent and forging of embedded standard ear-tags.

In the current state-of-the-art-based animal recognition approaches, different governmental organizations and private animal insurance providers identify and then verify the animals to solve the biggest problems of the false insurance claims by cutting their ear or snatching the embedded label of ear tags or notches from the animal's ear. The duplication, forgery, and fraudulent processes are responsible for the falsification in the labeled ear tags. Therefore, it is tough to recognize and verify the registered insurance animals (owner of cattle) or impostor (non-insurance) animals.

I continued to design and develop the methodologies that use face image and muzzle point features as biometric characteristics for recognition of individual cattle and provide a competent level of security to livestock animals. It was hard to get the face and muzzle point image database in the public domain or available literature.

In the beginning, I was not sure whether I would get the real biometric data of cattle to test my methodology. Therefore, we prepared these databases of cattle by capturing images from Department of Animal Husbandry and Dairy, Institute of Agricultural Sciences (I.A.S), Bananas Hindu University using the 20-megapixel camera. I performed the experimental results for identification of cattle over these databases under different identification settings.

To provide better solutions for identification and verification of false insurance claims, monitoring of livestock, assistance during health management of animals, efficient recognition is required. The efficient recognition prevents critical diseases, and distribution of cattle in the livestock framework.

These are the major problems of identification and monitoring of animal in the classical animal recognition approaches and traditional livestock framework based systems. These issues cannot be ignored by various scientists, veterinary professionals, animal experts, and different research communities before contributing their valuable efforts for the design and development of robust, non-invasive, and real-time animal biometric-based recognition systems. Therefore, it is required to develop a real-time cattle recognition system for identifying and monitoring of different animals.

In this thesis, we proposed a fast and cost-effective animal biometrics based cattle recognition system to quickly recognize and verify the false insurance claims of cattle using their primary muzzle point image pattern characteristics. The face images of cattle have been considered as a primary biometric characteristic for identifying cattle because cattle face images have rich skin texture information and distinct facial features. The primary property of facial feature includes universality, distinctness, and permanence.

The muzzle point image is a unique and stable discriminatory biometric characteristic of cattle for the purpose of recognition. The recognition of muzzle point image pattern is similar to the recognition of minutiae points in the human fingerprint.

The discriminatory biometric pattern of muzzle point images can be clustered into two important patterns known as beads and ridge pattern. The beads pattern of muzzle point image consists of irregular structures, and their shape is similar to the islands, whereas ridges pattern is similar to rivers structure. The ridge pattern always separates the beads. The beads and ridges of muzzle point are unique biometric identifiers for the recognition

of individual cattle. Finally, I was able to extract necessary and sufficient contents from the activities a coherent body of work to prepare this thesis.

The rest of the thesis is organized as follows:

The first chapter gives an overview of cattle recognition using face biometric features. In this chapter, a cattle biometric based recognition system has been proposed for the validation of prepared face image database of cattle for recognition individual cattle. This framework also has been utilized to evaluate the experimental results of cattle face image by applying the existing handcrafted feature descriptor technique and appearance based feature extraction and representation techniques. Moreover, the proposed cattle recognition based framework is also tested on the cattle face images using incremental machine learning approaches and better representation of extracted discriminatory features in the feature space.

The second chapter presents a comprehensive survey of animal identification using phenotypic appearance, biometric features, and morphological image patterns of different species and individual animals. The review work meticulously examines the main techniques and approaches for the recognition of individual cattle based on their face image and muzzle point (nose) image pattern as a biometric characteristics and the current state-of-the-art approaches. This will make it possible to evaluate the robustness of our approach when noisy, poor image quality, low illumination and blurred images are used as input. We validate performance and usability of proposed cattle recognition system by comparing it with the current state-of-the-art based approaches and its applicability as a component of a fully integrated system, respectively.

The chapter three gives an overview of a developed framework for recognition of cattle based on face biometric features of cattle. In this chapter, a biometric based cattle recognition system has been proposed for the validation of prepared face image database of cattle for recognition of individual cattle. The proposed recognition system also has been

utilized to evaluate the experimental results of cattle face image by applying the existing handcrafted feature descriptor technique and appearance based feature extraction and representation techniques. Moreover, the proposed cattle recognition based framework is also tested on the prepared face image database of cattle using incremental machine learning approaches for better representation of extracted discriminatory features in the feature space. It is shown that experimental results derived from our proposed recognition system are found stable and correct for recognition of individual cattle.

Chapter four presents a novel framework has been developed using hybrid texture feature extraction and classification approaches to identify cattle based on muzzle point image features. The hybrid texture feature extraction and representation methods characterize the extracted pattern of muzzle point image for better recognition and classification of cattle, as well as examines the discriminatory features of muzzle images using texture feature extraction technique and supervised machine learning based multi-classifier techniques. The generality of the proposed approach is validated by achieving the current state-of-the-art accuracy on muzzle point image database of cattle with standard identification settings.

In chapter five, a novel recognition algorithm has been proposed to extract the features of muzzle point images using handcrafted texture feature descriptor technique, such as speeded up robust features and local binary pattern for recognition of cattle. The proposed algorithm has been applied for the extraction of muzzle point features from the cattle muzzle point image database at different smoothed levels of Gaussian pyramid. The texture feature descriptors acquired at each Gaussian smoothed level are combined using fusion weighted sum rule technique.

The main objective of proposed approach is that it maximizes the between-class (S_B) feature of extracted muzzle point image database by minimizing the within-class (S_W) scatter matrix of muzzle point images to improve the recognition accuracy of cattle.

Our proposed approach has shown the better performance accuracy as compared to the appearance-based face recognition and representation algorithms.

Chapter six presents a hybrid deep learning based system for the recognition of cattle based on their muzzle point images. The proposed system applies a new convolution neural network, deep belief network based deep learning framework for the extraction and representation of muzzle point features. In the proposed approach, stacked denoising autoencoder, an unsupervised feature learner technique has been applied for feature representation by reconstructing the output of the previous layer followed by distance metric learning via one-shot similarity with one class-online support vector machine.

The proposed approach consist of two steps: (1) a deep mixture model to find accurate patch correspondence between muzzle point image patterns and (2) convolution neural network, deep belief network and stacked denoising autoencoder based fusion network to extract the features from muzzle point image pattern.

Finally, in chapter seven the summary of the thesis is presented along with the directions for future research.