Thesis Title: Human Recognition using 2D and 3D Ear Images,
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Synopsis

Authentication of a person to ascertain his/her identity is an important problem in the society. There are three common ways to perform authentication. First one relies on what a person possesses such as keys, identity cards etc. while second one is based on what a person knows such as passwords, personal identification numbers (PINs) etc. Third way of authentication relies on what a person carries, *i.e.* the unique characteristics of a human being (Biometrics). Even though the first two methods are well established and accepted in the society, they may fail to make true authentication in many occasions. For example, there is a possibility that items under possession may be lost, misplaced or stolen. Similarly one can forget passwords etc. As a result, authentication may not be correct. However, this is not true in case of biometrics. Thus, most of the limitations of traditional ways of authentication which are based on possession and knowledge can be overcome by the use of biometrics. Since it uses characteristics of a person's own body or behavior which he/she always carries, there is no chance of forgetting or loosing it. Moreover, body characteristics used for authentication are much more complicated and difficult to forge as compared to remembering a string (such as password) of very long size. The main motivation behind the use of biometrics is to provide a convenient mechanism for person authentication with the help of his/her biological or behavioral characteristics and to eliminate the use of much inconvenient ways of authentication such as the one which are based on ID card, password, physical keys, PINs etc.

There are two types of characteristics which are used in biometrics for person authentication. First type of characteristics are of physiological nature while other ones are based on behavior of human beings. Physiological characteristics depend on “what we have” and derives from the structural information of the human body whereas behavioral characteristics are based on “what we do” and depend on the behavior of a person. The unique biometric characteristic (be it physiological or behavioral) which is used for authentication is commonly referred as a biometric trait. Common examples of physiological biometric traits are face, ear, iris, fingerprint, hand geometry, hand vein pattern, palm print etc. whereas signature, gait (walking pattern), speech, key strokes dynamics etc. are the examples of behavioral biometrics.

Among various physiological biometric traits, ear has gained much popularity in recent years as it has been found to be a reliable biometrics for human recognition. Use of ear for human recognition has been studied by Iannarelli in 1989. This study has suggested the use of features based on twelve manually measured distances of the ear. It has used $10,000$ ear images to demonstrate the uniqueness of ears and has concluded that ears are distinguishable based on limited number of characteristics. This has motivated researchers in the field of biometrics to look at the use of ear for human recognition. Analysis of the decidability index (which measures the separation between genuine and imposter scores for a biometric system) also suggests the uniqueness of an individual ear. It has been found that the decidability index of the ear is in an order of magnitude greater than that of face, but not as large as that of iris. Below is a list of characteristics which make ear biometrics a popular choice for human recognition.

1. Ear is found to be very stable. Medical studies have shown that major changes in the ear shape happen only before the age of 8 years and after that of 70 years. Shape of the ear is found to be stable for rest of the life.
2. Ear is remarkably consistent and does not change its shape under expressions like face.
3. Color distribution of the ear is almost uniform.
4. Handling background in case of ear is easy as it is very much predictable. An ear always remains fixed at the middle of the profile face.
5. Ear is unaffected by cosmetics and eye glasses.
6. Ear is a good example of passive biometrics and does not need much cooperation from the subject. Ear data can be captured even without the knowledge of the subject from a distance.
7. Ear can be used in a stand alone fashion for recognition or it can be integrated with the face for enhanced recognition.

Even though ear has so many rich characteristics as compared to other biometrics, the performance of 2D or 3D ear recognition techniques is found to be low and hence it has kept it away from being widely used. In this thesis, an attempt has been made to improve the performance of ear recognition by developing efficient techniques for the same.

Ear recognition consists of two important steps and they are (i) Ear detection and (ii) Recognition. Ear detection carries out the segmentation of the ear from profile face before using it for recognition task. Most of the well known recognition techniques directly work on manually segmented ear images. This thesis has presented some efficient but automatic ear detection techniques for 2D as well as for 3D.

Recognition step deals with the task of human recognition based on the segmented ear. Major challenges in 2D ear recognition are due to poor contrast and illumination, presence of noise in the ear image, poor registration of gallery (database) and probe images. Challenges in 3D ear recognition arise mainly from poor registration of gallery and probe images and presence of noise in the 3D data. This thesis has proposed efficient recognition techniques both in 2D and 3D which have attempted to overcome these challenges.

This thesis consists of seven chapters. Brief description of the content of each chapter is as follows. Chapter 1 presents the motivation of the work carried out, basics of a biometric system, different biometric traits, various performance measures, information about databases used in experimental evaluation of the thesis etc. Chapter 2 reviews some of well known techniques for ear detection and recognition, both in 2D as well as in 3D.

Chapter 3 proposes an efficient ear localization technique. The proposed technique is invariant to scale, rotation and shape. It makes use of connected components of a graph constructed with the help of edge map of the profile face image to generate a set of probable ear candidates. True ear is detected by performing ear identification using a rotation, scale and shape invariant ear template.

Chapter 4 proposes an ear recognition technique in 2D which makes use of multiple image enhancement techniques and local features based on Speeded Up Robust Features (SURF). The use of multiple image enhancement techniques has made it possible to counteract the effect of illumination, poor contrast and noise while SURF based local feature helps in matching the images which are not properly registered and suffer from pose variations. For a given ear image, three enhanced images are obtained which are used by SURF feature extractor to generate three sets of SURF features for an ear image. Three nearest neighbor classifiers are respectively trained on these three sets of features and finally results of all the classifiers are fused to get the final result.

Chapter 5 proposes a technique for ear detection in 3D. For an ear recognition system, it is very essential to locate and crop automatically the ear from a whole 3D profile face image which may be affected due to scale and pose variations. However, detection of ears from an arbitrary 3D profile face range image is a challenging problem due to fact that ear images can vary in scale and pose under different viewing conditions. In this chapter, an attempt has been made to handle these issues by proposing a scale and rotation invariant technique for automatic ear detection in 3D profile face range images. The proposed technique does not require any registered 2D image for ear detection in 3D. Also, it can detect left and right ear at the same time without imposing any additional computational cost.

Chapter 6 proposes an efficient human recognition technique which makes use of 3D ear data along with registered 2D ear images. The technique first coarsely aligns the 3D ear data using local features computed from registered 2D ear images and then uses Generalized Procrustes Analysis and Iterative Closest Point (GPA-ICP) based matching technique for final alignment. It integrates GPA with ICP to achieve robust 3D ear matching. Coarse alignment of the data before applying GPA-ICP helps to provide a good initial point for GPA-ICP based matching algorithm.

Last chapter concludes the thesis. It also provides some future directions for the research in the field of ear biometrics.