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RECENT ADVANCEMENTS IN EAR BIOMETRICS: A REVIEW

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ABSTRACT

Ascertaining the identity of a person is quite an important aspect of Forensic Science. There are so many physiological features have been proved to be highly discriminating among individuals. Biometrics play a significant role in individualizing a person. Fingerprint, Palm print, Retina and Iris recognition are the most popular examples of it. Fingerprint and iris are generally considered to allow more accurate biometric recognition than the face, but the face is more easily used in surveillance scenarios where fingerprint and iris capture are not feasible. However, the face by itself is not yet as accurate and flexible as desired for this scenario due to expression changes, source of illumination, make-up, etc. Besides these limitations, ear images can be acquired in a similar manner to face images. A number of researchers have suggested that the human ear is unique enough to each individual to allow practical use as a biometric. In this article an attempt has been made to review all the recent researches of a decade made in the field of Ear Biometrics.

KEYWORDS: Ear Biometrics, PCA, SPSS, 3D Ear Image.

INTRODUCTION

Biometrics refers to metrics related to human characteristics. Biometrics authentication which is also known as realistic authentication is used in computer science not only as a form of identification and access control. [1] Public safety and national security enhance the needs for biometric techniques, which are among the most secure and accurate authentication tools. Biometric identifiers are the distinctive, measurable characteristics used to label and describe individuals. [2] Physiological characteristics are related to the shape of the body. Examples include, but are not limited to fingerprint, palm veins, face recognition, DNA, palm print, hand geometry, iris recognition and retina. The recent pulsating trend in biometrics is ear biometrics which is gaining momentum and the attraction of researchers these days.

Ear has been used since long times as an anthropometric feature to identify and individualize an individual. Alfred Innarelli is the most renowned scientist who worked over 10,000 ear samples.[3] That's why, his contribution in the field of ear recognition is well known. Assistance of computers has much changed this entire scenario now. A number of computational tools have been developed that not only helps in image processing but also in identification and verification through ear prints. Some great efforts have been made in this field by researchers as described in reviews given below:

Chen and Bhanu (2004) proposed human ear detection from side face range images. The images were scanned by Minolta Vivid 300. There were 30 subjects in the database and every subject had two side face range images taken at different viewpoints. The success of the approach relied on two facts: 1) there was a sharp step edge around the ear boundary which can be easily detected; 2) shape index was a good measurement to capture the geometric information of ears since the ear had much ridge and valley areas. According to the study, this approach was simple, effective and easily implemented.[4]

Kasprzak (2005) discussed the methodology to be adopted for human identification based on ear prints. The study material encompassed 9000 ear impressions obtained from 1500 person (590 women and 910 men) aged from 15 to 60 years. From each person, 3 prints of left and right ear were collected with pressure of 1 kg, 2 kg And 3 kg, measured with an otometer. During examination 5 shapes of human auricle were distinguished i.e. oval, round, triangular, rhomboidal and multi angular. Each ear print was divided into 24 fields and individual characteristics were denoted in each field. It was assumed that a categorical opinion stating that an evidential ear mark came from a given suspect required demonstrating conformity of at least 6 fields (out of a catalogue comprising 24). Consistence of other characteristics such as skin structure, scars or peculiar (non-catalogue) elements of morphology had been implemented in Police forensic practice.[5]

Shailza (2006) **worked on simple geometric approach for ear recognition. The side face images were acquired using Sony DSC-P10 in same lighting conditions. Images were taken from a 15 cm distance. The research was carried over 80 subject's 160 photographs. A simple two step geometric approach based on max line, the longest line fit in the ear had been proposed and was shown to be scale and rotation invariant and the advantage of classifying in two stages had also been discussed.** [6]

Singh and Purkit (2006) studied the somatometric and somatoscopic data relating to various parts of the auricle. 280 subjects (130 male & 150 female) who belongs to Thakur caste of district Sagar, Madhya Pradesh were studied. Ten measurement parameters were taken. These parameters are: ear length, ear breadth, Concha length, Concha width, lobular length, lobular width, Inclination angle of medial longitudinal axis of auricle, Height of auricle at super aurale level, Height of auricle at tragal level and Protrusion level. Dial caliper, Goniometer, Protractor and Setsquare with Zero Instrumental error was used for taking measurements. Results showed that most of the subjects have Oval shaped auricle. Very few triangular shaped auricles were observed. Pre-auricular region and external auditory meatus was found to be normal. Majority of subjects had normally rolled helix. Wide helix covering Scapha was totally absent in females. In nearly 15% males attached earlobe was observed which increased to about 25% in females. [7]

Meijerman *et al.* (2007) worked on cross sectional anthropometric study of external ear. They estimated the rate of expansion of external ear during adult life. In order to evaluate the extent to which anatomical features appearing in ear prints may vary with time, 919 male and 434 female subjects (Dutch) were chosen for analysis. The photographs were taken by digital photo camera i.e. Nikon Coolpix 995, 3.1 MP. Camera was provided into a frame and photographs were captured at 90 degree angle. Images were imported into adobe Photoshop and then printed. Making use of the depicted measuring scale in every photograph, auricle length, auricle width and earlobe length were determined for each photographed ear. One male and one female subject from each available birth year were selected at random. These numbers were then, again randomly and when available, supplemented to up to twelve male and twelve females per ten-year interval, resulting in a selection of 175 subjects (86 males and 89 females). SPSS software version 11.5 was used for analysis. Results depicted an annual increase in auricle length of approximately 0.18 mm for males and 0.16 mm for females. Increments in length appeared particularly great between age groups 18-29 and 30-39. [8]

Rahman et al. (2007) proposed human recognition using ear biometrics. The study was conducted on about 350 samples of 100 persons. They extracted information from ear by measuring pre-determined geometrical points. They used pixel value distance for successful recognition of objects. Experimental results got 89% accuracy. The complexity of this process was less since the method did not require considering the inner boundary of ear. [9]

Saleh (2007) studied several feature extraction techniques based on spatial segmentation of the ear image. Principal components analysis (PCA) was used in research for feature extraction and dimensionality reduction. Research also investigated the use of ear images as a supplement to face images in a multimodal biometric system. The base eigen-ear experiment resulted in an 84% rank one recognition rate, and the segmentation method yielded improvements up to 94%.[10]

Sana and Gupta (2007) presented an efficient ear biometric system for human recognition based on discrete Haar wavelet transform. The ear images generally had large background, so there was a need to detect ear which was done by template matching and detected image was scaled into constant size. From these ear images features were extracted as Haar wavelet coefficient from wavelet decomposed image and feature template was stored for each training image. Two sets of images were taken; first in IIT Kanpur and second in Saugor University. At IITK, a CCD camera was used to capture the photographs from the distance of 26-28 cm. Three images of each ear were captured of 600 subjects. At Saugor university, photographs of 350 subjects were captured by Kodak Easy Share CX7330 from the distance of 24-28 cm. Then image processing was done because raw image was not suitable for analysis because of its large background. The steps for image processing were: grayscale conversion, ear detection, scale normalization, wavelet transform and feature extraction. The approach achieved more than 96% accuracy for the two databases indicating a fairly reliable system. [11]

Yan and Bowyer (2007) presented the first fully automated system for ear biometrics using 3D shape. The work was done on 415 subjects in which number of males was 237 and number of females was 178. Data was acquired by a Minolta Vivid 910 range scanner from 1.5 meter distance. One 640□480 3D scan and one 640X 480 color images were obtained in a period of several seconds. Different steps were applied during analysis which include - segmenting the ear region from a profile image, ear pit detection, skin region detection, surface curvature estimation, surface segmentation & classification, ear segmentation using active contour algorithm, matching 3D ear shape for recognition. ICP algorithm was used for analysis. The system has 97.8% rank one recognition rate. [12]

Hunter *et al.* (2008) worked on elements of morphology of external ear. These elements were Antihelix, Antihelix inferior crus, superior crus, antitragus, concha, Frankfurt horizontal, helix, crux of helix, Scapha, triangular fossa. Along with this, various abnormalities of external ear like antitragus absent, Antihelix bifid, Concha extra folds etc. were also discussed in the paper. [13]

Lian *et al.* (2008) performed ear measurements in Singapore on new born population and seek to establish the applicability of the general accepted definition of "low-set ears" being that of "less than a third of the entire ear height being above the inter-medial canthal line". Babies managed by the Department of Neonatal and Developmental Medicine during a 3-week period were measured by 2 investigators using the Feingold and Bossert technique. Intra- and inter-rater reliabilities were calculated. The influence of various anthropometric factors on and their relationships with ear length (EL) and width (EW) was analysed. A total of 104 neonates (20% preterm at birth) were included in the study. Median gestation was 38 weeks (range, 32 to 42). Mean birth weight was 2910 ± 657 g. Mean EW and EL for term infants were 2.1 ± 0.1 cm and 3.6 ± 0.3 cm respectively, without significant differences for different-sided ears, investigators, race or gender. Mean percentage of right and left ear above the denoted line was 52 ± 9% and 47 ± 10% respectively (P = 0.000), with 3rd percentile being 33%. Results clearly demonstrated that Singaporean neonatal ears are comparable with other Asian neonates – larger than Hong Kong Chinese babies, though similar to Japanese newborns – but smaller than Caucasian neonates. [14]

Abaza and Ross (2010) **analyzed the symmetry of human ear. A typical ear recognition system had three modules viz. ear detection, normalization and ear edge segmentation.** A verification experiment using these 309 subjects was setup. For each subject, the left ear was used as the gallery while the right ear was used as the probe. Iannarelli's measurements were done for measurement the images. For statistical analysis, paired t-test was applied and this test was repeated 12 times. The Equal Error Rate (EER) for such an experiment was 16.75%.[15]

Lie et al. (2010) compared the consistency of external ear measurements obtained by electronic digital caliper, photocopier scanning and digital photographic methods. Corel DRAW dimension tool was used to create a dimension line that measured the vertical and horizontal length between any two landmarks. 30 subjects with normal ears were included. Pinna length and pinna width were used for study. Results showed that measurements obtained from photocopier scans and photogrammetric study did not significantly vary with time. [16]

Nixon and Bouchrika (2010) reviewed about the various use of biometrics in field of forensic science. It was described how gait and ear biometrics could be deployed for use in forensic identification. [17]

Dhandha *et al.* (2011) studied the development of latent print of external ear. In their work an attempt had been made to analyze the developed ear prints using powder, iodine vapours and ninhydrin solution. For present study 25 male and 25 females were selected. 100 ear samples of 50 individuals were taken on glass plate. Same 100 prints were collected on bond paper. To collect the ear prints, a glass plate measuring 5" × 5" was placed on the palm of the hand and pressed onto the volunteer's right ear to capture an impression. Optimum pressure was applied constantly with an upward motion that began from the top and ended with the printing of the helix of the ear. Developed ear prints were studied for 10 characteristics: helix, anti-helix, crux of helix, tragus, antitragus, crus of anterior anti-helix, lobule, inter-tragic notch, scapha and creases on ear lobe. Results showed that powdering method produced better results as compared to other methods. In the case of ninhydrin, the results were not very clear. [18]

Kaushal & Kaushal (2011) reviewed on human ear prints and described human external ear in detail and importance of external ear in forensic investigations. They studied and described the procedures to establish the identity of criminals and victims of crimes and accidents. Not only the auricle itself showed potential for establishing the identity of criminals, but also its prints. [19]

El-Desouky *et al.* (2012) tried to avoid problems in 2D images in ears and they proposed to divide the ear image into non-overlapping equal divisions and identify persons through these non-occluded parts separately and then combine outputs of the classification of these parts in abstract, rank and measurement level fusion. According to the results, ear recognition system was found better than many other famous biometric systems. [20]

Natekar and De Souza (2012) attempted to determine sex from external ear with 100% accuracy. The study was carried out in 100 male and 100 female students of medical college, Goa, without any genetic disorder or disease. The measurements were taken by a digital Vernier caliper in millimeters with an accuracy of 1/10 mm. The parameters were taken: Ear length, Ear length above tragus, Ear length below tragus, Tragus length, Ear breadth, Concha length, Concha breadth, Lobule height, Lobule width. It was found that most of the parameters were larger in males as compared to females. However, ear length below tragus, lobule height and lobule width were larger in females than males which were also statistically significant. It was also observed that in most of the parameters which were statistically significant when subjected to identification point analysis for sex determination, they showed a high percentage of differences between males and females. [21]

Pflaug and Busch (2012) categorized and summarized approaches towards ear detection and recognition in 2D and 3D images. Work was conducted on some publicly available ear database like USTB database, UND database, IIT Delhi database, IIT Kanpur database. Ear recognition approaches were divided into four different sub-classes namely holistic approaches, local approaches, hybrid approaches and statistical approaches. Pose variation and camera vibration were found unsolved challenges of 2D images. 3D model was deemed to be a possible solution of this problem. [22]

Amirthalingam and Radhamani (2013) reviewed and analyze the prime works in multimodal biometric system and its efficiency in recognition rate. Face recognition and ear recognition were the major fields highlighted by them. Main advantage of multimodal biometric over unimodal biometric was that there was multiple and independent trait. Multimodal biometric fusion combine the aspect from various biometric features to improve the strengths and reduce the limitations of the individual aspects. Multimodal biometrics based on the fusion of two different biometric modalities face and ear; provide a new approach of non- invasive biometric authentication. During image acquisition, ear and face data was captured using conventional cameras & further analysis was done. [23]

Deopa *et al.* (2013) determined the mean values of the different morphometric measurements of both ears giving sex related information. Subjects were 177 students (84 female 93 male) and measurements were done by Vernier caliper. Four parameters were taken viz. total ear height (TEH), ear width (EW), and lobular height (LH), lobular width (LW). Analysis was done by independent t-test and paired t-test. Results showed that all ear measurements were significantly larger in males than females. [24]

Kumar and Singla (2013) presented a passive biometric technique for detection and identification of human ear with the development of a biometric system using 2D ear image. Study was conducted on Yadav & Brahmin communities of Bundelkhand region. 400 Yadavs & 400 Brahmins were selected for study in which 200 were males and 200 were females in each community. Photography of both left and right ears were done by Canon Power Shot-A470 camera with a constant distance of 15 cm between ear and camera. After photography, image processing and normalization of image was done and resizing the images to unique fixed size of 220x380 pixels were made. Measurements of pre-determined geometrical points were done and values for the each measurement was tabulated and analyzed by SPSS Statistical Software 17 Version/PC. PCA technique was used. An overall accuracy achieved through all significant ear dimensions was 93.66%. Results achieved by using the proposed method were up to 94.3% which was also approximately equal to the value generated through PCA Method. Overall data showed the efficacy of PCA technique in study of ear biometrics correctly. [25]

Mathur (2013) worked on ear recognition by using principal component analysis (PCA) technique. The initial step was the detection of ear followed by normalization and equalization of the acquired image. This image was then processed through the steps of principal component analysis, resulting in a matrix of weights. Simultaneously the weights of the probes were calculated and used along with the original matrix for the purpose of deriving genuine and imposter scores. The results were viewed on a receiver operating characteristic curve thus defining the overall performance of the system under different conditions. [26]

Singh *et al.* (2013) worked on efficient and template based technique for automatic ear detection for side face images. Ear templates were created manually by cropping the side face images. In pre-processing step, skin areas of the input side face image were segmented and processed for edge computation. Ear localization step created a suitable size of ear template and performed the ear localization. Localized ears were verified using Zernike moment based shape descriptor at ear verification step. The technique was able to detect ears of different size and shape automatically from the side face image. Results showed that in real scenario, ear occurs in various sizes and the pre-estimated templates are not sufficient to handle all the situations. Further, detection of ear using templates of various sizes and then selecting best detection is a very computation intensive task. [27]

Singh and Singla (2013) reviewed the different techniques of ear detection and recognition. They discussed the physiological and behavioral biometrics along with their advantages and disadvantages. They also discussed about the various point of view of ear biometrics & told that 2D & 3D images are different than ear prints left behind by accused. [28]

Tayyaba *et al.* (2013) presented a novel ear identification system for security applications. System had three modules: database module, image processing module & identification module. Images were taken and image processing module extracted important information from them & stored templates as database. Same procedure was applied for suspect. Finally identification module compared them. Tayyaba et al. had tested this system in 24 images and they found 98% accuracy. [29]

Ugbaga and Sulong (2013) proposed a human ear classification. They made a new classification based on chain code signature of the Lobule and the dimensionality of the Helix. For the experimental validation of the proposed classification scheme, the University of Science and Technology, Beijing (USTB) ear database II was used. It contained 304 images from 77 candidates with 4 images from each candidate. The work proposed a human ear classification scheme using Chain Code Signature and Dimensionality features of the Lobule and the Helix respectively. USTB ear database was used for the evaluation of the experimental result of the classification method, with a success rate of 94.8% and 92.2%. On comparing the two basic features that were used, the Lobule Chain Code Signature gave a more accurate listing of the classes on the same samples of images. [30]

Wang and Mu (2013) proposed 3D auricle structural features (3DASF). According to them 2D images were greatly affected by pose variation, even reduced to below an accuracy of 30%. Commercial 3D laser scanner was used to obtain 3D shape of human ear: 3D auricle structural features i.e. 3DASF. The different colors represented the variation of ear surface depth. The data was taken from 415 individuals in which 237 were males and 178 were females. The 3DASF extraction was based on the estimating the variation of mesh surface, ICP algorithm was used further for fine alignment. Experimental results conducted on University of Notre Dame (UND) biometric datasets collection F and collection G outperform the state-of-the-art 3D ear recognitions based on ICP. The results also demonstrated that the proposed method was more
robust to pose variation than the state-of-the-art. [31]

Narayan and Dubey (2014) gave a detailed overview of different technical approaches that had been implemented for identifying subjects. They studied various ear database like IIT Kanpur, IIT Delhi etc. finally concluded that a person cannot be individualized from external ear. [32]

Verma *et al.* (2014) presented the significance of morphological or morphometric variation of ears for individualization. It was observed that in most of the parameters which were statistically significant when subjected to determination of identification, they showed a high percentage of differences between males. Studies presented in this research indicate that comparison of ear based on morphological examination and morphometric variations can be used as supportive tool and have a role in forensic science field by the identification of landmarks variations in peoples.[33]

Ordu *et al.* (2014) studied the inheritance pattern of earlobe attachment in Nigerian population. They did their research on 200 Nigerian families with the age group of 5 months to 60 years. They studied attached ear lobe and free ear lobe in parent generation and its transfer in 1st filial (F_1) generation only. They had used photography of external ear from lateral side of head by the help of a digital camera of two generations viz. F_1 generation and parent generation. Chi test was used to analyze the data at 0.05 significant level based on Mendelian inheritance. The percent of offspring with detached earlobe were found 74.17% and 25.83% were with attached ear lobe. Results showed that ear lobe is one of the defining features of human face and detached ear lobe is dominant over attached ear lobe. [34]

Anwar *et al.* (2015) presented a new algorithm for ear recognition based on geometrical features extraction like (shape, mean, centroid and Euclidean distance between pixels). Prior to analysis, the images were resized to272x204 pixels. Then edge detection and post processing was done & finally features were extracted. Seven values were extracted as feature vector which were mean of ear image, centroid of x coordinate, centroid of y coordinate, four different distances from matrix which contain Euclidean distance between every pixels in image. The extracted features were classified by using nearest neighbor with absolute error distance. The experimental results showed that the proposed approach gives better results and obtained over all accuracy almost 98%.[35]

Kalra *et al.* (2015) studied the anatomical and morphological differences and changes of the ear in relation to age and sex. They studied 177 healthy subjects (84 females & 96 males). Four parameters were taken for measurements viz. total ear height (TEH), ear width (EW), lobular height (LH) and lobular width (LW) for each subject's right and left ear. The methodology for measurement was adopted from Mc Kinney *et al* and Brucker *et al*. All the measurements were taken by using the Vernier calipers capable of measuring to the nearest of 0.1mm. The measurements were taken twice to ascertain accuracy and the arithmetical mean of the two measurements was used for each dimension. The numerical data was analyzed by SPSS 20.0. Comparisons of the measurements according to gender were performed by using an independent samples t-test. They found that the left ear indices were found to be higher than the right ones for all the subjects but in female subjects, the right indices were found to be greater than the left ones. With regard to the sex difference showed the TEH and EW were significantly higher in men as compared to other measurements. [36]

Muteweye and Muguti (2015) worked on prominent ear of children. Ear lengths, ear projection and face height were taken for measurements and measurements were done by the help of sliding caliper. Three hundred and five healthy people of the age range 9-13 years of both sexes were included in the study. Ear projection was higher in males compared to females. Among males, 7.69% had prominent ears whilst 6.17% of females had prominent ears. [37]

Purkait (2015) proposed a classification of ear features for personal identification based on the seven most variant ear characteristics. The study was conducted in Central India covering the districts of Sagar, Raisen and Ujjain. The data was collected from 2008 to 2012. The study sample included members of 90 general and 30 tribal families (Bhil and Saura) of Central India. Total 648 members of general and 243 members of tribal families took part in the study. All the subjects were normal and healthy. An additional sample consisting of monozygotic twins was collected to investigate the variation among the closest genetic relations. Ninety pairs of twins were examined from Central India and Allahabad district in North India. Images were captured by Kodak Easy Share CX7330, 3.2 Mega pixel digital camera from 30 cm distance. Somatoscopic features of each subject were observed and a ten character comparison was made with other members of the family who had genetic relation with him/her. Results showed that even the ears of genetically closest relative, identical twins were similar but had distinct morphology. Few ear characteristics were identified which despite genetic closeness exhibited marked dissimilarity in morphology. [38]

Shireen and Karadkhelkar (2015) worked on normal anthropometric measurements of external ear of medical students of BRIMS, Karnataka. Total numbers of samples were 147 in which 70 were females and 77 were males between the age group of 18-25 years. Four parameters were taken for measurements: total ear height, ear width, lobular height and lobular width. Vernier caliper was used for the measurements of ear. After analysis, they found that dimensions were higher in males as compared to females and right ear indices were significantly larger than the left ear indices in both male and female subjects. [39]

Suryawanshi (2015) worked to develop a new biometric authentication using external ear. The project was aimed to develop a biometric authentication system using the ear. The process involved several steps from acquisition of the image to the point where a positive identification could be made using the system. The image was acquired using a digital camera. The photo was then processed, stored and used for the identification process. After the raw data was obtained, the Region of Interest (ROI) which was the area containing the ear image was chosen. Feature extraction filtered the uniqueness data out of the raw data and combined them into the biometric feature. Recognition involves either verification or identification. [40]

CONCLUSION

With every passing day, scope of application of latest techniques in the field of ear biometrics is gaining momentum. The technique has already been improved a lot by the application of different techniques and softwares like PCA, SPSS, etc. Ear prints are not only gaining the attention of researchers as a mean of identification but individualization as well. Different scientists have worked on the shape, size and other minute features of auricle and have also attempted to determine the gender from ear. This article would assist the researchers in having an over view of the emerging trends in relation to ear biometrics. However, much advanced techniques could be used to get more accurate and better results.

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