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ORIGINAL ARTICLE

External ear: An analysis of its uniqueness

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Abstract: In modern times the establishment of personal identity has widened its scope considerably by encompassing various morphological traits e.g. face, iris, retina, hand etc. apart from traditional dactyloscopy. For any trait to be used for identification purposes it is essential that its uniqueness is proved in all individuals. The external ear being a new entrant in this field has not yet been investigated in this aspect.

In the present study an investigation into its uniqueness was undertaken on a large database (1404 adult male and 1257 female subjects) from Central India. Every ear pattern was paired and compared with every other ear present in the sample. Each ear was represented as a feature point in 17 dimensional feature space. The dissimilarity in the ear pattern was measured by Euclidean distance between members of the pair.

More than 99.9% of ears were found to occupy a distinct position in the multi-dimensional feature space. Few pairs which could not be distinguished by the above method were successfully differentiated by subjecting their images to direct superimposition. When the left and right ears of the same individual were compared by the above methods, none of the pairs were left undistinguished. A validation test conducted in North India (on 132 adult males and 168 adult females) supported the above findings.

Hence, the individuality of every ear has been confirmed which may find use in personal identification studies. The study is a step towards providing scientific support for admitting ear evidence in the Court of Law.

1. Introduction

With ubiquitous use of Closed Circuit Television (CCTV), camera phone, digital camera and other electronic gadgets in the present day life, the comparison of images are more frequently encountered for identification in Forensic cases. Establishing identity from human morphology and behaviour (Biometrics) has been practiced for a long time. With the advent of computerization and automation there is immense improvement in the computation time and thereby identification process. Apart from the common traits like face, fingerprint, hand geometry, etc. in recent times scientists are experimenting with new traits to make biometric a wholesome identification system. The external ear is a new entrant in this field. The possibility of using the external ear as a tool for

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establishing personal identity was recognized as early as 1893 by Bertillon[1] and later the aspect was extensively researched by Iannarelli[2] on a large sample. Since then, several studies have been reported on ear pattern by computer scientists.[3–9] The chances of identification are greatly enhanced if information regarding the shape of morphological parts of ear, e.g. shape of ear lobe or any peculiarity like tragal tag, lop ear, Vulcan ear etc. is available. Even the presence or absence of ear piercing itself is a useful attribute in personal identification.[10]

The ear has few additional advantages over the conventional biometric traits, e.g. face. The ear is more coplanar, has uniform distribution of colour, less affected by ageing, unaffected by change of facial expression and not affected by facial make-up like moustaches, spectacle; though hair and ear ornaments can occlude its appearance.[3–7,9] Unlike traits like the iris and retina, imaging of the ear causes less anxiety and can be captured from a distance.[11] The external ear does suffer from a few limitations. It is an established fact that various parts of external ear do exhibit changes with progression of age. The elongation of the lobule contributes the most to the overall increase of ear length, especially after 60 years of age.[12,13] This will necessitate law enforcement agencies to frequently update the biometric database for all ages beyond 60 years.

Any trait used for establishing personal identity must possess few essential properties, one of which is being unique in all individuals. So far little attention has been paid in this direction, and most of the studies so far undertaken (by computer scientists)[3–8] work on the premise that 'nature never duplicates itself' or that 'nature creates things and shapes with great variation between individuals and that there might be enough variation for an ear to be individualised'.[8] But the Court of Law following stricter criteria (Frye v. United States 1923 & Daubert, et al. v. Merrell Dow Pharmaceuticals 1993 rulings)[14] demands a more scientific and objective approach for the admission of any evidence. This has compelled other age old accepted evidence traits like fingerprint or documents to conduct uniqueness test in their field.[14–16] Hence, a preliminary study on a limited sample of 700 individuals was undertaken by the author in 2008.[17] The study was based on 12 direct measurements taken on the external ear. The outcome of the study was quite encouraging. The majority of the members of the population studied were well distinguished in the twelve dimensional feature space so developed.

The aim of the present study was to conduct a detailed investigation into the uniqueness of the external ear on a large database with increased dimensions of the feature space. Since images are more frequently encountered in investigations the present study was undertaken on them. Improving on the last attempt[17] the external ear was represented by 17 different parameters measured across its structure. It is a fact that the larger the number of parameters defining any anatomical structure the finer the assessment will be on its morphology. Hence, in an effort to present the morphology of ear in totality, the seventeen distances measured in the study covered every possible feature of the ear.

2. Materials and methods

2.1. Subjects

The study presented is a part of the research work undertaken for the degree of Doctor of Science. The data collection for the research spanned over a period of four years, 2008 to 2012 from all cross sections of people residing in the state of Madhya Pradesh (Central India). Three districts out of 51 districts constituting the state had been covered for the present study. Wards and villages in two tehsils, Sagar and Khurai of Sagar district, Tarana tehsil in Ujjain and Begumgunj tehsil in Raisen districts formed the study area. The majority of the data were collected by personal house visits; while subjects were also approached at the University campus, colleges, Police academy, Military cantonment, government offices etc.

All the subjects were adults (ranging in age from 20 to 50 years), normal and healthy. None of them suffered from any auricular (congenital or traumatic) or maxillofacial deformity. Data for the present cross-sectional study were collected by the non random method. Unrelated subjects belonging to all caste groups and religion in the general population were inducted. Data were also collected from two tribal groups, Bhil and Saura. Images were procured from 2661 subjects of which 1404 belonged to male and 1257 to female subjects. Any image not conforming to the standard set in the study was rejected.

As a validation test the same study was carried out in Hamirpur district of Himachal Pradesh in North India, a state located in a different geographical setting (hilly area) with a different ethnic composition. 300 adult subjects photographed formed the test sample of which 132 were males and 168 females.

The subjects were informed in detail about the study and those who volunteered to participate were inducted. Participation information sheet explaining the details of the study, its purpose etc. was prepared in English and Hindi scripts (local language) conforming to the guidelines set by Indian Council of Medical Research, New Delhi (Fig. 1). The information sheets were distributed and the details verbally explained to the subjects. Only those subjects who voluntarily agreed to take part in the study were recruited. Confidentiality and anonymity was maintained regarding the identity of the subject by allotting a code number (Fig. 2).

2.2. Method

Detailed descriptions of the theoretical background of the technique, method of comparison of images and imaging technique adopted have been discussed in an earlier study.[18] A brief description of the experimental method is provided here.

The subjects were positioned at a distance of 1.10 m from the camera with his/her head in the Frankfurt horizontal (FH) plane. The face of the subject rested on a fabricated 'Chin stand'. A rectangular scale (60 * 80 mm) was affixed in front of the ear so that it was a common tangent to the bulge of temporal and zygomatic bone (Fig. 3). Care was taken to keep the vertical axis of the scale parallel to the vertical plane of the ear. The horizontal midline of the scale was positioned to be parallel to the FH plane. During photography the focal plane of the camera was parallel to the vertical plane of the rectangular scale. Bilateral profile images were acquired with Kodak Easy Share CX7330, 3.2 Mega Pixel digital camera using 3× Optical zoom.

Using the devised programme ten anatomical landmarks (superaurale P_1, subaurale P_2, intertragica inferior P_3, protragion P_4, antitragus superior P_5, incisura anterior auris posterior P_6, concha superior P_7, posterior most point on the