# Ear Biometric: An Aid to Personal Identification

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## INTRODUCTION

In this electronic age the issue of identification is no longer confined within the walls of Penitentiary. In today's scenario where computers, CCD cameras and other sophisticated electronic gadgets are invading every nook and corner, personal identification has emerged as a global problem.

There is an ever-growing need to authenticate individuals. Conventionally, one establishes his identity using passports, identity cards, keys, or by remembering passwords and personal identification numbers (PIN) when one gains access to a restricted area. Unfortunately the possessions can be lost, duplicated or stolen, and passwords and PIN can easily be forgotten, compromised, or observed. Such deficiencies of conventional personal identification techniques cause major problems to all concerned. In UK itself the rapidly growing identity theft industry is now estimated to be costing GBP 1.7 billion per year. To address the deficiencies of conventional techniques a robust, reliable and foolproof personal identification solution is sought. 'Biometrics' could be the answer to this.

## BIOMETRICS

Though it had been used throughout history, Biometrics first came to limelight in 1879 when Alphonse Bertillon (1853–1914), a French Criminologist, introduced his *anthropometrical signalment or Bertillonage* system for identifying convicted criminals. He developed a method of identification based on anthropometry of various parts of the body including head, ear, fingers etc., the size of which remain constant throughout life after attaining full growth. He even included description of morphological facial features and any peculiar mark observed on the surface of the body. The measurements were incorporated into a formula that referred to a single unique individual, and recorded onto cards which also bore photographic frontal and profile images of the suspect. The cards were then systematically filed and cross-indexed, so they could be easily retrieved. The system was a huge breakthrough and adopted by law enforcement agencies across the world.

With time, some drawbacks of the system came to light. For instance, some large cities had huge databases of cards, and sorting and searching for a particular card could take days. The anthropometrical signalment was found not to be a totally unique biometric. This was discovered when they found that some people shared the same measurements. Eventually this led to abandonment of Bertillonage system in favour of fingerprint identification.

Though *Bertillonage* seemed to slip into history with the success of finger print system, the advent of computers has brought a flourish of new technologies based on human morphological characteristics. This has ushered personal identification to a more accurate, automatic and highly secure world of 'Biometrics'.

### Types of Biometrics

Biometrics is a method of identifying or verifying the identity of an individual based on the physiological and behavioural characteristics. *Physiological biometrics* is based on data derived from direct measurement of a part of the human body. Fingerprint, iris-scan, DNA fingerprinting, retina scan, hand geometry, and facial recognition are leading physiological biometrics. *Behavioural biometrics*, in turn, is based on data derived from an action taken by a person. Voice recognition, keystroke-scan, and signature-scan are leading behavioural biometric traits. Any human physiological or behavioural characteristic can be used as a biometric characteristic as long as it is *Universal, Unique and Permanent* (Jain et al., 2004).

Biometrics can be either Passive or Active. Facial recognition, for example is a Passive biometrics. It does not require user's active participation and can be successful without persons even knowing that they have been analysed. But Active biometrics, fingerprint, retina scanning, signature recognition etc. however, do require personal cooperation and will not work if one denies participation in the process.

### Identification / Verification

Biometric-based personal identification systems can be classified into two main categories: identification and verification. Biometric verification requires comparing an enrolled biometric sample (biometric template) against a newly presented one. It is a "one-to-one matching" process. On arrival at The Netherlands Airport, a 'Frequent Flyer' who is enrolled in the "Privium" programme can enter the country without passport inspection. Instead, he submits his iris scan which is compared against a previously enrolled sample to determine whether the person is 'who he claims to be'.

*Identification* ("one to many matching") implies matching a biometric sample against all records in a database of templates. In this mode, the individual does not claim an identity. The individual presents a biometric sample and the system tries to identify the individual from a database of stored biometric samples. This process intends to answer the question "Who is he?" This mode is usually associated with law enforcement applications.

### Uses of Biometrics

Biometrics is a rapidly evolving technology which has not only found its use in forensics such as for identification of criminal and prison security, but potentially can be useful in a large range of civilian application areas. Biometrics can be used to prevent unauthorized access to ATMs, computer networks, cellular phones, workstations etc. It can be used during transactions conducted via telephone (using voice recognition technique) and internet (electronic commerce and electronic banking). In automobiles, biometrics can replace keys with key-less entry devices.

Iris and fingerprint recognition technology are probably the most widely used and well-known active biometrics. While face recognition being a passive biometrics is very popular with law enforcement agencies engaged in surveillance and monitoring crime. It is the only biometric system that can routinely be used in a covert manner, since a person's face is easily captured by video technology. Face recognition technology identifies individuals by analysing certain facial features, such as the medial and lateral corners of the eye or sides of the mouth, nose etc. But the technology suffers from few inherent problems, difficulty in collecting consistent features from the face as it is the most changing part of the body due to facial expressions, cosmetics, growth of facial hair and hair styling. Added to this difficulty is the effect of age which brings about changes in the facial topography.

## EAR BIOMETRICS

In this paper, ear is proposed as a new class of biometrics for passive identification. Ear has few advantages over facial recognition technology. It is more consistent compared to face as far as variability due to expression, orientation of the face and effect of aging, especially in the cartilaginous part is concerned. Its location on the side of the head makes detection easier. Data collection is convenient in comparison to the more invasive technologies like iris, retina, fingerprint etc.

### Review of Earlier Work

Despite being a newcomer in the biometrics field, ear has long been recognized as a potential tool for personal identification. The importance of ear in establishing identity was realised by Imhofer (1906), an ear doctor at Prague. He found that in set of 500 ears he only needed 4 characteristics to uniquely distinguish them. Fields et al. (1960) made an attempt to identify newborn babies in hospitals on the basis of ear details. They studied 206 sets of ears and concluded that there were enough variations in ear forms in individual sample babies to distinguish visually the ears of one baby from that of another.

Alfred Iannarelli (1989) has made a significant contribution in this field. He has made two large scale ear identification studies. The first study compared 10,000 ears drawn from a randomly selected sample in California and the second study examined identical twins and triplets (who have identical genetic makeup). In both the studies all examined ears were found to be unique, though identical multiple birth siblings had similar, but not identical ear structures.

Iannarelli's system is based on twelve measurements taken on ear photographs. The measurements were taken on specially aligned and normalized photograph of right ear. While developing the negative, the image was projected to fit on to a predefined easel. Various distances on the ear were measured and assigned integer value. The classification system consists of the twelve measurements and the information about sex and race.

### Biometrics as Automated Recognition System

Although ear biometrics is a relatively new topic, researchers have already come up with various approaches for its use as an automated recognition system. Some of them are proved practice in the field of human recognition (e.g. principal component analysis, neural networks etc.) while some present a whole new perspective (force field transformation, Haar wavelet decomposition). Few methods so far used are briefly discussed below.

Principal component analysis (PCA) is by far the most widely adopted methods used in ear biometrics. PCA is a technique for reducing the dimension of feature vectors while preserving the variation in the dataset. A low dimension space called 'Eigen space', which is defined by a set of 'Eigen vectors' of dataset is used in classification. Victor et al. (2002) compared the performances of PCA when applied on face and ear recognition. In their experiments, a total of 294 subjects were used. Factors such as time, lighting, expression and time lapse between successive image acquisitions were taken into account. Results showed that in all experiments, face based recognition gives better performance than ear based recognition.

However, a different conclusion was reached, in similar experiments by Chang et al. (2003). It was found that there was no significant difference between the face and ear in terms of recognition performance. In one experiment, the recognition rates for face and ear were 70.5 percent and 71.6 percent respectively. Using both ear and face together (bimodal recognition) significantly improved the result to 90.9 percent.

Moreno et al. (1999) investigated the performance of various neural classifiers and combination technique in ear identification. The ear image of a person was analysed by neural classifiers using feature outer ear points, information obtained from ear shape and wrinkles and macro features extracted by compression network. Results showed that compression network achieved the best identification result (93%, without considering rejection threshold).

Instead of coming up with a model to describe the ear, Hurley et al. (2002) tackled the problem by simulating the natural process of electro-magnetic force field. By treating every pixel on the image as a Gaussian attractor, an ear image is transformed into a force field. Although experimented on a small data the results are quite promising.

Burge and Burger (1999) used a graph matching approach for ear identification. This approach is based on building neighborhood graph from Voronoi diagrams of the detected edges of ear. No experimental results were given in the literature. One problem however was that the edges detected from ear image can be very different even in presence of relatively small changes in camera-to-ear orientation or lighting. They proposed the use of thermogram imagery to circumvent the problem of ear images partially occluded by hair. Hair being at lower temperature than ear, especially external auditory meatus, can be segmented out from the image.

In India, a novel approach of extracting features from the ear image using Haar wavelet decomposition technique has been adopted by Computer Science department of IIIT, Kanpur (Sana et al., 2007). Haar wavelet decom-position is applied on ear images and the extracted wavelet coefficients represent the pattern of the ear. Decision regarding identification depended on matching one test image with *n* trained images using Hamming distance algorithm. This study has for the first time incorporated soft ear biometrics information to improve upon the identification performance. Soft biometrics are anthropometric and anthroposcopic data, stature, weight, skin colour for example of an individual which are collected during enrollment. Such information can be used for filtering, by reducing the search zone for a large database, thereby improving the speed and search efficiency of the biometric system. For example if the shape of the ear is round in test sample, the search can be restricted only to the subjects with this profile enrolled in the database. The method was implemented and tested on two image databases pertaining to 600 individuals from IIT, Kanpur and 350 individuals from Saugor University. The results showed 98.4% and 97.3% accuracy for IIT Kanpur and Saugor University databases respectively.

### Non-automated Application

Coming to its use in identification of unknown person especially in cases of mass disaster, burn, drowning etc. where the face is severely disfigured, the task of establishing identity becomes quite difficult for the investigating officer. In case the ears are found unharmed, the identity can be established through methods based on the morphology and measurements of ears of the victim. Post mortem photographs of left and right ears taken are compared with the victim's ante mortem photographs supplied by his family. Some research in this direction has been undertaken by the Disaster Victim Identification team of Federal Police of Belgium (De Winnie and Purkait, 2004).

In India, morphology of ear was used to confirm the identity of Veerappan, the sandal wood smuggler who was killed by the Special Task Force (STF) in 2004. Veerappan's missing 'handlebar moustache' had triggered speculation that it may not be Veerappan after all who was killed by the STF.

Professor P. Chandra Sekharan, the Forensic Scientist who studied the anatomical structure of Veerappan's external ear from ante-mortem and post-mortem photographs, gave the confirmation. Combination of various features, a flat tragus being contiguous with the curved portion of the helix, an enlarged and squarish lobule made Veerappan's ear unique, thus helping in his identification.

## CONCLUSION

In conclusion, one may add that though ear is still an infant in the ever enlarging field of biometrics, it is already proving its grit and is on the verge of emerging as a major passive biometric tool.

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**ABSTRACT** Personal identification had been an age-old problem for the law enforcement organisations and Forensic Scientists. The advent of sophisticated electronic gadgets though on one hand has multiplied the problem manifold, on the other, has introduced new techniques for surveillance and monitoring crime. Biometric is one such tool which uses human characteristics for personal identification. Ear biometrics, a relatively new class of biometric trait for personal identification has been discussed in this paper. A brief introduction to the field and review of leading works including those appearing in the research world lately are discussed.

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