# Ear Biometrics in Passive Human Identification Systems

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**Abstract.** The article discusses various issues concerning ear biometrics in human identification systems. The major advantage of ear as the source of data for human identification, is the ease of image acquisition, which can be performed even without examined person's knowledge. Moreover, user's acceptability and easy interaction with the system make ear biometrics a perfect solution for secure authentication e.g. in access-control applications. In the article the focus is on the ear biometrics motivation, ear identification system design and interaction with the user. Feature extraction methods from ear images are also discussed.

## 1 Motivation for Passive Human Identification Systems

Biometrics methods of human identification have gained much attention recently, mainly because they easily deal with most problems of traditional identification, since users are identified by who they are, not by something they have to remember or carry with them. The passive methods of biometrics do not require any action from users. Some systems can even verify the identity of humans without their cooperation and knowledge, which is actually the future of biometrics. Crowd-surveillance, monitoring of public places like airports or sports arenas are the most important applications that need such solutions. Possible passive methods include popular and well-examined face recognition, but one of the most interesting novel approaches to human passive identification is the use of ear as the source of data.
The most interesting human anatomical parts for passive, physiological biometrics systems based on images acquired from cameras are face and ear. Both of those body parts contain large volume of unique features that allow to distinctively identify many users and can be implemented into efficient biometrics systems for many applications. However, still the automated system of ear recognition has not been commercially implemented, even though there are many advantages of using ear as a source of data for person identification (small size, stable features, uniform colours). Furthermore, ear is one of our sensors, therefore it is usually visible (not hidden underneath anything) to enable good hearing. In the process of acquisition, in contrast to face identification systems, ear images cannot be disturbed by glasses, beard or make-up. However, occlusion by hair or earrings is possible, but in access control applications, making ear visible is not a problem for user and takes just single seconds (Fig. 1).

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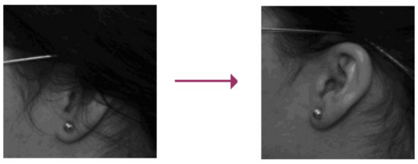

**Fig. 1.** Ear visibility can be easily achieved in access control systems.

## 2 Ear Biometrics Systems: Feature Extraction Methods

The first, manual method used by Iannarelli was based on measuring the distances between specific points of ear [1]. Another well-known method by Burge and Burger [2] was based on building neighbourhood graph from Voronoi diagrams of the detected edges. Hurley et al. [3] introduced a method based on energy features of the image. Another method used by Victor et al. [4], in the experiment comparing ear and face properties in order to identify humans was based on PCA. Their work proved that ear images are a very suitable source of data for identification and their results for ear images were not significantly different from those achieved for face images. The method, however, was not fully automated, since the reference points had to be manually inserted into images. Another approach presented by Moreno et al. [5] was based on macrofeatures extracted by compression networks. Recently, various approaches towards 3D ear biometrics has been developed and published [6][7].

### 2.1 Geometrical Feature Extraction

Our methods based on geometrical feature extraction are motivated by actual procedures used in police and forensic evidence search applications. Nowadays, human ears and earprints are standard features of identity taken into account by forensic specialists and criminal policemen (so called *ear otoscopy*). In reality, well-established procedures of handling ear evidence are based on geometrical features such as size, width, height and earlobe topology [8].
Therefore we decided to compute geometrical parameters of ear contours extracted from ear images. Such approach gives information about local parts of the image, which is more suitable for ear biometrics than global approach to image feature extraction. Moreover, geometrical features of extracted contours are more adequate for ear identification than colour or texture information, which is not distinctive enough for various ear images. On the other hand, contours corresponding to earlobes are very diversified and contain enormous amount of information allowing ear identification.
In the proposed method of feature extraction from ear images in order to perform human identification we use the geometrical parameters and properties of ear contour images. The first step of the method is the extraction of contours from ear images in such way, that the extracted contours contain distinctive information about shape and geometrical properties of given ear. Then for each of the extracted contours we construct the feature

vector on the basis of geometrical parameters.
Our method of human identification based on ear image analysis consists of the following stages:

- ear image preprocessing - we perform such operations as contrast enhancement, filtration and histogram equalization,
- contour detection - we use local-based method based on pixel illumination, mean and variance changes in $3 \times 3$ window,
- contour processing - the aim of contour image processing is the selection of contours containing the most distinctive information characterizing human ear images. For each extracted contour, we calculate its length, and then on the basis of the selection algorithm we eliminate contours which are classified as $short$. Usually we obtain binary ear contour images with 7-10 longest contours.

**Fig. 2.** Longest and numbered contours for the test images 'macfir' and 'szysob'.

- image normalization - image size is normalized and invariance to rotation, translation and scaling is achieved,
- geometrical feature extraction algorithms - we developed 5 novel algorithms,
- classification algorithms based on feature vector distances in feature space.

On the basis of the extracted and selected contours we proposed 5 methods of feature extraction, described in our previous work [9][10][11]:

- concentric circles based method - $CCM$,
- contour tracing method - $CTM$,
- angle-based contour representation method - $ABM$,
- geometrical parameters method $GPM$ which is divided into:
  - triangle ratio method - $GPM - TRM$,
  - shape ratio method - $GPM - SRM$.

In the feature extraction methods binary contour images with the selected number of contours and normalized coordinates are processed. Feature extraction methods are based on concentric circles centred in the centroid point obtained from binary contour image. Contour tracing method is also based on extracting characteristic contour points analogically to fingerprint $minutiae$ search [12]. Moreover, methods based on the developed geometrical parameters, calculated for selected contours, were developed.
After experiments we came into conclusion that the proposed geometrical methods, which were motivated by the manual process of feature extraction used in criminology,

allow effective person identification on the basis of features extracted from ear images. The most effective methods were $GPM$ and $CTM$ and the achieved results are comparable with face recognition systems. All the tests were performed on our own ear image database, which is secured and used only for research in our laboratories. According to the Polish law (Personal Data Protection Law), human features which are analysed and processed in the biometrics systems are a subject of protection. In the identification systems the problem of overcast ears (e.g. by hair) is marginal, since there is always the possibility of a proper ear image acquisition (with the user's cooperation) (Fig. 1). Therefore in the experiments we focused on images of the visible ears. The cumulative results in the first scenario for all the methods are presented in the Table 1.

**Table 1.** The cumulative results of the developed identification methods for the first scenario. The presented parameter is the standard false rejection ratio $FRR$.

| method | number of tests | number of acceptances | number of rejections | FRR |
|---|---|---|---|---|
| $CCM$ | 40 | 36 | 4 | 10 |
| $CTM$ | 40 | 39 | 1 | 2.5 |
| $ABM$ | 40 | 36 | 4 | 10 |
| $GPM$ | 40 | 40 | 0 | 0 |

## 3 Applications and Test Scenarios

In order to verify the effectiveness of the presented feature extraction methods we proposed two experimental scenarios. The first one involves the finite ear images database. One of the users, who took part in the enrolment process and his ear image is surely stored in the database, is chosen randomly. The acquisition of the user's test ear image is performed. Next, we compute the feature vectors for the test user and we search for the corresponding image from the database. In result of such scenario we obtain one ear image for which the computed feature vectors are the closest to test image feature vectors in terms of distance in the feature space [13]. The first scenario reflects such applications of the biometrics identification systems as access control to controlled places (company's buildings, rooms). For one test user only the identification decision (yes/no) is expected.

In the second scenario the finite ear image database is also considered, but it is not known if the test user's ear image is also in the database (the user didn't have to take part in the enrolment step and therefore his ear image might not be stored in the database). In the result of the second scenario we obtain $H$ images with the most similar feature vectors in terms of distance in the feature space.

Such scenario is similar to Content Based Image Retrieval Systems, in which for the user's input query (test image), a number of the most similar images are found. It is not a popular situation in real-time biometrics identification systems, but it might be useful in criminal applications. In such case (where there is no place for mistake) the trained policeman/forensic expert gets $H$ images with the most similar feature vectors to the input query and, on the basis of his knowledge, he verifies the result.

## 4 Ear Biometrics System Design and Studies on Interaction with Users

Besides verification of the effectiveness of the proposed methods, we also studied interaction with the users aspects. Those aspects are always crucial for biometrics and other HCI (Human Computer Interaction) systems development.
In order to perform the experiments our own ear image database of over 100 users' ears was used. In the process of enrolment, by analogy with face recognition methods, we store 10 images for each person (perpendicular to the camera $0°$, $30°$ and $-30°$, $60°$ and $-60°$) for 2 values of illumination in the room.
We mainly worked with students who agreed to take part in the enrolment process. All of the students had little time to make decision whether to take part in experiments or not, and all of them were astonished by our request (it is due to the fact that none of them had heard about ear biometrics before).
During ear image enrolment we came to important conclusion that potential users are not afraid to interact with ear biometrics system, which means that ear biometrics is less stressful than dactyloscopy. Moreover, our test users admitted that they would feel less comfortable while taking part in face images enrolment (people tend to care how they look on photographs). Furthermore, in ear biometrics there is no need to touch any devices and therefore there are no problems with hygiene. Therefore ear biometrics seems to be a perfect solution for passive identification systems. After user studies we concluded that ear biometrics is more favourable than fingerprint, iris or even face recognition.
Since security of biometrics features is a hot topic nowadays, it is worth mentioning that ear images are more secure than face images, mainly because it is very difficult to associate ear image with a given person (in fact, most of users are not able to recognize their own ear image). Ear image databases do not have to be as much secured as face databases since the risk of attacks is much lower.
Therefore, storing and processing ear images in a biometric identification system is more secure that in the case of face databases. It is more difficult to perform identity-stealing on the basis of ear images. It is an important issue for biometrics system developers since the number of such crimes is tripled each year.

## 5 Conclusion

Human ear is a perfect source of data for passive person identification in many applications. In a growing need for security in various public places, ear biometrics seems to be a good solution, since ears are visible and their images can be easily taken, even without the examined person's knowledge.
Moreover users' acceptance of ear biometrics is very high. We examined user interaction in the enrolment step and we concluded that ear images acquisition is more user-friendly and less stressful than other methods, even face recognition.

The proposed geometrical feature extraction methods can be used to determine personality of some individuals, for instance terrorists at the airports and stations. Access control to various buildings and crowd surveillance are among other possible applications of ear biometrics.

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