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Research paper

Systematic Review on Ear Identification

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Abstract

Context: The topic is permitted from modern topics of interest for researchers to find logical solutions to problems of detection and recognition for ear identification. Therefore, we are looking for a solution to the problem of occlusion, detection and recognition of the person create an integrated system based on the latest research and to find new results in terms of accuracy and time and be comprehensive for everything.
Objective: To survey researchers' efforts in response to the new and disruptive technology of ear identification systems, mapping the research landscape form the literature into a coherent taxonomy.
Method: We use a systematic review as the basis for our work. a systematic review builds on 249 peer-reviewed studies, selected through a multi-stage process, from 1960 studies published between 2005 and 2017.
Results: We develop a taxonomy that classifies the ear identification systems. The results of these articles are divided into three main categories, namely review and survey article, studies conducted on ear biometrics and development of ear biometric applications.
Conclusion: The paper is, to our knowledge, the largest existing study on the topic of ear identification. This typically reflects the types of available systems. Researchers have expressed their concerns in the literature, and many suggested recommendations to resolve the existing and anticipated challenges, the list of which opens many opportunities for research in this field.

Keywords: *Ear biometrics, Ear identification, Ear recognition, Ear detection.*

1. Introduction

Biometrics is a system of identifying or verifying the identity of an individual, and it has the capability to reliably distinguish between original and fake. At present, there are numerous strategies to characterize and check the identity of a person. Biometrics offers higher authenticity than the customary techniques. A perfect biometric must be novel, changeless, widespread, and collectible. Ear biometric has good advantages over the other recognition technologies since its structure does not change due to aging and, unlike other biometrics, it is unaffected by facial expression [1].
The person, who wants to enter one of the government office would need to be authenticated in some ways such as using an identity card, an identity key, or using advanced technologies such as fingerprint, iris, retina or other techniques [2]. In all the previous methods, their efficiency is limited for reasons such as the possibility of the keys being stolen or forged cards being used. A crowd in the entrance may facilitate a way for unauthorized users to slip into those offices without the knowledge of security staff [3]. Therefore, there is a need for passive identification without knowledge of the examined person [4].

2. Systematic Review

The main key words used are "ear biometrics", "ear identification", "passive identification", "ear detection" and "ear recognition". We limited our scope to papers written in English language only. Also papers would be confined to those published from 2005 to the search date (the search was conducted in April 2017). Five databases were explored to search for articles consisting of IEEEXplorer, Web of Science (WoS), Scopus, Springer link and Science Direct.
All the papers went through three steps of filtering. In the first step of filtering, all articles unrelated to the proposal were removed. For the second step, the titles and abstracts were checked for any duplicates. Finally, we reviewed the full-text articles and discarded papers that are not within the scope of study.

3. Results

The initial query resulted in 1960 papers: 538 from IEEEXplorer, 322 from Web of Science (WoS), 543 from Scopus, 375 from Springer link, and 182 from Science Direct. From the first filtering phase, 1446 out 1960 papers were out of the scope of our study. After scanning the titles and abstracts to check for duplicates, we further excluded 21 papers. In the final full-text review to check for papers that falls within our scope, 244 papers were further excluded, and a total of 249 papers remain in the final set. The whole process is summarized in Figure 1.
Figure 2 shows the five engine boxes (IEEE Xplore, Science Direct, Scopus, Springer Link and Web of Science).
That store numerous research works and were used in this systematic review. The results of these articles are divided into three main categories, namely review and survey article, studies conducted on ear biometrics and development of ear biometric applications. Most of the studies come from IEEE Xplore which consists of 151 articles, which are divided into 4 review and survey articles, 24 studies conducted on ear biometrics and 123 papers on ear biometrics applications development.

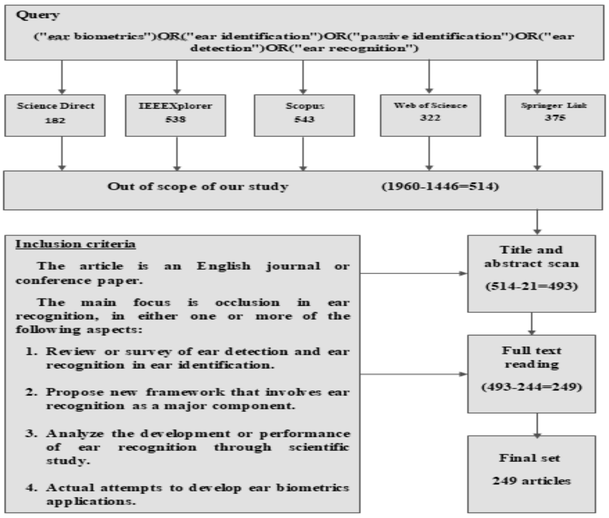

Fig. 1: Flowchart of paper selection, including the search query and inclusion criteria

As for Science Direct, there are 32 total articles where 6 papers are on ear biometrics studies and 26 papers on ear biometrics applications development. The total number of papers from Scopus is 35, further divided into 1 review and survey article, 7 on ear biometrics studies and 27 papers on ear biometrics applications development.

The least number of papers comes from Springer Link with total of 14 articles with 3 studies conducted on ear biometrics and 11 articles on ear biometrics applications development. Web of Science contributed 17 articles with 3 studies conducted on ear biometrics and 14 articles on ear biometrics applications development.

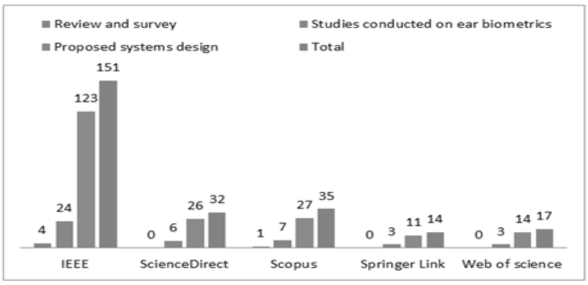

Fig. 2: Number of papers in various categories for journal publications

Figure 3 shows the papers in the four categories aforementioned according to year of publication (from 2005 to 2016). The highest number of publications was on 2013 and the least in 2006.

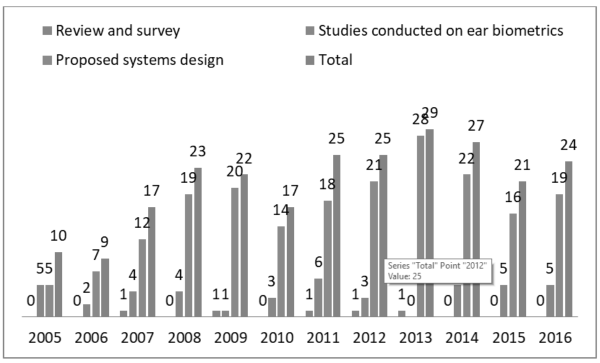

Fig. 3: Different categories by year of publication

Figure 4 displays the distribution of the studies by authors' countries, where the studies on ear biometrics were done in 34 countries. From final set of 249 articles, the geographical distribution of the selected papers on ear biometrics in terms of numbers and percentages shows that the most productive authors are from China with 84 articles followed by 34 articles from India. For further details please refer to Figure 5.

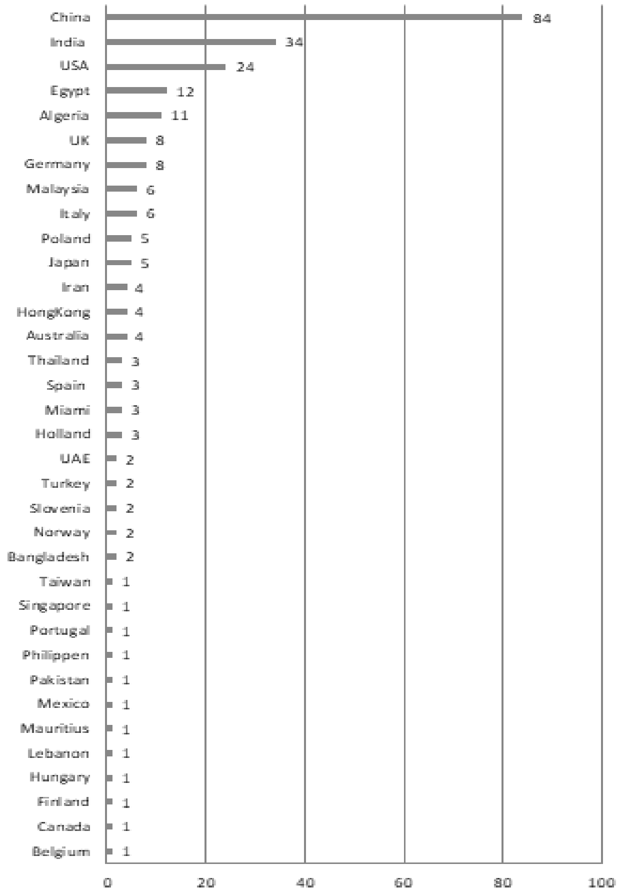

Fig. 4: Distribution by authors' countries

The selected papers were reviewed diligently to produce the taxonomy of literatures shown in Figure 5. The taxonomy centralizes the comprehensive development of different studies and implementations of main streams of research focusing on ear biometrics.

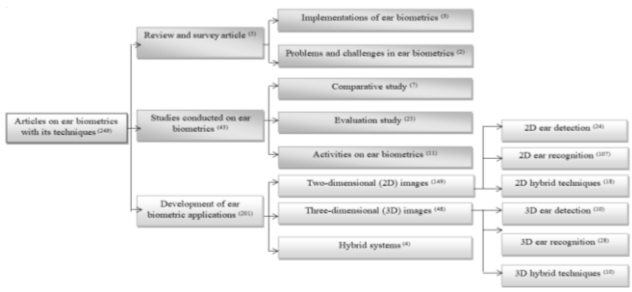

Fig. 5: Taxonomy of literature on ear biometrics

3.1 Review and Survey Articles

The first category includes survey and review article related to ear biometrics (5/249 articles) to summarize the current state of understanding on ear biometrics. The papers could be categorized to i) implementations of ear biometrics and ii) problems and challenges in ear biometrics.

3.1.1. Implementations on Ear Biometrics

In this category, there are three papers (3/5) that surveyed and reviewed the state of the art implementations of 2D and 3D ear biometrics detection and recognition systems [5], [6] and also further described about improvements of the accuracy in 2D ear recognition [7].

3.1.2. Problems and Challenges on Ear Biometrics

Two papers under this category (2/5) gave the overview of the various approaches and solutions to the problem of pattern extraction from 2D and 3D ear images [8], [9].

3.2 Studies Conducted on Ear Biometrics

The second category includes articles of studies on actual attempts to develop the ear biometrics applications (43/249 articles). These studies could further be divided into comparative studies, evaluation studies and activities of ear biometrics.

3.2.1. Comparative Study

The comparative studies were studies that developed their system and made comparison with other related studies (7/43). [10], [11] compared the performance of the system using 2D and 3D images while [12]–[14] compared their applications with other standard methods and techniques. Ear recognition and face recognition were also compared [15] and another study looked at the comparison of rotation and scaling techniques on ear images [16].

3.2.2. Evaluation Study

In the category of evaluation study of ear biometrics (25/43), ear uniqueness was studied in detail by [17]–[19]. Evaluation of feature extraction methods are also popular studies [20]–[25], as well as evaluation of various ear biometric databases and toolboxes [26]–[29]. There are studied which looked at the effect of time on ear biometrics [30], [31] and also effects of image compression on ear biometrics [32].
Other evaluation studies looked at specific issues such as evaluation of 3D ear biometric based on cumulative match characteristic (CMC) curve and the receiver operating characteristic (ROC) curves [33], new efficient feature selection scheme [34], locally linear embedding (LLE) algorithm for multi-pose ear recognition [35], use of multi-modal biometrics in recognition system [36], and performance of segmentation under various illumination conditions in 2D ear images [37]. Several studies we concerned with improvement of forensic ear identification [38], acoustic ear recognition [39], ear recognition for identification of newborn [40], also improvement by combining more biometrics in one system [41].

3.2.3. Activities of Ear Biometrics

Papers in this category were concerned with real activities and application of ear biometrics (11/43). [42]–[45] studied on authentication by using different methods and techniques, [46], [47] looked at on usage of mobile by using different methods and techniques, and [48] investigated on passive identification by using different methods and techniques. Several researchers presented overview studies on ear biometrics by using different methods and techniques [49]–[52].

3.3 Development of Ear Biometric Applications

This category presents the articles on systems that were developed for ear biometrics application (201/249). All related techniques and methods used in the actual attempts to develop and implement the ear biometrics applications are further divided into two-dimensional (2D) images, three-dimensional (3D) images and hybrid systems.

3.3.1 Two-Dimensional (2D) Images

Developments of ear biometrics applications which are based on 2D ear biometrics (149/201) are presented in this category. The techniques and methods are divided to 2D ear detection, 2D ear recognition and 2D hybrid techniques.

2D Ear Detection

The first step towards accomplishing a practical ear identification system is the ear detection from profile face images (24/149). In this step, the proposed technique will search on the ear images to locate the ear part from the image. 2D ear detection was based on various different methods. Among the popular methods proposed were:

- 2D hybrid ear detection [3], [53]–[56],
- structural ear image [57]–[59],
- AdaBoost algorithm [60]–[62],
- arc-masking extraction and AdaBoost polling [63], [64], and
- skin-color [65], [66].
- active contour model [67],
- distance transform and template matching [68],
- wavelet and principal component analysis [69],
- scale invariant feature transform algorithm [70],
- geometrical feature extraction [2], jet space similarity [71],
- Canny edge detector [72],
- Gaussian classifier [73], and
- mathematical morphology [74].

2D Ear Recognition

The richness and stability of the ear structure are the characterization of the human ear pattern that provides a large amount of information such as size, color and texture; allowing differentiation between people to identify them in recognition system. We found (107/149) articles in 2D ear recognition which uses various ear recognition methods [75]–[85]. Among the popular ear recognition methods were based on:

- sparse representation [86]–[97],
- geometric feature extraction [4], [98]–[109],
- principal component analysis PCA [110]–[116],
- neighborhood preserving embedding [117]–[119], principal independent components analysis (ICA) [120],
- neural network [121]–[127],
- wavelets [128]–[133],
- Gabor features [134]–[141],
- scale invariant feature transform (SIFT) [142]–[149],
- local binary patterns (LBP) [150]–[156],
- active shape models (ASM) [157]–[162],
- linear discriminant analysis with other methods [163]–[165],
- fisher discriminant analysis [166], [167],
- thermal profile face image [168], [169],
- support vector machine (SVM) [170], [171],
- force field transforms with other methods [172], [173],
- Poisson-Binomial Radius (PBR) [174],
- weighted wavelet transform and discrete cosine transform (DCT) [175],
- ear morphology [176],
- features histogram [177],
- One Sample per Person [178]
- partial least square discrimination (PLSD) [179], and
- isometric mapping algorithm [180].

2D Hybrid Techniques

Hybrid techniques in this category mean the proposed systems performed both ear detection and ear recognition in the same system (18/149). Among the various techniques used by researchers

for performing both tasks were based on:
- geometric feature extraction method [181]–[184],
- wavelet transforms [1], [185], [186],
- scale invariant feature transform (SIFT) [187]–[189]¸
- contourlet transform [190], [191],
- maximum and the minimum ear height lines [192], ear identification system [193],
- kernel fisher discriminant analysis (KFDA) [194],
- Gabor scale information [195],
- unsupervised clustering [196], and
- artificial neural network [197].

3.3.2 Three-Dimensional (3D) Images

Developments of ear biometrics applications (48/201) using 3D images are presented in this category. The techniques and methods are divided to 3D ear detection, 3D ear recognition and 3D hybrid techniques.

3D Ear Detection

As stated previously, detection of the ear from profile face images is the first step in ear identification system, which also common for 3D images (10/84). Previous researchers attempted 3D ear detection based on several techniques:
- feature extraction [198]–[201],
- histograms of categorized shapes (HCS) [202], [203],
- entropic binary particle swarm optimization (EBPSO) [204],
- locating human ears in side face range images [205],
- new coordinate direction normalization schema [206],
- ear contour which combines both intensity and depth image [207].

3D Ear Recognition

We found (28/48) articles in 3D ear recognition that attempted on using the large amount of information from 3D ear image structures (such as size, color and texture) for recognition system. The following are the various approaches and techniques used:
- geometric feature extraction [208]–[211],
- 3D hybrid ear techniques [212]–[215]
- iterative closest point algorithm [216]–[221],
- Gaussian-weighted average of the mean curvature [222], [223],
- sparse representation [224], [225],
- scale invariant feature transform (SIFT) [226],
- wavelets on geometry images [227],
- structure from motion (SFM) and shape from shading (SFS) techniques [228],
- shape-based interest point descriptor (SIP) [229],
- removal of false mapped features of 3D shapes [230],
- local histograms of surface types for feature extraction [231],
- Local Salient Shape Feature [232],
- spherical harmonics transform algorithm [233],
- slice curve matching [234], and
- combination of feature embedding [235].

3D Hybrid Techniques

Similar to the same hybrid definition in 2D category, the papers in this section deals with systems that performed both ear detection and ear recognition but using 3D images (10/48). The systems were developed and implemented using the following techniques:
- histogram of indexed shapes (HIS) feature [236]–[238],
- feature extraction [239]–[241],
- iterative closest point (ICP) algorithm [242], [243],
- sparse representation [244], and
- logic scoring of preference (LSP) [245].

3.3 Hybrid Systems

In this category, the systems were developed for applications that could handle both 2D and 3D ear biometrics (4/186). The numbers are few considering that it is quite a challenging problem to have a robust and fully automatic system for 2D and 3D images with a good balance between speed and accuracy.
Hybrid multi-key point descriptor sparse representation-based classification (MKD-SRC) ear recognition approach based on 2D and 3D information were attempted by[246], [247]. [248] proposed the use of 2D AdaBoost detector that is combined with fast 3D local feature matching and fine matching via an Iterative Closest Point (ICP) algorithm while [249] proposed a fully automatic ear biometric system using 2D and 3D information.

4. Conclusion

A recent trend in ear identification is the ear biometrics systems that address ear detections and ear recognitions.
Research on this trend has already been active, and there is still a need for insight into what already happens in this emerging line at the present stage. Thus, this article aims to contribute to such vision by conducting surveys and reclassifying literature.
Specific patterns can be derived from the works done on the biometrics and the classification of the search which is divided into three distinct categories: review and survey articles, studies conducted on ear biometrics, and development of ear biometric applications. Some specialties have received more attention from researchers as well as few functions. This usually reflects the types of systems available in the wild but it gives a clear indication of where gaps exist in system development and / or evaluation.
The researchers have expressed concern in the literature, and many of the recommendations have suggested solution to the existing and expected challenges, which paves the way for other studies and research in this area. The present article focuses on improving performance and reducing arithmetic time. The proposed automated system is expected to be efficient and effective.
Few studies are found on systems that control ear detection and ear recognition to solve ear occlusion. Also, calls for an important line of research that may intersect with several other technological and scientific lines are limited.

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