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# Human Earprint Detection Based on Ant Colony Algorithm

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**Abstract:** In recent years, the human ear has grown in importance as a biometric application. This work describes a new technique for sensing the construction of the external human ear that is based on the use of ant colony optimization. During the detection phase, IIT Delhi-I datasets were used to test the system, which contained (120) human ear photographs of the left and right profiles. The proposed method was able to discover and extract the human outer ear structure with very high detection rates (97.6%).

***Keywords:*** *ACO, Gaussian filter, optimization, IIT Delhi-I, biometric, earprint.*

## 1. Introduction

The unique structure of the human ear makes it a remarkable biometric for passive identification. They have trustworthy and strong qualities, and their future seems promising [1], [2]. The pinna, or external ear anatomy, varies widely from person to person while being relatively straightforward. The outside human ear has several distinguishing qualities as shown in Fig. 1, making it a preferred choice for a variety of projects, including identification, common identity validation, safety applications, and admission control [3–7]. Furthermore, machine learning (ML) algorithms can provide techniques and resources for classifying data and dividing it into two or more groups [8].

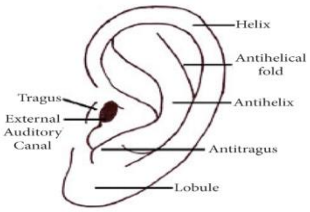


**Fig. 1.** Outer ear Diagram [9].

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Since Alfred Iannarelli [10] in 1989 was a pioneer in this field and proposed the early study of ear detection. On the basis of 12 metrics, he divided the ear into eight parts. Abbreviations and Acronyms

However, the difficulty of localizing anatomical points made this method ineffective. Many studies after then used ear identification as an essential biometric object. They suggested a graph matching algorithm for ear recognition that was only effective for passive identification.

Additionally, Moreno *et al.* [11] proposed a new technique for identifying ears based on the feature points of the outer ear contour and details found in the shape and wrinkles of the ear.

Zhichun *et al.* [12] suggested a person identification system for ears based on form and structural features. Edge detection, ear description, feature extraction, and ear recognition based on the feature vector that has characteristics of both the outer and inner ear (form and structure) are all included in this edge-based ear recognition technique.

An ear identification system employing a bi-orthogonal and Gabor wavelet-based area covariance matrices technique was proposed by Yazdanpanah *et al.* [13]. On the USTB database, they had acceptable average accuracy.

An automated ear recognition method utilizing back propagation neural networks and energy edge density features was proposed by Daramola *et al.* [14].

For most recent studies, Alagarsamy and Murugan [15], a contemporary system was presented. This technique uses segmentation adaptive approach runge-kutta (AARK) segmentation to provide a new system for ear identification. The major use of the AARK segmentation approach is to recognize the boundaries and objects in ear pictures. Additionally, the AARK has strong form connection and helps accelerate segmentation. In addition, ear pictures are classified using a classifier dubbed the Classification and Ear Recognition System utilizing Random Forest and Histograms of Oriented Regression Tree (CART), and features are extracted from the images using the discrete wavelet transform (DWT). The photos used in this study have been reduced from two dimensions to one. This approach has proved to have the maximum sensitivity of 95.45%, accuracy of 97.69%, and F-measure of 96.55%. Even yet, this method's maximum accuracy is still not promising.

An optimization technique (e.g., genetic algorithm) was utilized in the work in [16], [17] for the use of ear recognition. The genetic algorithm is used to find the optimal chromosome for a characteristic and to eliminate extraneous features. To extract distinctive elements from the ear pictures, the local and global features have been integrated. Gabor-Zernike operator (GZO) was used to extract the global features, while local phase quantization was used to extract the local features (LPQ). Additionally, the contrast-limited adaptive histogram equalization (CLAHE) approach used in the pre-processing stage has increased the quality of ear pictures. The closest neighbour classifier is used in the classification process to categorize people based on the pictures of their ears. Additionally, three separate databases of ear images—IIT125, USTB-1, and IIT221—have been utilized to assess the proposed approach. According to the methodology's results, the average accuracy for the IIT125 database, USTB-1 database, and IIT221 database may all be as high as 99.2%, 100%, and 97.13%, respectively. There are other significant metrics that may be used to evaluate the system, such as precision, recall, specificity, and f-measure, however this technique has only been examined in terms of accuracy.

We can identify the number of study flaws from prior studies, such as the fact that the majority of systems have not been evaluated using execution time and other evaluation criteria. The results of numerous systems in this field are also not encouraging.

The main idea of this study is the recognition of ear photocopies using the Ant Colony (ACO) algorithm as average exposure system. The ACO procedure combines information about the composition of a good resolution from the past with information about the assembly of previously discovered good explanations [18].

The remainder of the paper is as follows: Section 2 discusses main ideas behind the proposed method and the supplied algorithm. The work results and outcomes are in Section 3, and the conclusion are in Section 4.

## 2. Proposed Method

In this work, a variety of techniques were utilized to enhance contrast, smooth the colorful picture, and convert it to grayscale in order to determine the primary structure of the outer ear. The next sections will explain these methods:

### 2.1. Gaussian Filter

It is a 2D convolution operator. The form of filter is explained by Equation 1.

$$f(x,y) = \frac{1}{2\pi\delta^2} e^{\left(\frac{-x^2+y^2}{2\delta^2}\right)} \quad (1)$$

Where, x and y are the horizontal and vertical axes' distances from the origin. This is the Gaussian distribution's standard deviation.

The initial goal of using this type of filter is to denoise the image, and the second goal is to blur the image [19, 20].

### 2.2. Grayscale Image

With each pixel value being specified by 8 bits [0-255], the exceptional brightness value is the only element that makes up grayscale. Considering Eq. 2, the Gray value was determined. [21]:

$$G(x,y) = Threshold\left(\frac{R+G+B}{255}\right) \quad (2)$$

Where,

G(x, y) : is the grey value.

R, G, B: are red, green, and blue respectively.

### 2.3. Contrast Enhancement

The main goal of this improvement is to widen the brightness value distribution such that it spans the whole histogram. Contrast extending is used in this method, and Eq. 3 is acquired to generate new pixel intensity values [22, 23].

$$C(x,y) = round\left(\frac{(m(x,y)-Min)^{\propto *255}}{(Max-Min)}\right) \quad (3)$$

Where,

*C(x,y)* is new pixel intensity values. m(x, y) is old intensity values. The minimum and maximum intensity levels are called Min and Max, respectively. Within the range, is the sigma value (3–10).

### 2.4. Ant Colony Optimization (ACO)

A population-based meta-heuristic technique called ACO is used to find the best resolutions [18]. ACO is based on how actual ants hunt food. Figure 1 illustrates how ants leave a substance known as pheromone on the approach as they go from their layer to the food base and vice versa. Due to evaporation, the pheromone's target gets weaker with time. Pheromones are employed to signal which path has to be taken. The more ants travel down a certain path, the more challenging the pheromone choice becomes and the more desirable this path becomes. The transition probabilities probabilistically control the movement of ants from one pixel to the next. All of the image's pixels are initially initialized with low pheromone values. [18], [24], and [25].

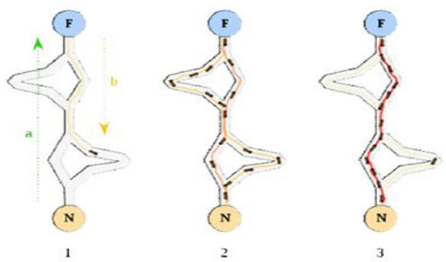



**Fig. 1.** Ants follow a route between Nest and Food

For the proposed method, the general overview of ACO algorithm is illustrated in Figure 2.

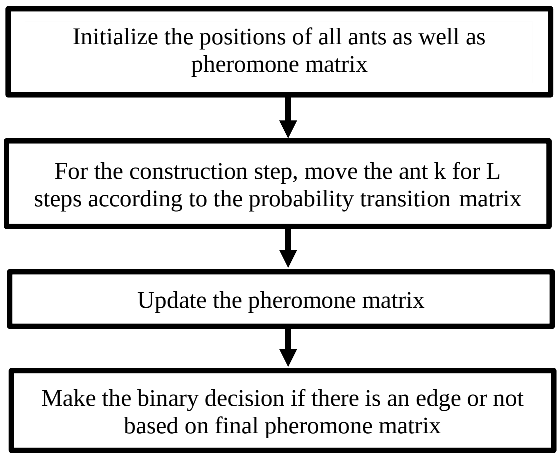



**Fig.2.** The Layout of the ACO algorithm

## 3. Results and Discussions

### 3.1. Proposed Algorithm

This part provides both a thorough discussion and an explanation of the study findings. Figures, graphs, tables, and other easy-to-understand formats can be used to show results [18], [25]. The discussion can be made in several sub-sections.

The structure of identifying human outer ear structure as revealed in Fig. 3, consists of the following stages:

**Stage 1:** Read an RGB ear image (m) of size (272 × 204), where N and N are rows and lines of the illustration respectively.

**Stage 2:** Smooth (m') is gained by applying the Gaussian filter as explained in section (3.1) to m

**Stage 3:** Converting the smooth (m') to greyscale image (g') clarified in section (3.2).

**Stage 4:** (g') is gained by applying contrast enhancement to the g resulting from step 3 as explained in section (3.3).

**Stage 5:** (e) is gained by applying ACO on the image (g') resulting from stage 4 as explained in section (3.4); (e) represents the final output of the proposed algorithm.

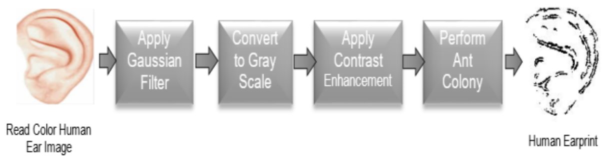
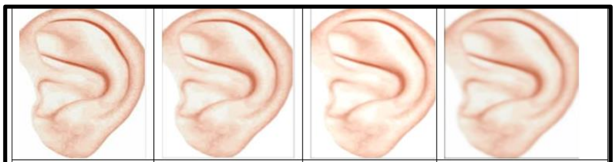



**Fig.3.** The layout of the presented algorithm.

### 3.2. Image Smoothing Step

At this point, the smoothing method outlined in Eq. 1 is applied. Gaining better control over the results of abstraction is the aim of this step. Using a filter with mask sizes of 33, 55, and 77 with sigma values of 0.5, 0.8, and 1.5 is demonstrated in Fig. 3. The sigma value for this investigation was set at 0.8.



| Ear image | Sigma= 0.5 | Sigma= 0.8 | Sigma= 1.5 |
|---|---|---|---|
| Sigma | 0.5 | 1 | 1.5 |
| Kernel Size | 3×3<br>001 007 001<br>007 055 007<br>001 007 001 | 5×5<br>001 004 007 004 001<br>004 020 033 020 004<br>007 033 055 033 007<br>004 020 033 020 004<br>001 004 007 004 001 | 7×7<br>001 003 006 007 006 003 001<br>003 009 018 022 018 009 003<br>006 018 035 044 035 018 006<br>007 022 044 055 044 022 007<br>006 018 035 044 035 018 006<br>003 009 018 022 018 009 003<br>001 003 006 007 006 003 001 |

**Fig. 3.** application of filter with mask size (3×3), (5×5) and (7×7) and sigma values (0.5, 0.8, and 1.5)

### 3.3. Convert to Grayscale step

The suitable threshold value of 50 is used in this step of the project using Eq. 2 after experimenting with several threshold values on the picture produced during the smoothing phase. Fig. 4a illustrates the conversions of the ear image to grayscale with sigma=0.8 and Fig. 4b displays the outcomes of applying each threshold value in the range (50, 80, and 100).

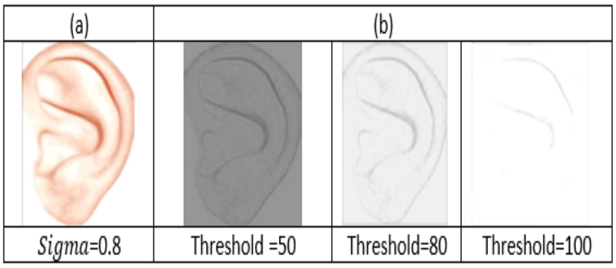



**Fig. 4.** Applying of different threshold on Ear images. (a) Ear image after converting to Grayscale. (b) Ear image after Gaussian filter

### 3.4. Contrast Enhancement Step

The ear details are even more suitable for the following step thanks to the enhancement technique of the suggested method. Two steps make up the practical approach: The first involves defining the threshold values. After that, linear extending is employed. Fig. 5, illustrates the result.

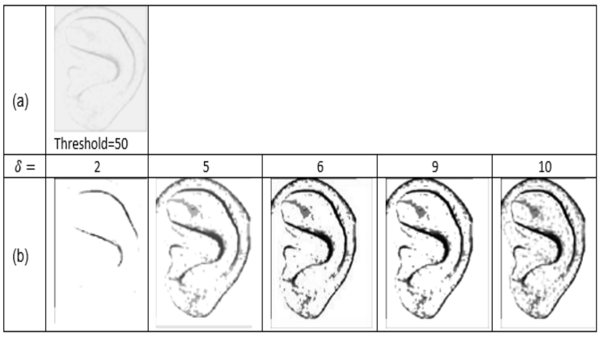



**Fig. 5.** The contrast enhancement with a different sigma value. (a) Ear image in grayscale. (b) Ear image after contrast enhancement.

### 3.5. Ant Colony optimization for edge detection

In the ACO edge recognition approach, ants move across a search space that is a graph with nodes and edges. Pixels can be used to depict the nodes of a network. Following are the phases of the ACO system:

**Stage 1: The initialization process is the first stage.** Entirely on an image with a size of n1, n2, ..., $n_m$ (N ants are subjectively assigned to each pixel), which can be considered a node. The first value of each element of the pheromone matrix, m(), is typically a persistent minute.

**Stage 2: The Building Process.** One ant is subjectively picked from the total ants at the n-stage construction, and this ant will move on the image in l movement-steps. This ant moves from the node (l, m) to another node (I, j), resulting in a move. Possibilities are as certain as the following calculation.

$$P^{(n)}{}_{(l,m),(i,j)} = \frac{\left(t_{i,j}{}^{n-1}\right)^{\propto}\left(\eta_{(i,j)}\right)^{\beta}}{\Sigma_{(i,j)\epsilon\Omega(l,m)}\left(t_{i,j}{}^{n-1}\right)^{\propto}\left(\eta_{(i,j)}\right)^{\beta}} \qquad (4)$$

M(n1) I, j) represents the pheromone total of the node (I j), and (l, m) represents the node's nearby nodes (l, m), and $n_{(I\ j)}$ represents the node's heuristic material (i, j). Factors A and B represent the pheromone and heuristic grounds' influence, respectively.

**Stage 3: The Process of Upd.** The suggested algorithm uses two update processes for updating the pheromone matrix. The initial update is applied after each building step's movement to each ant. This equation is rebuilt for each component of the pheromone matrix:

$$T_{i,j}^{(N-1)} = \begin{cases} \{(1-p).T_{i,j}^{(n-i)} + p.\Delta_{i,j}^{(k)} T_{i,j}^{n-1}\} \\ otherwise,\ if\ f(i,j) is\ visited\ by\ the\ current\ A \end{cases} \quad (5)$$

Where,

P is a letter that is defined in Eq. 2. The heuristic matrix specifies (k) I j; that is, (k) I j) = (ni, j). The second apprise is used once all the ants in each building phase have moved, for example, T((n)) = -1. (n-1)+ T((n-1)+ T((n-1)+ T((n-1)+ T((n-1)+T (6) ((0))

**Step 4: Deciding.** By linking a threshold T to the final pheromone matrix m, a dualistic option is prepared at each pixel location to control whether it is on the verge or not (N). Based on the progression described in [9], the above-mentioned T can be adaptively estimated in this study.

### 3.6. Experimental with comparison results

The current technique used a dataset in two *circumstances* yielded 120 photos. IIT Delhi-I, an Indian institute with 121 people, and 471 photographs with an image size of (272×204) pixels are among the files used.

In experiments, the current method produced good edge detection rates, as shown in Fig. 6. This study has shown that the effects of smoothing degree, lightness, and point of contrast enhancement are fundamentally a practical method for accurately generating an ear print from an ear picture that can be utilized for feature extraction and acknowledgement purposes in further processing.

The metrics of accuracy and sensitivity are shown in Eq. 6 and Eq. 7, respectively. They rely on the following variables and used to describe the method:

**TrueP:** ear print exists and can be detected correctly.

**TrueN:** there is no ear print and it cannot be detected.

**FalseP:** It is possible to identify non-ear prints.

**FalseN:** no ear print exists.

$$Sensitivity(\%) = \frac{TrueP}{TrueP+FalseN} * 100 \quad (6)$$

$$Accuracy(\%) = \frac{TrueP+TrueN}{TrueP+TrueN+FalseP+FalseN} \quad (7)$$

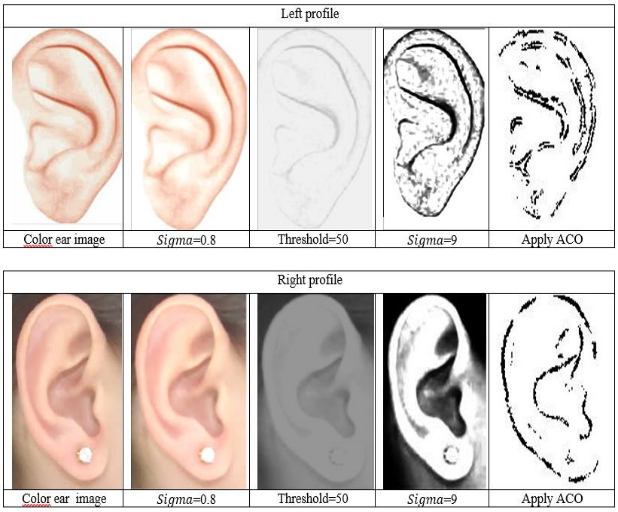



**Fig. 6.** the outcomes of the presented algorithm for Left and Right profiles.

Table I illustrates the performance of the proposed method. In this table, the proposed method labeled 122 images as true positive, while 3 cases only recorded as false negative and 5 cases as true negative. This latter is due to the fact that some images are in low resolution even after applying Gaussian filter and contrast enhancements.

**Table I.** demonstrate the performance of the proposed detection algorithm

| Nb. of images | True P | True N | False P | False N | Sensitivity | Accuracy |
|---|---|---|---|---|---|---|
| 120 | 122 | 5 | 0 | 3 | 97.6% | 97.69% |

Table II in the other hand shows the comparisons with related previous studies. In this table, the technique utilized presents the method applied for ear detection and the recognition rate demonstrates the overall accuracy percentage.

**Table II.** Comparison of the proposed detection algorithm

| Work number | utilized techniques | Recognition rate |
|---|---|---|
| Work in [17] | Its's approach is based on GA+PCA | 87.2484% |
| Work in [26] | Gaussian filter and Canny edge deep learning-based, Convolutional neural network, the database provided by the University of Science and Technology (USTB) | 93.345% |
| Proposed Method | Gaussian filter Ant Colony algorithm | 97.69% |

## 4. Conclusions

In this paper, we suggested a method for identifying biometric outer ears. IIT Delhi-I, a dataset of 120 photos, was used, and it contains variously acquired photographs in terms of resolution and size. Additionally, a gaussian filter and contrast enhancement were utilized in a pre-processing stage to improve and resize the photos. The latter will draw attention to the ear's outer borders. Using the values of the factors window size of Gaussian filter equivalent (33) and its sigma value (0.8), the threshold of Gray measure correspondent (50), and sigma value for contrast enhancement equivalent (9), a meta-heuristic algorithm of Ant colony (ACO) algorithm was applied as an optimization algorithm on-ear image. The modeling of the pheromone deposits left by ants in their search for food sources helped with the creation of the algorithm to create the human ear print biometric application. The end result from the proposed method achieves 97.69% accuracy over 122 examined images.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## Author contributions

**Samira A.K. Hussein:** Conceptualization, Methodology, Software, Field study, and Writing-Original draft preparation. **Dalia S. Ahmed and Samar A. Qassir:** Data curation, Software, Validation., Field study. **Bassam AlKindy:** Visualization, Investigation, Writing-Reviewing and Editing.

## Conflicts of interest

The authors declare no conflicts of interest.

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