# An Algorithm for Person Recognition Based on Ear Images

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Keywords: Biometrics, Biometric Technologies, Face Recognition, Local Binary Pattern (LBP) Algorithm, Ear Image, Chi-Square Distance, Cosine Similarity.

Abstract: Currently, personal identification based on biometric parameters is one of the fastest growing areas. Systems developed based on biometric parameters are widely used in access control systems, electronic payments, forensics and a number of other areas. Therefore, the demand for personal identification systems based on biometric parameters is increasing day by day. Currently, we can cite biometric parameters such as facial images, fingerprints, ears, irises as examples of widely used biometric parameters. Methods and algorithms for identifying a person by ear images occupy an important place among biometric technologies. As it turned out, the accuracy and reliability of personal identification systems based on ear images are superior to other types of biometric technologies. Biometric technology based on personal identification based on this technology has several advantages over other biometric technologies. Firstly, unlike the human face, the ear practically does not change throughout a person’s life and depending on his mental state. Secondly, unlike biometric technologies based on the pupil of the eye, no complex devices other than a simple camera are required to obtain an image of the ear. From this it can be concluded that biometric technologies based on the image of the ear have good prospects. Nevertheless, the development of algorithms for identifying a person based on the image of the ear and its application in practical issues have not been sufficiently studied. Therefore, the issue of identifying a person based on the image of the ear is in the focus of attention of world scientists. The article proposes the use of a local binary character separation algorithm in combination with a Gabor filter in the development of a recognition system based on the image of the ear. This proposed work can be used in recognition systems based on biometric parameters.

## 1 INTRODUCTION

Identity recognition is one of the main problems of intelligent systems, which is solved on the basis of biometric technologies. Systems based on biometric technologies are systems that distinguish one person from other people, taking into account their unique characteristics. These systems allow recognizing a person by converting biometric characteristics into digital data.

Examples of biometric characteristics of a person include iris, voice signals, fingerprint, hand (shape) geometry, facial image, ear image, gait, signature, and the like [1].

The field of science that studies the physical and biological characteristics of a person and performs recognition based on them is called biometrics.

Biometric methods are based on habitual and physiological movements. We will briefly discuss these methods below.

Recognition methods based on habitual movements evaluate human behavior. The following recognition methods based on habitual movements are currently widely used:

- recognition based on a person's handwriting;
- recognition based on a "signature" on the keyboard.

Physiological methods are based on the anatomical uniqueness of each individual. Anatomical features include facial features, irises, fingerprints, hand shape, ear, and other similar biometric features.

The technology of personal identification based on the ear image is superior to other biometric technologies due to the following features.

- The ear features are formed earlier than those of other biometric technologies, i.e. 56 days after their appearance in the womb;
- The fact that they retain their characteristics throughout the life of the individual;

- The fact that they are preserved for a longer period of time than other organs after the death of the individual.

Although the technology of recognizing a person based on the image of the ear has many advantages over other biometric technologies, it also has some disadvantages. For example, the person's ear may change as a result of some mechanical effects, the presence of some disturbances in the image of the ear (some part of the ear is completely or partially closed), etc. [2]. In some cases, due to congenital defects, accidents, diseases or injuries, it may not be possible to perform recognition based on facial images and fingerprints and some other biometric features. In such cases, it is advisable to use the technology of recognizing a person based on the image of the ear.

The simplicity of the methods and algorithms used in this technology and the above-mentioned advantages have attracted the attention of many researchers.

Identification of a person based on the image of the ear is one of the main directions of biometric technologies and is widely used in practical control systems. However, the increasing volume of information nowadays requires the reform of existing systems. Although many methods and algorithms for recognizing a person based on an ear image have been developed, they need to be improved or faster methods and algorithms developed to ensure their fast operation on large volumes of information. It should be noted that to date, a number of well-known and popular methods for recognizing a person based on an ear image have been developed [3]. However, for these methods to be highly accurate, it is necessary to have several ear images of one person in the database. In particular, these methods give good results when there are more than 10 facial images of one person in the database, otherwise the accuracy of the methods decreases. However, in practice, it is not always possible to form such a database. In such cases, it is necessary to compare the ear images in a "one-to-one" manner, that is, by comparing two images with each other, it is necessary to determine whether they belong to the same person or not [4], [5].

In this article, an algorithm for recognizing a person based on an ear image is developed.

# 2 STATEMENT OF THE PROBLEM

Problem statement. Suppose that we are given a set of ear images of the same size $Q$. Let us consider m images taken from this set:

$$I_1, I_2, .., I_m (I_i \in Q).$$

The main problem is to determine the closest incoming image $I'$ from the given m images.

Solution. The problem of recognizing a person based on an ear image is carried out as follows:

## 2.1 Converting the Incoming Image to a Grayscale Image

When pre-processing images, it is much more convenient to work with grayscale images than with color images. Therefore, in most cases, during pre-processing, images are converted to a grayscale image (Fig. 1).

Converting a color image to a grayscale image is done according to the following formula:

$$T_{ij} = r * R_{ij} + g * G_{ij} + b * B_{ij},$$

where,

$$r = \frac{R_{ij}}{R_{ij}+G+B}, g = \frac{G_{ij}}{R_{ij}+G+B}, b = \frac{B_{ij}}{R_{ij}+G+B}.$$

The corresponding red, green, and blue values of the brightness of the pixels with coordinates $i, j$.

This transformation is used to solve problems related to the application of image processing methods in various practical areas. Experimental studies have shown that these transformations do not always give good results when used in biometric systems. Therefore, it is proposed to implement the transformation of a color image into a grayscale image in the following form:

$$T_{ij} = 0.55 * R_{ij} + 0.44 * G_{ij} + 0.01 * B_{ij}.$$

The coefficients for converting this color image to a grayscale image were calculated using the principal components method [6], [7].

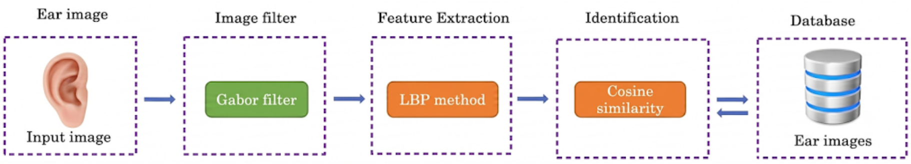



Figure 1: The process of recognizing a person based on an ear image.

## 2.2 Gabor Filtri

Factors such as the characteristics of the technical devices receiving data and the light levels during the shooting can affect the image quality in different ways. If the image quality is poor, it is necessary to improve it. Because in poor-quality images, the separation and recognition of characters may not be effective. Therefore, it is necessary to improve the image quality in the case of person recognition.

Recently, much attention has been paid to Gabor filters, as these filters have shown their optimal localization properties in both spatial and frequency domains [8]. Gabor filters have been widely used in many areas, including texture segmentation, object separation in images, document analysis, image boundary detection, iris-based identification, image coding and representation [2], [3], [9], [10].

A Gabor filter consists of the following steps:

Step 1. Begin.

Step 2. Calculate $g_x$ and $g_y$ using the Sobel operator.

Step 3. $v_x$ and $v_y$ are calculated, i.e. $v_x = \sum_{k=-n}^{n}\sum_{l=-n}^{n} g_x g_y$, $v_y = \sum_{k=-n}^{n}\sum_{l=-n}^{n}(g_x^2 + g_y^2)$.

Step 4. $\theta$ is calculated, that is, $\theta = \frac{1}{2} arctan( v_x / v_y)$.

Step 5. $x^{'}$ and $y^{'}$ are calculated, that is, $x^{'} = x\,cos(\theta) + y\,sin(\theta)$, $y^{'} = y\,cos(\theta) - x\,sin(\theta)$.

Step 6. $G$ is calculated, that is, $G = exp(-\frac{x^{'2}+y^{'2}}{2\sigma^2})\,cos\left(2\pi\frac{x^{'}}{\lambda} + \psi\right)$..

Step 7. $T^{'} = \sum_{k=-n}^{n}\sum_{l=-n}^{n} G * T$.

Step 8. End.

Where, T is the given image, $n$ is the window size, $\sigma$ is the Gaussian filter parameter, and $\lambda$ is the wavelength.

## 2.3 LBP Algoritmi

In the LBP algorithm, calculations are performed for each pixel of a grayscale ear image by considering the intensity values of its eight neighboring pixels.

The LBP algorithm operates as follows. Within a 3×3 neighborhood, the intensity value of the central pixel is selected as the threshold value (T). The intensity value of each of the eight neighboring pixels is then compared with T. If the neighboring pixel intensity is greater than or equal to T, it is assigned a value of 1; otherwise, it is assigned a value of **0**. After all neighboring pixels have been processed, an 8-bit binary number is obtained. This binary number is subsequently converted into its decimal equivalent, which represents the LBP code for the central pixel.

The LBP operator is defined by the following expression (Fig. 2):

$$LBP(x_c, y_c) = \sum_{n=0}^{7} S(i_n - i_c)\cdot 2^n;\ S(x) = \begin{cases}1, x \geq 0\\ 0, x < 0\end{cases}.$$

where $x_c, y_c$ are the coordinates of the center of the working window (3×3); $i_c$ is the color value of the pixel in the center of the window; i_n is the color value of the 8 neighboring pixels around the window [11].

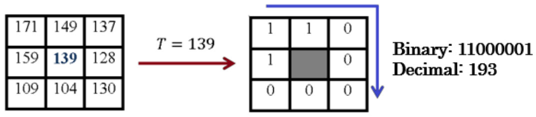



Figure 2: General scheme of the LBP operator.

The standard LBP operator described above is based on a 3×3 neighborhood, corresponding to a radius of 1 and eight neighboring sampling points. However, the LBP algorithm can be extended to neighborhoods with different radii and numbers of neighboring sampling points. Figure 3 illustrates LBP neighborhoods with radii of 1, 2, and 3. As the radius increases, the number of neighboring sampling points also increases, enabling the extraction of texture information at different spatial scales.

Examples of ear images encoded using the LBP operator are presented in Table 2.

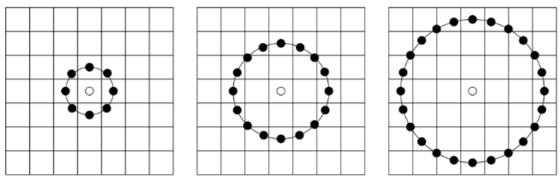


Figure 3: LBP neighborhoods with radii of 1, 2, and 3.

## 2.4 Evaluating the Similarity of Ear Images [12]

The LBP (Local Binary Patterns) algorithm uses various distance measures to assess the similarity of images. Based on these distances, the similarity of ear images is assessed. For example, when developing personal recognition systems based on ear images, the LBP algorithm often uses the Chi-square distance, Euclidean distance, and Cosine similarity comparison methods [4].

Chi-Square distance method for evaluating the similarity of ear images.

The Chi-square distance method is one of the distance measures used to estimate similarity based on the histogram of two biometric images.

The formula for Chi-square distance is as follows:

$$\chi^2 = \frac{1}{2}\sum\frac{(O_2-E_2)^2}{O_2+E_2},$$

where, $O_2$ is the ith histogram value in the first ear image; $E_2$ is the ith histogram value in the second ear image.

Euclidean distance in assessing the similarity of ear images.

In the ear image similarity assessment, the Euclidean distance is used to calculate the distance between two points. In the LBP algorithm, this distance is used to measure the distance between pixels in two ear images to assess image similarity.

The formula for the Euclidean distance is as follows:

$$d = \sqrt{\sum_{i=1}^{n}(p_i - q_i)^2},$$

where,

- $p_i$ is the ith pixel of the first ear image;
- $q_i$ is the ith pixel of the second ear image;
- $n$ is the number of pixels in the ear image.

Cosine similarity in assessing the similarity of ear images.

In the development of ear-based face recognition systems, cosine similarity is used to assess the similarity between two vectors. This distance focuses on the direction of the vectors in the ear images and indicates the degree of their similarity.

The cosine similarity formula is defined as follows:

$$c = \frac{\sum_{i=1}^{n} p_i q_i}{\sqrt{\sum_{i=1}^{n} p_i^2}\sqrt{\sum_{i=1}^{n} q_i^2}},$$

where,

- $p_i$ is the ith pixel in the first ear image.
- $q_i$ is the ith pixel in the second ear image.

# 3 EXPERIMENTAL RESEARCH RESULTS

To solve practical problems using the LBP algorithm, an ear image recognition program was developed in the Python programming language and PyCharm environment. In order to test the functional capabilities of this program, the problem of distinguishing the features characterizing the ear images of 40 individuals was solved. In this case, 6 ear images were obtained for each class.

The results obtained on images of one person from different angles based on the LBP algorithm are presented (Fig. 4).

The similarity level of the images was as follows.

Table 1: Results obtained on the ear images of one person.

| Method name | LBP+Gabor | LBP |
|---|---|---|
| Chi-Squared Distance: | 0.001 | 0.22 |
| Euclidean Distance: | 0.020 | 0.19 |
| Cosine Similarity: | 1.00 | 0.85 |

The results obtained on images of different individuals based on the LBP algorithm are presented (Fig. 5).

The similarity level of the images was as follows.

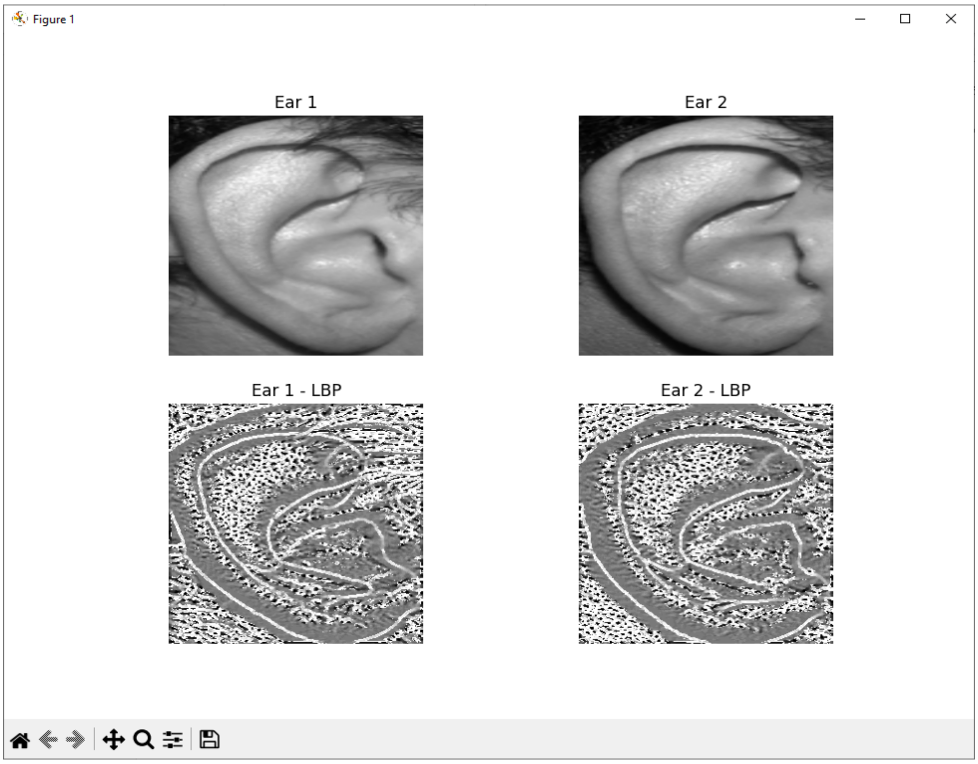
Table 2: Results obtained on ear images of different individuals.

| Method name | LBP+Gabor | LBP |
|---|---|---|
| Chi-Squared Distance: | 0.14 | 0.32 |
| Euclidean Distance: | 0.29 | 0.44 |
| Cosine Similarity: | 0.64 | 0.78 |

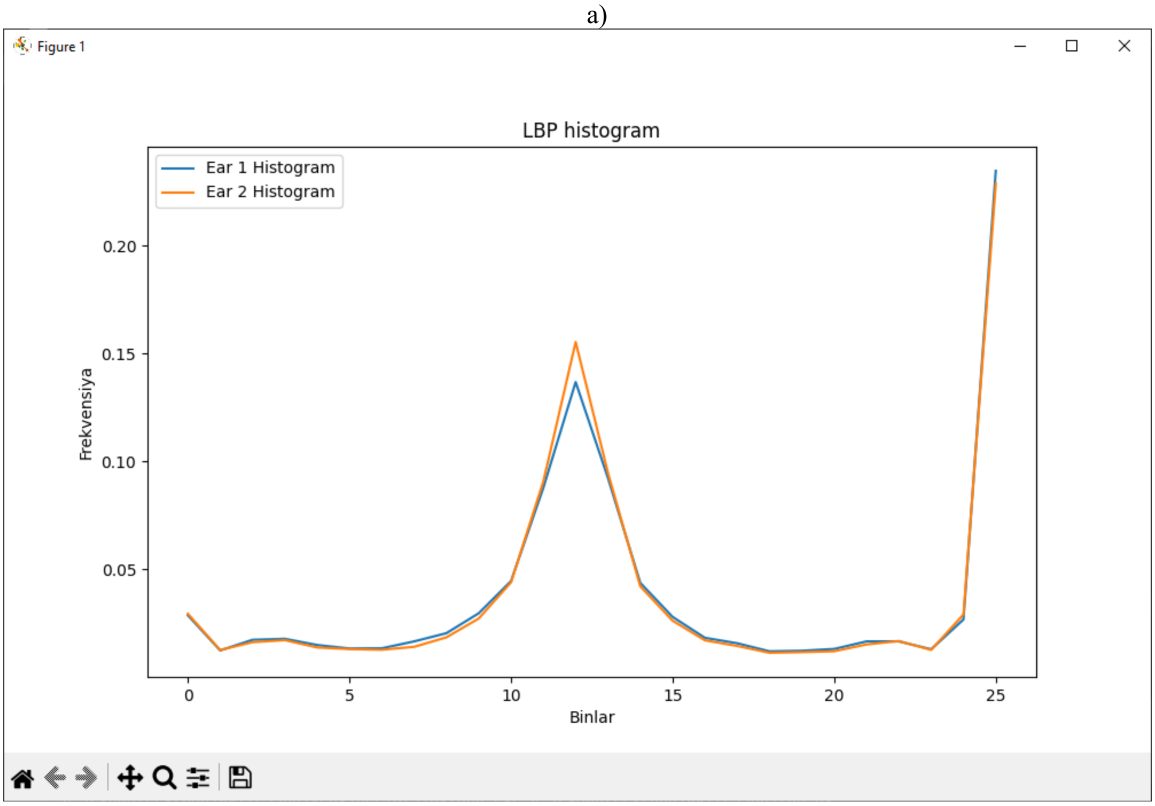
The LBP algorithm based on the Chi-Squared distance and Euclidean distance methods return values in the range [0, 1] for the recognition system based on ear images. If the value is close to zero, the images are similar, and if it is close to one, the images are not similar.

In the cosine similarity method, on the contrary, if the value is close to one, the images are similar, and if it is close to zero, the images are not similar.

These results are presented in Tables 1 and 2, where the LBP algorithm is used in combination with the Gabor filter to recognize a person based on ear images.

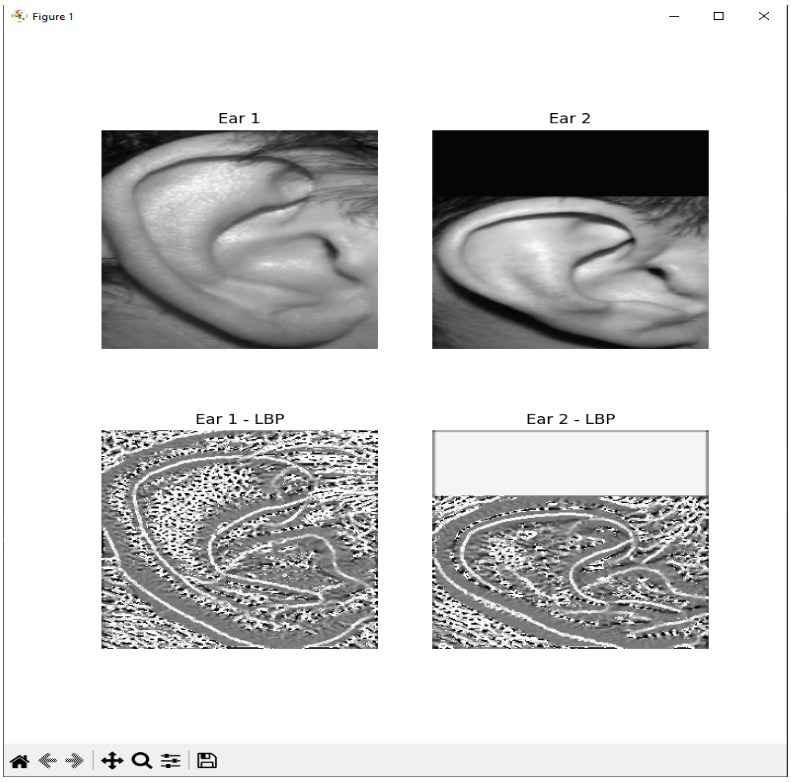



a)

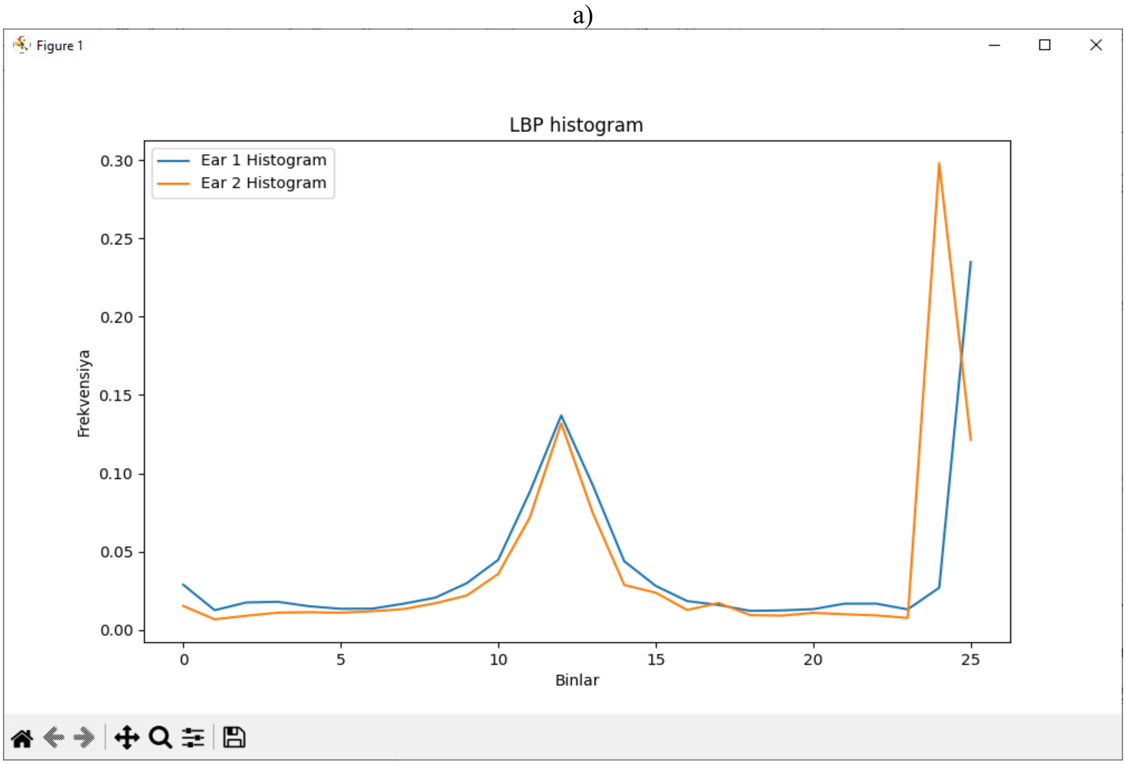



b)

Figure 4: LBP feature extraction for ear images of the same individual captured from different viewing angles: a) LBP map and b) corresponding LBP histogram.




a)




b)

Figure 5: LBP feature extraction for ear images of different individuals: a) LBP map and b) corresponding LBP histogram.

# 4 CONCLUSIONS

This article aims to develop and analyze a person recognition system based on ear images using Gabor filter and LPB (Local Binary Patterns) algorithm. Initially, the given images were converted to grayscale images using the coefficient values obtained based on the color image to grayscale image conversion algorithm developed based on the principal component method, which also had a positive effect on the recognition result. The similarity level of ear images was evaluated using the chi-square distance, Euclidean distance and cosine similarity of all LPB algorithms in the database. Then, all images in the database were replaced based on the Gabor filter. In experimental studies, it was found that the results obtained by using the Gabor filter in combination with the LPB algorithm are higher. The best result in the LBP algorithm was achieved when the radius is equal to one and the number of points around it is equal to 8. This work can be widely applied not only in the development of personal recognition systems based on ears, but also in systems based on facial images, fingerprints, and other biometric parameters.

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