# FITTING EAR CONTOUR USING AN OVOID MODEL.

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**ABSTRACT**

*Ear analysis is an emergent biometric application. The main advantages are the no requirement for subject contact and acquisition without demand. To recognize a subject's ear, we aim to extract a characteristic vector from a human ear image that may subsequently be used to identify or confirm the identity of the owner. Towards this end, a new technique, combining geodesic active contours and a new ovoid model, has been developed, which can be used to compare ears in an independent way of the ear location and size.*

## 1. INTRODUCTION

In the context of machine vision, ear biometrics refers to the automatic measurement of distinctive ear features with a view to identifying or confirming the identity of the owner.

The biometric of ear is a very interesting issue in biometric identification systems. Although a newcomer in the biometrics field, ears have long been used as a means of human identification in the forensic field. Traditional and manual methods for description of ear features and ear identification have been developed for more than 14 years [1]. Just like fingerprints, the long-held history of the use of ear shapes/marks suggests its use for automatic human identification.

The main advantage concerning other well-known biometric measures as eye or finger biometric, is that you can use it in cases where the other methods are not available, as for instance, in the case you have just an image of the face of an human being (where the ear is visible), and you want to identify him. On the other hand, the biometric of ear has not been so explored in the literature as the eye or finger biometric. Clearly, there are some limitations in ear analysis application, such as occlusion by hair, the use of a hat or earrings, etc…, but here we are concerned with the simple case where we the whole ear is visible.

An ear recognition system is very much like a typical face recognition system and consists of five components: image acquisition, preprocessing, feature extraction, model training and template matching.

During image acquisition, an image of the ear is captured, usually with a camera. Although other methods such as the use of range sensors are also adopted, 2D image data as input remains the mainstream choice. For preprocessing, standard techniques such as histogram equalization and normalization are often used. Although ear recognition is a relatively new topic, researchers have already come up with various approaches with drastically differ from each other in terms of raw data interpretation and feature extraction. Some of them are proved practice in the field of human recognition (e.g. Principal component analysis [2], Neural networks [3], etc…), while some present a whole new perspective (e.g. Force field transformation [4]).

Lastly, the template matching stages is largely the same and standard statistical error analysis methods are adopted.

## 2. OUR CONTRIBUTION

In this paper we propose a new way to fit the contour of an ear in an image by combining snake techniques and a new ovoid model. Roughly speaking the proposed technique can be divided in the following steps:

1. The user, click by hand, very roughly, a first initial ear contour.
2. Using a snake model, we improve the ear contour location.

3. Once the ear contour is estimated, we use an ovoid model to fit the ear contour. We find the ovoid parameters which better match the ear contour using an euclidean distance criterion. In figure 1 we illustrate these 3 steps.

**Figure 1.** On the left, original ear image with an original contour drawn by hand (in white). In the middle, improvement of the ear contour using snakes (in white). On the right, estimated ovoid from the ear contour (in white)

The estimation of the ovoid parameters allows us, on the one hand to compare two ears using the ovoid parameters and, on the other hand, to align to ear contours in order to compare them in an independent way of ear location and size.

We propose two contributions in this paper: The first one is the adaptation of a known snake model to contour ear requirements. The second one is the proposed ovoid model to fit ear contour. Next we describe, very briefly, these two contributions.

### 2.1. An snake model adapted to ear contour requirements.

We will use an adaptation of the snake technique proposed by V. Caselles, R. Kimmel, and G. Sapiro in 1997 [5]. This approach is based on deforming an initial contour $C_0$ towards the boundary of the object to be detected (ear contour in our case). The snake model is obtained using a level-set implementation of the PDE

$$\frac{\partial u}{\partial t} = g_s(I)\, div\left(\frac{\nabla u}{\|\nabla u\|}\right)\|\nabla u\| + l\nabla u \nabla g_s$$
$$u(0,x,y) = u_0(x,y)$$

where $l = 0$, $I(x,y)$ represents the grey level intensity of the input image and $u(t,x,y)$ represents the snake evolution. $u(0,x,y)$ represents the characteristic function associated to the initial snake contour $C_0$. For simplicity we assume that $C_0$ is a single Jordan curve given by a polygon whose points has been clicked, on the original image, by user, close to ear contour. We assume that $C_0$ is a level-set of a function $u(0,x,y)$, so $u(0,x,y)$ is an implicit representation of the curve $C_0$. This representation is parameter free, then intrinsic, and it is also topology free.

$g_s(I)$ is defined by

$$g_s(I) = \frac{1}{\sqrt{1 + a\|\nabla G_s * I\|^2}}$$

$a > 0$ and $G_s * I$ is the convolution of $I$ with a Gaussian kernel of standard deviation $s$.

In this active contours model, the curve is deforming by means of a velocity that contains two terms, one related to the regularity of the curve (first term of the sum) and the other shrinks or expands it towards the boundary (second term of sum).

The main contribution we present in this paper concerning this snake model is that in the above model, the snake is a closed curve, however, as it is showed in Figure 1, the ear contour is defined by an open curve, so we have to adapt the model to this new situation. In order to make that possible, in our algorithm, last segment joints the last and first point clicked by user, to close the polygon, remain fixed over scheme iterations.

### 2.2. An ovoid model to fit the ear contour.

The ovoid we use to adjust to the ear contour is obtained by the deformation of an ellipse. The usual parametric model for an ellipse is:

$$\begin{pmatrix} x(t) \\ y(t) \end{pmatrix} = \begin{pmatrix} x_0 + a\cos t \\ y_0 + b\sin t \end{pmatrix}$$

In order to better fit a human ear contour, we add an ellipse distortion factor given by a new *g* parameter, using the deformed ellipse model:

$$\begin{pmatrix} x(t) \\ y(t) \end{pmatrix} = \begin{pmatrix} x_0 + a\cos t \\ y_0 + b(1 + g\ \cos t)\sin t \end{pmatrix}$$

The factor *g*, as it can be appreciated in Figures 2, 3 and 4, causes a distortion in the vertical axis of the ellipse that allows it to better adapt its forms to more complex geometries as those present in the shape of a human ear.

The general model also includes a rotation with respect to the center of the ellipse, which should be given by the angle *a* and its corresponding rotation matrix:

$$R(a) = \begin{pmatrix} \cos a & \sin a \\ -\sin a & \cos a \end{pmatrix}$$

This rotation matrix acts as follows:

$$\begin{pmatrix} x(t) \\ y(t) \end{pmatrix} = \begin{pmatrix} x_0 \\ y_0 \end{pmatrix} + R(a)\begin{pmatrix} x(t) - x_0 \\ y(t) - y_0 \end{pmatrix}$$

So, the parametric equation of the ovoid is:

$$\begin{pmatrix} x(t) \\ y(t) \end{pmatrix} = \begin{pmatrix} x_0 + \cos a\ \ a\cos t + \sin a\ \ b(1 + g\ \cos t)\sin t \\ y_0 - \sin a\ \ a\cos t + \cos a\ \ b(1 + g\ \cos t)\sin t \end{pmatrix}$$

and it has 6 free degrees of freedom: $(x_0,\ y_0)$ which represents the center of the ovoid, *a* which represents the orientation, *(a,b)* which represents the usual ellipse axis size parameters and finally *?* which represents the deformation of the ovoid which respect to an ellipse. *? = 0* corresponds to an ellipse, and bigger is *?*, a stronger ellipse deformation we have.

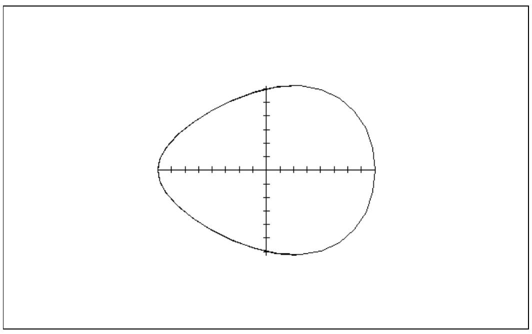

**Figure 2.** Ovoid image without rotation, with parameters values $(x_0,\ y_0) = (0,\ 0)$, *a = 2*, *b = 1.5*, *a* =0 and *g = 0.3*. Its equation is given by $(2\cos(t), 1.5(1 + 0.3\cos(t))\sin(t))$

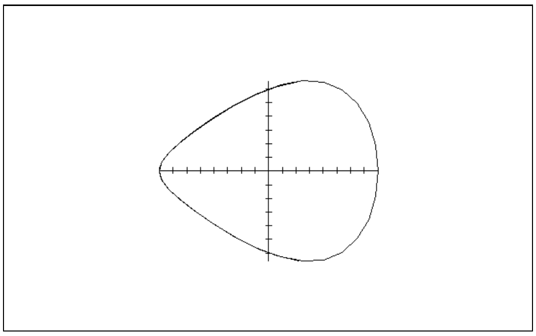

**Figure 3**. Ovoid image. All the parameters values are the same as those on previous figure except for *g = 0.5*. Its equation is given by $(2\cos(t), 1.5(1 + 0.5\cos(t))\sin(t))$

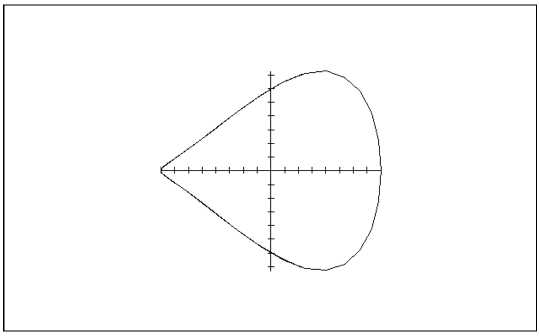

**Figure 4.** Ovoid image. All the parameters values are the same as those on previous figure except for *g = 0.8*. Its equation is given by $(2\cos(t), 1.5(1 + 0.8\cos(t))\sin(t))$

In Figure 1 (on the right) we can observe the shape of the ovoid, and we can realize that it can fit quite well the ear shape. The advantage of this ovoid model is that it is quite simple (just one more parameter than an ellipse). It can fit quite well a human ear, and some of the parameters could be used to compare two ears. For instance the parameters *(b/a, ?)* are Euclidean invariants of the ear and it could be used to compare ears in an independent way of the ear location and size. On the other hand the ovoid parameters could be used to align two ear contours in order to compare them in a more accurate way.

**2.3. Ovoid Estimation**.

In practice, the ovoid model would be unusefulness if we do not provide an algorithm to estimate the ovoid parameters from an ear contour. Fortunately, we have developed some algorithms to estimate automatically the ovoid which better fit an ear contour using an euclidean distance criterion. Next we will describe the algorithm to estimate ovoid parameters which is divided in the following steps:

**1.-** We compute the area of the form *($m_{00}$)* and its centroid *($m_{10}$, $m_{01}$)* using the following moments:

$$m_{00} = \int_S dx\,dy \qquad m_{10} = \frac{1}{m_{00}} \int_S x\,dx\,dy$$

$$m_{01} = \frac{1}{m_{00}} \int_S y\,dx\,dy$$

where $S$ represents the surface enclosed by the ear contour extracted from the snake model. Note that the centroid of the form is not the same as the center of the deformed ellipse, because the aforementioned centroid will be displaced in the direction of the symmetry axis of the ellipse. However, it can be shown that the area of the ovoid is the same of the deformed ellipse, this is a very interesting property that will be used in the algorithm.

**2.-** We obtain the matrix of second-order centered moments

$$M_2 = \begin{pmatrix} m_{20} & m_{11} \\ m_{11} & m_{02} \end{pmatrix}$$

given by

$$m_{20} = \int_S (x - m_{10})^2\,dx\,dy \qquad m_{02} = \int_S (y - m_{01})^2\,dx\,dy$$

$$m_{11} = \int_S (x - m_{10})(y - m_{01})\,dx\,dy$$

The eigenvector $v_{max}$ = *($x_{max}$, $y_{max}$)* corresponding to the maximum eigenvalue of the matrix $M_2$, determines the deformed ellipse's main direction of symmetry, therefore the $a$ orientation of the deformed ellipse is extracted simply through the relationship:

$$\tan(a) = \frac{y_{\max}}{x_{\max}}$$

**3.-** Next, we proyect all the points of the form $S$ on the straight line that goes by the centroid and it has $v_{max}$ as director vector. If we named $p_{max}$ the projected point that is far away from the centroid in the direction of $v_{max}$, and $p_{min}$ the projected point that is far away from the centroid in the opposite direction $-v_{max}$, then we can get the center and semiaxis from the deformed ellipse just doing:

$$(x_0, y_0) = \frac{p_{\max} + p_{\min}}{2}$$

$$a = \frac{\| p_{\max} - p_{\min} \|}{2}$$

**4.-** In order to obtain $b$ (the deformed ellipse's minor semiaxis) it is enough to take into account the fact that since the area of the deformed ellipse is equal to the ovoid area we have that $m_{00}$ = *pab*. Finally, to obtain the distortion factor $g$ we compute the surface *($A_+$)* of the deformed ellipse that remains on one of the semiplanes generated by the straight line that goes by the center of the deformed ellipse and it has the main direction $v_{max}$ as normal vector. We will obtain $g$ from

$$A_+ = \frac{p\,a\,b}{2} + \frac{2}{3}\,a\,b\,g$$

**5.-** Finally, to improve the ovoid parameters we minimize the Euclidean distance

$$E(x_0, y_0, a, a, b, g) = \sum_{i=0}^{N} dist(Ovoid, (x^i, y^i))$$

where $(x^i, y^i)$ represents the points of the ear contour. We minimize such Euclidean distance using a gradient descent algorithm taking as initial approximation the parameters of the ovoid computed is steps 1-4.

To conclude this paper, we would like to point out that the proposed technique to estimate the ear contour and the ovoid is the first step in the ear analysis. In the next future we will test this new technique in an ear image database in order to evaluate the performance of the method for ear identification.

## 3. REFERENCES


[1] A. Iannarelli, *"Ear Identification"*, Forensic Identification Series, Paramont Publisshing Company, 1989.

[2] B. Victor, K.W. Bowyer and S. Sarkar, *"An Evaluation of Face and Ear Biometrics"*, Proc. Int'l Conf. Pattern Recognition, Aug. 2002, pp 429-432.

[3] Carreira-Perpinan, *"Compression neural networks for feature extraction: Application to human recognition from ear images"*, MSc. Thesis, Faculty of Informatics, Technical University of Madrid, Spain, 1995.

[4] D.J. Hurley, M.S. Nixon and J.N. Carter, *"Automatic Ear Recognition by Force Field Transformations"*, IEE Colloquium on Visual Biometrics, March 2000.

[5] V. Caselles, R. Kimmel, y G. Sapiro. *"Geodesic Active Contours"*, Internacional Journal of Computer Vision, 22(1): 61-79, 1997.