A Multiscale Circum-ellipse Area Representation for Planar Shape Retrieval

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Abstract: In this paper, we propose a new Multiscale Circum-ellipse Area Representation (MCAR) for planar contours. The proposed representation deals with a multiscale shape signature defined from the local area delimited by the circumscribed ellipse of the triangle formed by three contour points and the contour. This shape signature describes, at each scale level, the concavity/convexity at each contour point. Then, Fourier descriptors are obtained by applying Fourier transform to the proposed multiscale signature. Thus, the proposed MCAR based Fourier Descriptors handle the local and global shape characteristics. Furthermore, it is invariant to affine transformation and robust to local deformations. The performance of our proposed method was evaluated through the precision recall and bull's-eye tests on the two well-known databases (MCD and MPEG7-setB). Obtained results indicate that our method outperforms the shape signatures based Fourier descriptor proposed in the literature.

1 INTRODUCTION

Shape representation and description of planar objects, which are subjected to certain viewpoint variation and partially occultation, is widely considered as a fundamental subject in many applications of pattern recognition and computer vision, such as robotic vision, content-based image retrieval, and pose estimation.
Deformations induced by capturing a planar object from the real space in different viewpoint is often approximated by an affine transformation when the object is far away from the camera. Thus, a shape descriptor should be invariant under affine transformations which includes scaling, changes in orientation, shearing and translation.
A variety of shape descriptors have been proposed in the literature during the last decades that can be divided in two main classes: contour based-techniques and region based techniques.
In region based technique, all the pixel within a shape are used to derive the shape representation, but only the boundary points are used to obtain the contour based shape representation technique.

Common region-based shape descriptors are, moment based techniques including geometric, Zernike, pseudo Zernike and Legendre moments (Hu, 1962; Lin and Chou, 2003), Angular radial transform (ART) (Bober, 2001), shape matrix (Bober, 2001) and generic Fourier descriptor.

In recent years, several contour based-shape descriptors have been proposed in the literature due to its good performance in different applications.

Fourier descriptors is a promising contour based approach for shape retrieval. In general, the planar contour is firstly converted to a periodic 1-D signature and followed by the application of the Fourier transform. Many signatures have been proposed as a Fourier descriptor in the literature (T.Zahn, 1972; D.S.Zhang, 2005; I.Kunttu, 2007). Some of them are, the complex coordinates (CC), the radial distance (RD), the triangular centroid area (TCA),Angular radial coordinates (ARC) and the farthest point distance (FPD)(A.El-Ghazal, 2007). Most of Fourier descriptor are based on the magnitude of the Fourier transform and ignore the phase information in order to make descriptor invariant to rotation and independent to starting point. To maintain the phase information,(Bartolini et al., 2005) have proposed a Fourier descriptor by using the magnitude and the phases of Fourier transform. In (F.Chaker, 2003), an affine and complete based Fourier Descriptors has been pro-

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posed.

Multiscale approaches are widely studied in the recent years and they are based on a natural representation of shape information at multiple level of details. In general multiscale descriptors could be classified in two main categories: Those based on a multiscale geometric contour representation and those based on a multiscale signature definition. In the first category, the contour is gradually smoothed and a shape signature is obtained from each contour scale. We can cite the well-known MPEG 7 shape descriptor, called Curvature scale space descriptor (CSS) (Abbasi et al., 1999; Abbasi et al., 2000) where the initial contour is gradually smoothed with an increasing value of Gaussian kernel, and the shape signature is computed by the ranking of the inflexion points at different scales. Similar to the CSS, multiscale concavity/convexity (MCC) (Adamek T., 2004), represent the shape contour by the degree of the concavity/convexity between two consecutive Gaussian contour scales. This representation is invariant to Euclidian transformation and robust to partial occultation but suffers from the high time complexity needed to solve shape matching problem. The Multi-resolution affine invariant Fourier descriptor (FD-APS) proposed in (T.Faidi, 2015), is based on a multi resolution representation of the contour. For each contour resolution, the shape signature is computed as the area of the triangle formed by the centroid points of the original contour and two given points from respectively original contour and the contour at a given scale. This representation is invariant to affine transformation and robust to small occultation.

In the second approach, the descriptor is derived from a multiscale definition of the signature such as the Triangular area representation (TAR) (Alajlan et al., 2007) and the multiscale contour flexibility based Fourier descriptor(Xin Shu, 2015). The Triangular area representation (TAR) define the multiscale representation by a progressive triangle side length at each point and take the area of each triangle as a shape signature. The contour flexibility concept is firstly introduced in (C.Xu, 2009) where an interior and exterior neighboring regions centered to a landmarks points in the contour are used to measure the contour flexibility by an Euclidean distance function. Recently, Xin Shu and al are extending flexibility signature to a multiscale approach by taking different level of bendable parameter in order to describe the shape by a local and global representation (C.Xu, 2009). This representation it can reflect how extensively the neighborhood of a given point in the contour are connected to the main body but it is not invariant to affine transformation.

In this work we propose a new multiscale shape descriptor, denoted MCAR, derived from a multiscale signature definition based on the area of triangle circum-ellipse. Furthermore, the proposed descriptor is by definition invariant to affine transformations.
This paper is organized as follows: Section 2 introduces the proposed multiscale shape signature (MCAR). Section 3 describes the MCAR based Fourier Descriptors obtained by applying Fourier transform to the proposed multiscale signature. In Section 4, experimental results are presented to evaluate our descriptor and compare it to state of the art methods.

2 MULTISCALE CIRCUM-ELLIPSE SHAPE SIGNATURE

Let $\Gamma = (x(t), y(t))$ be a closed contour of a 2D planar shape.

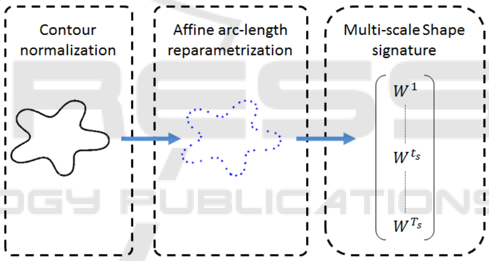


Figure 1: MCAR shape descriptor bloc diagram.

In figure1 we show the main steps needed to compute our proposed multiscale shape signature. First, the contour Γ is normalized by translating the contour centroid to the origin of the 2D coordinate system. Furthermore, the initial contour parametrization would not be necessary the same for different views. The descriptors computed from two different parameterizations of the same geometric curve are generally different. This is due to parametrization dependance on transformations. One solution to this problem consist in performing a G-invariant reparametrization of the curve where G is the considered geometric transformations group.
In the case of affine transformations group, we carry out a reparametrization by the normalized affine arc-length defined as:

$$\bar{s}_a(t) = \frac{1}{L_a}\int_0^t (||\det(\gamma'(t), \gamma''(t))||)^{\frac{1}{3}} dt,\ t \in [0, T]. \quad (1)$$

where L_a is the curve affine length.

Finally, a multiscale shape signature is computed. This latter is detailed in the next section.

2.1 Formulation

In this section, we denote by $\{P_i = \{x_i, y_i\}\}_{i=1\cdots N}$ the discrete affine arc-length reparametrization of Γ where N is the number of obtained contour points.
Let E_{n,t_s}, the circumscribed ellipse of the triangle $\triangle_{n,t_s} = P_{n-t_s}P_nP_{n+t_s}$ where $P_{n-t_s} = (x_{n-t_s}, y_{n-t_s})$, $P_n = (x_n, y_n)$ and $P_{n+t_s} = (x_{n+t_s}, y_{n+t_s})$ are three consecutive contour points and t_s is the triangle side length (See figure 2. a).

The multiscale signature at scale t_s denoted by $W(n,t_s)$ is defined according to the intersection between the arc $\gamma_{n,t_s} = \widehat{P_{n-ts}P_{n+t_s}}$ of the ellipse E_{n,t_s} and the shape contour. Two cases can occur:

- case1 (See figure 2.b): $\gamma_{n,t_s} \bigcap \gamma = \emptyset$.
  The shape signature at scale t_s is defined as the area of the region delimited by γ_{n,t_s} and the segment $[P_{n-t_s}P_{n+t_s}]$. It's given by:

$$W(n,t_s) = \frac{4\pi}{9\sqrt{3}} Area(\triangle_{n,t_s}) \quad (2)$$

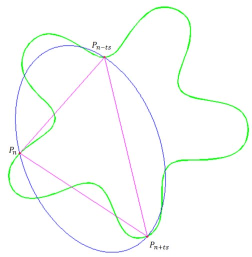
- case 2 (See figure 2.c): $\gamma_{n,t_s} \bigcap \gamma = \{p_n^i\}_{i=1\cdots m}$.
  The shape signature at scale t_s is defined as the sum of the area of the regions $\{S^i_{n,t_s}\}_{i=1\cdots m}$ delimited by the elliptic arc $\widehat{p_i p_{i+1}}$ and the segment $[p_n^i p_n^{i+1}]$. It's given by the following equation:

$$W(n,t_s) = \sum_{i=0}^{m} Area(S^i_{n,t_s}) \quad (3)$$

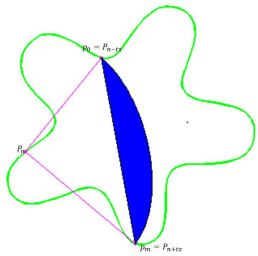
2.2 Properties

Affine Invariance. The proposed shape descriptor is invariant to affine transformations. Given a three points A, B and C from the contour and A', B', C' their image by an affine transformation. If E is the circumscribed ellipse of the triangle $\triangle = ABC$ then the circumscribed ellipse E' of the triangle $\triangle = A'B'C'$ exist and it's the image of E by the same affine transformation. This property is verified due to the following claims :

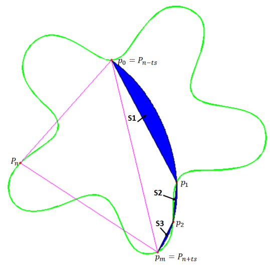
- The affine transformation maps an ellipse to an ellipse and preserves the intersection between curves.
- The uniqueness of the triangle circumscribed ellipse.



(a) E_n^{ts} : Circumscribed ellipse



(b) $W(n,t_s)$: Shape signature (case 1)



(c) $W(n,t_s)$: Shape signature (case 2)

Figure 2: Shape signature steps.

Discrimination Property. Figure3 shows the MCAR shape signature of three shapes from two different classes (figures 3 (a), (c) and (e)). We can see that their corresponding shape signatures (figures 3(b), (d) and (f)) are similar for the same class shapes (camel shape) and dissimilar for those from different classes (camel and star shape).

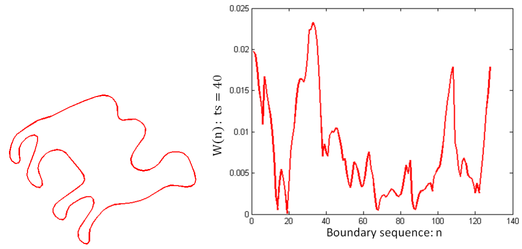
Relation Between MCAR Signature and Contour Concavity/Convexity. Figure 4 shows the signature at different scales. We can notice that at the scales (c, d, e and f) all the concavity/convexity parts of the contours are described by the signature and only dominant features persist over the scales (f and g).

3 MULTISCALE FOURIER SHAPE DESCRIPTOR

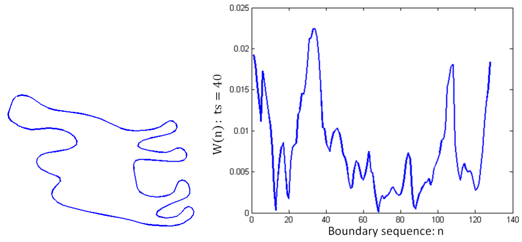
Fourier Descriptors of the multiscale signature are computed. The discrete Fourier transform of the signature $W(t,t_s)$ is given by:

$$a_n^{(ts)} = \frac{1}{N}\sum_{t=0}^{N-1} W(t,t_s)\exp\left(\frac{-j2\pi nt}{N}\right), n = 0,\cdots,N-1$$

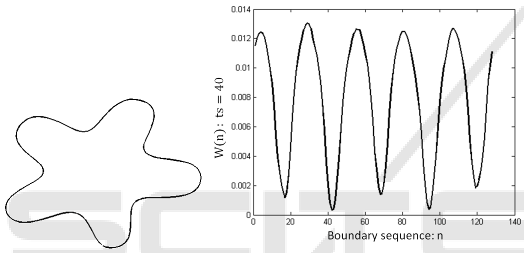
. A Fourier descriptor of the signature $W(t,t_s)$ are derived from the Fourier coefficients $a_n^{(t_s)}$ as follows:



(a) (b)

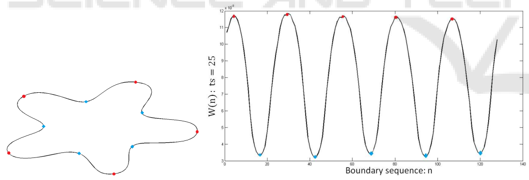


(c) (d)

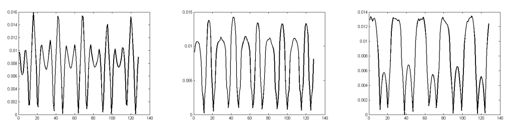


(e) (f)

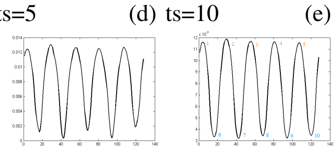
Figure 3: MCAR Signature of For 3 shapes at scale ts=40.



(a) Shape boundary (b) Concavity/convexity at the scale:ts=25



(c) ts=5 (d) ts=10 (e) ts=15



(f) ts=20 (g) ts=25

Figure 4: MCAR Signature at different scales ts={5,10,15,20,25}.

$$DF^{(t_s)} = DF(W(t,t_s)) = \left\{ \frac{|a_n^{(t_s)}|}{|a_0^{(t_s)}|} \right\}_{n=1\cdots p}, \quad (4)$$

where p is the number of Fourier coefficients. Therefore, the proposed descriptor is defined by $\{J_k\}_{k=1\cdots N}$:

$$\{J_{t_s}\}_{t_s=1\cdots T_s} = \{DF^{(t_s)}\}_{t_s=1\cdots T_s}, \quad (5)$$

where T_s is the number of scales. In this work, we consider $\frac{N}{2}$ scales.

The similarity measure used to compare two shape contours $\Gamma 1$ and $\Gamma 2$ is formalized as follows:

$$d(\Gamma 1, \Gamma 2) = \frac{1}{T_s} \sum_{k=1}^{t_s} \|J1_k - J2_k\|_2 \quad (6)$$

where T_s is the number of contour scales and $\|.\|_2$ is the L_2 norm.

Since the Fourier Descriptors of the signature are invariant to rotation and starting point, the proposed descriptor is invariant to affine transformations and starting point.

4 EXPERIMENTAL RESULTS

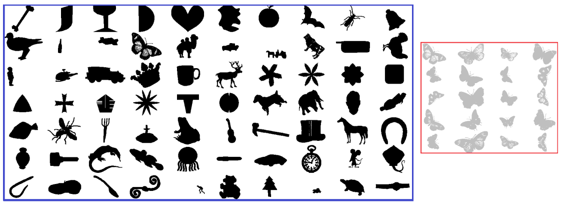
In this section, the performance of our proposed method is shown using two standard shape datasets MPEG7-setB and MCD.
Also, it's compared with some commonly used signatures such as Multiscale Contour flexibility shape signature for Fourier descriptor, Curvature scale space(CSS), Perimeter area function(PAF) and the Multi-resolution Affine Invariant Planar Contour Descriptor(DFAP).

4.1 Datasets Description

The well-known MPEG-7 setB dataset (figure5), consists of 1400 images classified into 70 classes. It's used for similarity-based retrieval accuracy and shape descriptors robustness under various arbitrary shape distortions, that include rotation, scaling, arbitrary skew, stretching, defection, and indentation. The Multiview Curve dataset (figure 6) is composed of 40 shape classes selected from MPEG-7 database, where Each class contains 14 shape samples that correspond to different perspective examples of the original curve. This dataset is used in order to evaluate shape descriptors under affine transformation.

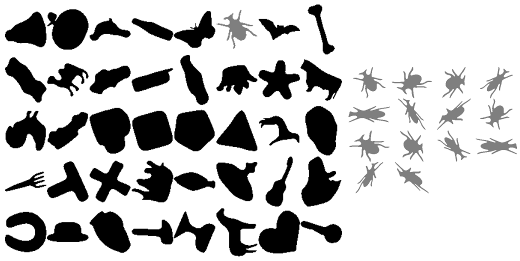
4.2 Performance Evaluation

In order to evaluate the performance of our shape descriptor in the context of image retrieval, we deal with



(a) (b)

Figure 5: MPEG7 setB dataset.



(a) (b)

Figure 6: MCD dataset.

the precision-recall and the bull's-eye test which are the most commonly used test measures.

The precision is defined as the number of relevant shapes retrieved divided by the total number of shape retrieved, while the recall is defined as the number of relevant shapes retrieved divided by the total number of relevant shapes in the class. The average of the precision and recall over all the database is used to plot the precision-recall curve. In the case of the Bull's-eye test each shape from the database is used as a query, if the retrieved shape is in the same class as the query one then it is considered as a correct response. The number of correct retrievals in the top 2M (where M is the size of the class) ranks is counted, including the query. Retrieval rate is the percentage of the maximal possible number of correct retrievals shapes.

In order to be in the same conditions when comparing our approach with other methods in the MPEG-7 Set B data set, 128 points are sampled from each contour.

The bulls-eye test results obtained for the the MPEG7-SetB database are shown in table 1 and indicate that our descriptor outperforms Fourier based shape signatures proposed in the literature such as Fourier Decriptors of TAR, multiscale contour flexibility descriptors and the DFAP proposed in (T.Faidi, 2015). The MCAR signature's performance is equal to 71.41%. In fact, this is tied to the theoretical invariance property of our descriptor under affine transformations and it's capability to perfectly capture the local and global information thanks to the multiscale technique.

However, the CSS outperforms our descriptor in term of bulls-eye test. It's important to note that this descriptor requires high complexity time to solve shape matching problem. Our proposed descriptor is easy to compute and uses a simple L_1 distance to measure the distance between two shape signatures.

Table 1: The Bull-eyes test for our descriptor and other signatures using MPEG-7 database setB.

Shape descriptor	Bull-eyes
CSS	75.44
PAF+CD	74.36%
MCAR (proposed)	71.41%
TAR + Fourier descriptor	68.67%
Multiscale Contour flexibility Fourier descriptor (W+)	67.57%
PAF	66.49 %
DFAP	66.46%
Multiscale Contour flexibility Fourier descriptor (W+)	65.39%

Figure 7 shows ten random retrieval results from the MCD database based on the proposed MCAR descriptor. Incorrect responses are obtained for only one query at the 8, 11, 12 and 13 ranks.

In figure 8, we show the average precision and recall curves of MCD database for different shape descriptors : Fourier Descriptors of TAR, DFPAS Descriptor and the CSS descriptor. Our proposed descriptor outperforms the others.

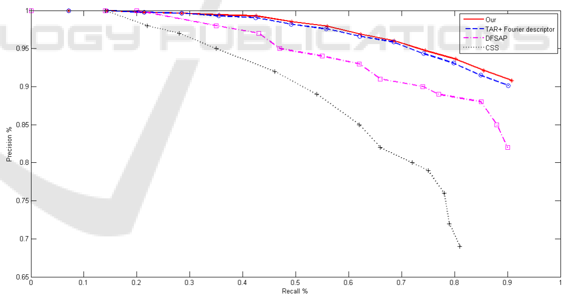


Figure 8: Average precision and recall of MCD database retrieval.

5 CONCLUSION

In this paper, a closed-boundary multiscale shape signature invariant to affine transformation has been introduced. It is defined from the local area delimited by the circumscribed ellipse of the triangle formed by three contour points and the contour. At each scale level, the proposed shape signature, denoted MCAR, depicts the contour point concavity/convexity. Then, Fourier descriptors of the MCAR signature are generated. The multiscale approach combined with the

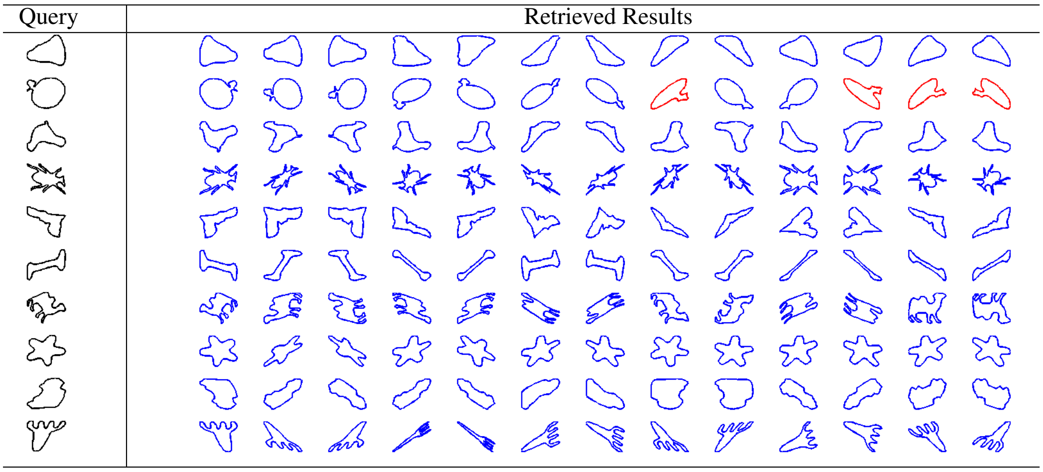


Figure 7: 10 random retrieval results from MCD database.

Fourier Descriptors captures both global and local geometric characteristics of the shape. Furthermore, it is invariant to affine transformation and robust to partial occlusion. The performance of our proposed method was evaluated through the precision recall and bull's-eye tests on the two well-known databases (MCD and MPEG7-setB). Obtained results indicate that our method outperforms the shape signatures based Fourier descriptor proposed in the literature.

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REFERENCES

Abbasi, S., Mokhtarian, F., and Kittler, J. (1999). Curvature scale space image in shape similarity retrieval. *Multimedia Syst*, 7(6):467–476.

Abbasi, S., Mokhtarian, F., and Kittler, J. (2000). Enhancing css-based shape retrieval for objects with shallow concavities. *Image and Vision Computing*, 18(3):199–211.

Adamek T., O. N. (2004). A multiscale representation method for nonrigid shapes with a single closed contour. *IEEE TRANSACTIONS, Circuit Syst,Video Technol*, 14:742–753.

A.El-Ghazal, O.Basir, S. (2007). A new shape signature for fourier descriptors. *14 th IEEE International Conference on Image Processing SanAntonio,Texas,USA*, pages 161–164.

Alajlan, N., Rube, I., M.S.Kamel, and G.Freeman (2007). Shape retrieval using triangle-area representation and dynamic space warping. *Pattern Recognition*, 40(7):1911–1920.

Bartolini, I., Ciaccia, P., and Patella, M. (2005). Warp: accurate retrieval of shapes using phase of fourier descriptors and time warping distance. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, 27(1):142–147.

Bober, M. (2001). Mpeg-7 visual shape descriptors. *IEEE Trans. Circuits and Systems for Video Technology*, 11(6):716–719.

C.Xu, J.Liu, X. (2009). 2d shape matching by contour flexibility. *IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE*, 31.

D.S.Zhang, G. (2005). Study and evaluation of different fourier methods for image retrieval. *Image and Vision Computing*, 23:33–49.

F.Chaker, M.Bannour, F. (2003). A complete and stable set of affine-invariant fourier descriptors. *12th International Conference on Image Analysis and Processing*, pages 578–581.

Hu, M.-K. (1962). Visual pattern recognition by moment invariants. *Information Theory, IRE Transactions on*, 8(2):179–187.

I.Kunttu, L. (2007). Shape-based retrieval of industrial surface defects using angular radius fourier descriptor. *IET Image Processing*, 1:231–236.

Lin, T.-W. and Chou, Y.-F. (2003). A comparative study of zernike moments. In *Web Intelligence, 2003. WI 2003. Proceedings. IEEE/WIC International Conference on*, pages 516–519.

T.Faidi, F.Chaieb, F. (2015). A new multi-resolution affine

[1] http://www.pasri.tn/
[2] http://www.cert.nat.tn/
[3] http://www.arts-pi.org.tn/cristal.php/

invariant planar contour descriptor. *Image Analysis and Processing-ICIAP 2015*, 9280:494–509.

T.Zahn, R. (1972). Fourier descriptors for plane closed curves. *IEEE Transactions on Computers*, 21:269–281.

Xin Shu, Lei Pan, X.-J. W. (2015). Multi-scale contour flexibility shape signature for fourier descriptor. *Journal of Visual Communication and Image Representation*, 26:161167.