A Contour-Oriented Approach to Shape Analysis via the Slope Chain Code

Ernesto Bribiesca

Department of Computer Science
Instituto de Investigaciones en Matemáticas Aplicadas y en Sistemas
Universidad Nacional Autónoma de México
Apdo. Postal 20-726, México, D.F., 01000, México

Copyright © 2015 Ernesto Bribiesca. This article is distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Abstract

We present a noncircularity measure for 2D (two-dimensional) shapes and an approach to the computation of the Euler number based on the Slope Chain Code (SCC). The SCC was developed for representing and analyzing open and closed curves in the 2D domain. Now, in this paper we describe more properties of the SCC, such as: the independence of scaling and starting point for simple closed curves, arithmetic operations among convex shapes, the minimum and maximum values of the proposed noncircularity measure, the computation of the number of holes in a picture, and the computation of the Euler number. Finally, in order to illustrate the capabilities of the proposed method, we present the computation of topological properties of an example of a picture of the real world.

Keywords: Slope chain code, Euler number, simple closed curves, noncircularity measure, pictures, chain coding, tortuosity

1 Introduction

Shape analysis is an important topic in pattern recognition, digital image processing [17], and computer vision. Two fundamental properties of shapes are
their circularity and genus, this work deals with these above-mentioned properties. We proposed a measure of noncircularity and a method to compute the Euler number, both techniques are based on the Slope Chain Code (SCC) definition [6, 7]. Using the SCC notation of any shape, geometrical and topological properties of the shape are preserved. The SCC is similar to other chain codes [16, 4, 8] since it uses numerical sequences, but has some important differences from them. The SCC of a curve is obtained by placing constant straight-line segments around the curve (the endpoints of the straight-line segments always touching the curve, so a better description of the curve is obtained), and calculating the slope changes between contiguous straight-line segments scaled to a continuous range from $-1$ to $1$. The main properties of the SCC are: 1) invariant under translation; 2) independent of rotation; 3) optionally, invariant under scaling; 4) it does not use a grid; 5) the straight-line segment size ($l$) is always the same for the whole shape; 6) the range of slope changes is unlimited (goes continuously from $-1$ to $1$); 7) the chain elements produces sequence of discrete elements (a chain), i.e. the alphabet of the string (the chain) is finite. Thus, grammatical techniques [21, 30, 1] may be used for shape classification. In the content of this work, we use some of the concepts of the SCC for defining our proposed measure of noncircularity and the computation of the Euler Number.

There are many shape descriptors, such as: linearity [31], convexity [25], elongation [32], rectilinearity [37], sigmoidality [27], compactness [9], circularity [26, 18, 35, 28, 38, 20], and others. This work proposed a measure of noncircularity based on the SCC. Other important shape descriptor corresponds to the Euler number or genus. The Euler number is a fundamental topological property of shapes. The Euler number is a basic feature in many applications: in the recognition of industrial parts [34], in character recognition, in the computation of porosity of objects, in biological imaging, in graph theory, and so forth. Many authors have proposed different methods to compute the Euler number, for example in refs. [34, 5, 13, 24, 15, 2, 12, 11, 3, 36, 14, 10].

Some authors have used chain-code techniques to compute the Euler number. For example, Using the Vertex Chain Code [8]: Wulandhari and Haron [33] proposed an interesting method to calculate the genus by means of the chain elements. They analyzed shapes with only one hole, so obtained two Vertex-Chain-Code chains of the outer and inner boundaries of the analyzed shape. Next, they add all chain elements and compare with the number of elements of both chains multiplied by two. Living and Xuejun [23] gave an algorithm for calculating the Euler number of image on the basis of Vertex Chain Code and tree structures of contours. Sossa-Azuela et. al. [29] presented an interesting approach to compute the Euler number by means of the Vertex Chain Code. Now, in this paper we proposed a method to compute the Euler number based on the SCC.
A contour-oriented approach to shape analysis

In the content of this paper, definitions 2, 4, 6, and 9, propositions 7 and 15 are based on refs. [6, 7]. On the other hand, definitions 1, 3, 5, 8, 10, 14, 16, and 18, propositions 12, 13, and 17, theorems 19 and 20, and corollary 11 are the contribution of this paper.

This paper is organized as follows. In Section 2 we describe some concepts and definitions. Section 3 presents a summary of the SCC. Section 4 gives the proposed measure of noncircularity. In Section 5, we describe the computation of the Euler number using the SCC. Section 6 presents some results of the computation of topological features of an object of the real world. Finally, in Section 7 we give some conclusions.

2 Concepts and definitions

In order to introduce the proposed noncircularity measure and our approach to the computation of the Euler number using the SCC, a number of concepts and definitions are presented below:

- Shape is referred to as shape-of-object, and an object is considered to be a geometric entity [19].
- A simple closed curve is a curve which does not cross itself.

An important assumption in this section is that an entity has been isolated from the picture plane. This entity is called the curve, and is the result of a previous process.

DEFINITION 1. A chain a is an ordered sequence of n elements, and is represented by

\[ a = a_1a_2 \ldots a_n = \{a_i : 1 \leq i \leq n\}. \quad (1) \]

DEFINITION 2. An element \(a_i\) of a chain indicates the slope change of the contiguous straight-line segments of the curve in that element position. The range of the slope changes goes continuously from \(-1\) to 1.

DEFINITION 3. The slope change between contiguous straight-line segments is ordinarily counted as positive if counterclockwise, negative if clockwise [22].

3 The Slope Chain Code

In order to have a self contained paper, this section summarizes the SCC, which was presented in refs. [6, 7] and presents new concepts which are the
contribution of this paper. The SCC of a curve is obtained by placing constant straight-line segments around the curve (the endpoints of the straight-line segments always touching the curve, so a better description of the curve is obtained), and calculating the slope changes between contiguous straight-line segments scaled to a continuous range from $-1$ to $1$. The SCC of a curve is independent of translation, rotation, and optionally, of scaling, which is an important advantage in pattern recognition.

**DEFINITION 4.** *The independence of scaling of a curve is obtained by normalizing the length of its perimeter $P$ to a fixed number $m$ of straight-line segments around it.*

The SCC may be computed for open and simple closed curves [7]. However, in the content of this paper we only focus on simple closed curves. In order to obtain the SCC of a continuous closed curve, first, we calculate its perimeter $P$ and define the number $m$ of straight-line segments. For instance, Fig. 1(a) illustrates an example of a simple closed curve. Next, we define a fixed number $m$ of straight-line segments to represent it. In this example, $m = 20$. Furthermore, we select an origin, this origin correspond to the point of maximum inflection of the whole curve. In some cases, may be exist one or more points of maximum inflection (this is common in symmetrical curves). Thus, in order to select the appropriate origin, additional criteria must be included.

Once this length is known, i.e. $l = \frac{P}{m}$ see Fig. 1(a). The origin of the curve is represented by a point and an endpoint of one of the straight line-segments is set to coincide with this origin. The opposite endpoint is set over the curve, determining the starting point of the next segment, and so on. Graphically, this process amounts to superimposing a sequence of circles traversing the curve, where the intersections of the curve and circles determine the points of the discrete shape (Fig. 1(a)). The radius of each circle corresponds to the length of the previous defined segment $l$.

Then, the slope changes between contiguous-straight line segments are computed. Positive and zero slope changes are scaled to lie within the interval $[0, 1]$; negative slope changes are scaled to lie within the interval $(-1, 0]$ (the range of slope changes are shown in Fig. 1(b)). The sequence of slope changes is the chain which defines the discrete shape of the continuous closed curve, see Fig. 1(c). Thus, the chain of the simple closed curve shown in Fig. 1(c) is as follows: $-0.2 -0.2 0.3 0.2 0.2 -0.2 0.3 0.2 0.2 -0.2 -0.3 0.2 0.1 0.2 0.3$. Note that the chain elements in Fig. 1(c) have a predetermined accuracy ($10^{-1}$) in the slope changes; this may, of course, be changed. This accuracy generates a finite alphabet composed of 19 symbols. For instance, a predetermined accuracy equal to ($10^{-2}$) produces a finite alphabet composed of 199 symbols. The digitalization of the slope changes at different resolutions produces a sequence of discrete elements (a chain), i.e. the alphabet of the string (the chain) is finite.
Thus, grammatical techniques [21, 30, 1] may be used for shape classification. In this manner, it is possible to manipulate the advantages and disadvantages of the continuous and discrete domains depending on the required study.

Figure 1: How to obtain the SCC of a simple closed curve: (a) a continuous curve with a selected origin and a previous defined straight-line segment, traversing the curve using circles (the radius of each circle is equal to the straight-line segment length) to determine slope changes; (b) the range of slope changes [0, 1) and (−1, 0]; (c) the discrete curve and its ordered sequence of slope changes.

3.1 Independence of starting point for simple closed curves

The closed curves described via the SCC may be invariant under starting point. Generally speaking, the point of maximum inflection of all the simple closed curve corresponds to the unique starting point. However, when the above-mentioned curve is digitalized and represented by the SCC depending on the resolution may be this changed. Therefore, in order to have a unique starting
point of any curve already represented by chain elements (see Fig. 2(a)), we define the following:

**DEFINITION 5.** A simple closed curve is invariant under starting point by choosing the starting point so that the resulting sequence of elements forms a chain of values of minimum magnitude.

Thus, in order to make a curve invariant under starting point, we have to rotate the chain elements until the chain is minimum as follows:

01) -.2 -.2 .3 .2 .2 .3 -.2 -.2 .3 .2 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3
02) .3 .2 .2 .3 -.2 -.2 .3 .2 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3
03) .2 .2 .3 -.2 -.2 .3 .2 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3
04) .2 .2 .3 -.2 -.2 .3 .2 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3
05) .2 .3 -.2 -.2 .3 .2 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2
06) .3 .2 -.2 -.2 .3 .2 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2
07) -.2 -.2 .3 .2 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .2 .3
08) -.2 .3 .2 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3
09) .3 .2 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3
10) .2 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3
11) .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3
12) .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3
13) -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3
14) -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3
15) .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3
16) .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3
17) .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3
18) .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3
19) .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3
20) .3 -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3

Therefore, the rotation 13 indicates the sequence of the values of the chain elements of minimum magnitude. Thus, finally the chain elements: -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .1 .1 .2 .3 represent the chain of the curve illustrated in Fig. 2(b) invariant under starting point. In some cases, may exist two or more unique starting points. This is common in symmetrical curves. Then additional criteria must be included.

### 3.2 The accumulated slope, the slope change mean, and tortuosity

**DEFINITION 6.** The accumulated slope $A_{cc}$ of a chain is the sum of all the slope changes around the curve, and is defined by
A contour-oriented approach to shape analysis

Figure 2: Independence of starting point: (a) a continuous curve with a selected origin and a straight-line segment, traversing the curve using circles (the radius of each circle is equal to the straight-line segment length) to determine slope changes; (b) the range of slope changes $[0, 1)$ and $(-1, 0]$; (c) the discrete curve and its ordered sequence of slope changes.

\[ A_{cc} = \sum_{i=1}^{n} a_i. \] (2)

For example, the sum of all the slope changes shown in Fig. 2(b) is equal to 2, which corresponds to its accumulated slope.

**Proposition 7.** The accumulated slope $A_{cc}$ of simple closed curves always is equal to 2.

**Definition 8.** The slope change mean $a_m$ of a curve is the arithmetic mean of all the slope changes around the curve. The slope change mean is the accumulated slope divided by the number of elements, and is defined as follows:

\[ a_m = \frac{1}{n} \sum_{i=1}^{n} a_i = \frac{1}{n} A_{cc}. \] (3)

For example, the slope change mean of the curve illustrated in Fig. 2(b) is equal to 0.1.

**Definition 9.** The tortuosity $\tau$ of a curve represented by a chain is the sum
of all the absolute values of the chain elements, and is defined by
\[ \tau = \sum_{i=1}^{n} |a_i|. \] (4)

The \( A_{cc} \) and \( \tau \) are preserved at different resolutions [7]. For any curve the minimum and maximum values of \( \tau \) belong to the range \([0, n)\), respectively. For example, the numerical value of the measure of tortuosity \( \tau \) of the curve shown in Fig. 2(b) is equal to 4.4.

3.3 Convex and concave shapes

A convex polygon is described as a polygon which lies entirely in one half-plane of any line containing one of its sides; also, its interior is the intersection of half-planes determined by these lines. Otherwise it is concave [22]. Our discrete shapes are considered as polygons.

**DEFINITION 10.** A simple closed curve is convex when the absolute value of the accumulated slope is equal to its tortuosity, i.e., \( |A_{cc}| = \tau \).

**COROLLARY 11.** A simple closed curve is concave when the absolute value of the accumulated slope is less than its tortuosity, i.e., \( |A_{cc}| < \tau \).

**PROPOSITION 12.** The tortuosity \( \tau \) of any circumference, independent of its resolution, always is equal to 2.

**PROPOSITION 13.** The tortuosity \( \tau \) of any square, independent of its resolution, always is equal to 2.

Fig. 3 shows some examples of convex and concave simple closed curves. The left-hand side of Fig. 3 describes the continuous versions of the shapes and the right-hand side the discrete versions, respectively. Taking into account the Preposition 7, all the accumulated slopes of all the shapes shown in Fig. 3 are equal to 2. Fig. 3(a) shows two examples of convex shapes, in this case their values of tortuosity are equal to 2. Considering the Definition 10, these above-mentioned curves belong to the family of convex curves. On the other hand, the shapes presented in Fig. 3(b) belong to the family of concave curves (Corollary 11) where the accumulated slopes of the discrete shapes are less than their values of tortuosity.

3.4 Arithmetic operations among convex shapes

Using the concepts of the convex shapes and the SCC, it is possible to do arithmetic operations among convex shapes. For example, the average of a circumference and a square. This average never exceeds the maximum permitted
A contour-oriented approach to shape analysis

Figure 3: Examples of convex and concave curves, the shapes shown in the
to the continuous versions and the shapes in the right-hand side the discrete versions, respectively: (a) the convex shapes and their
measures of tortuosity; (b) the concave shapes and their measures of tortuosity.

value of slope change. Fig. 4 shows different averages between a circumference
and a square. In these mathematical operations is very important to consider
both origins of the above-mentioned curves. These arithmetic operations are
performed element by element of both chains. These simple closed curves are
normalized to have the same number of straight-line segments, i.e. they are
isoperimetric.

4 The noncircularity measure

Haralick [18] states that “a good measure for the circularity of simply closed
figures would have the following properties: 1) as a figure becomes more circular, the measure of its circularity increases; 2) the values for digital figures
follow the values for the corresponding continuous figures; 3) it is orientation independent; 4) it is area independent”. The noncircularity measure proposed
here complies with the above-mentioned properties.

DEFINITION 14. The noncircularity measure $D_c$ of a curve is the sum of all
Figure 4: Examples of arithmetic operations among convex shapes.

the absolute values of the differences between the chain elements and the slope change mean, and is defined as follows:

\[ D_c = \sum_{i=1}^{n} |a_i - a_m| \tag{5} \]

Fig. 5 shows 13 examples of continuous closed curves from (a) to (m). Fig. 6 presents the discrete versions of all the curves illustrated in 5 from figs. 6(a) to (m), respectively. These curves were normalized to 20 straight-line segments and their chains are as follows:

(a) .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1
(b) .1 .1 .1 .1 .1 .2 -.1 .2 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1
(c) .1 .1 .1 .3 -.1 .1 .3 .1 .1 .1 .1 .1 .3 -.1 -.1 .3 .1 .1 .1
(d) .1 .1 .1 .1 .8 -.1 -.1 -.1 -.1 -.1 -.1 .8 .1 .1 .1 .1 .1 .1 .1
(e) .0 .0 .0 .0 .5 .0 .0 .0 .0 .5 .0 .0 .0 .0 .5 .0 .0 .0 .0 .5
(f) .1 .1 .5 -.1 -.1 -.1 .5 .1 .1 .1 .5 -.1 -.1 -.1 .5 .1 .1
(g) -.2 -.2 .3 .2 .1 .1 .2 .3 -.2 -.2 .3 .2 .3 -.2 -.2 .3 .2 .3
(h) .1 .7 -.1 -.1 -.1 -.1 .7 .1 .1 .1 .5 -.1 -.1 -.1 .5 .1 .1
(i) .5 .0 .0 .0 .5 .0 .0 .5 .5 .0 -.5 .0 .0 -.5 .0 .5 .5 .0 .0
(j) .5 .5 .0 .0 .0 .5 .5 .0 -.5 .0 .0 .5 .5 .0 .0 .0 -.5 .0
A contour-oriented approach to shape analysis

Fig. 5: 13 examples of continuous closed curves from (a) to (m).

Fig. 6 presents the examples of all the closed curves illustrated in 5 and their measures of tortuosity and noncircularity. All the above-mentioned curves are presented in ascending order of noncircularity. Note that the measure of tortuosity is independent of the circularity measure. The measures of tortuosity of the curves presented in Fig. 6 are not shown in ascending order of tortuosity.

It is important to note that the noncircularity measure proposed here is a contour-oriented approach which depends on the perimeters of the analyzed shapes. This is different to other measures of circularity which are region-oriented approaches.
4.1 The minimum and maximum values of the noncircularity measure

The minimum value of noncircularity measure is equal to zero and corresponds to the most circular shape, whose chain elements have the value of the slope chain mean each one. Fig. 6(a) represents the minimum value of the noncircularity measure (of course at this resolution), i.e. $D_c = 0$. In other words, the shape shown in Fig.6 (a) has the maximum circularity. On the other hand, the maximum value of noncircularity of any curve corresponds to the approximated value of $n$. For instance, the shape presented in Fig. 6(m) has a large value of the noncircularity measure. Thus, the noncircularity measure varies in a continuous range between $[0, n)$. 

Figure 6: The discrete versions of the 13 examples of curves shown in Fig. 5. These discrete curves were normalized to 20 straight-line segments.
5 Computation of the Euler Number using the Slope Chain Code

In this section, we only consider shapes with holes. The Euler number or genus is a fundamental topological property of shapes. Mathematically speaking, the Euler number \( E \) or genus is defined as number of connected regions \( C \) minus number of holes \( H \) and is represented as follows.

\[
E = C - H. \tag{6}
\]

**PROPOSITION 15.** The inverse of a chain of a curve is another chain formed of the opposite-sign elements of the first chain arranged in reverse order.

**DEFINITION 16.** The inverse chain of a shape corresponds to a hole, in which the contour of the original object is preserved.

**PROPOSITION 17.** The accumulated slope \( A_{cc} \) of a hole always is equal to \(-2\).

**DEFINITION 18.** In order to obtain the chains of contours of shapes and holes in a picture, we always have to walk on contours holding the matter side to the left hand and the empty side to the right hand, respectively.

**THEOREM 19.** The number of holes \( H \) of any shape is the minus sign of the sum of all its slope changes divided by \( 2 \) plus \( 1 \) and is defined as follows:

\[
H = -\frac{\sum_{i=1}^{n} a_i}{2} + 1. \tag{7}
\]

**Proof.** For the base case, when the shape has no hole the \( \sum_{i=1}^{n} a_i = 2 \) and therefore using Eq. (7): \( H = 0 \). Next, when the shape has only one hole, we have \( \sum_{i=1}^{n} a_i = 0 \). Therefore, using Eq.(7) \( H = 1 \). For the next holes in the same binary shape, according to Eq. (7) the term \( \sum_{i=1}^{n} a_i \) will be incremented by \(-2\) (Proposition 17) for each new hole in the shape, which we know is true. Q.E.D.

**THEOREM 20.** The number of holes \( H \) of any picture is the minus sign of the sum of all the slope changes of all the contours divided by \( 2 \) plus \( C \) and is defined as follows:

\[
H = -\frac{\sum_{i=1}^{n} a_i}{2} + C. \tag{8}
\]

**Proof.** The proof of this theorem is similar like the proof of Theorem 19, just considering the variable \( C \). Q.E.D.
Substituting $H$ from Eq. (8) in the Euler-number equation (Eq. (6)), we have.

$$E = \frac{\sum_{i=1}^{n} a_i}{2}.$$  \hspace{1cm} (9)

For example, for the shape presented in Fig. 7, the sum of all the slope changes is equal to $-6$ and $C = 1$. Using Eq. (8), we obtain $H = 4$ and the Euler number $E = -3$ (eqs. (6) or (9)).

Figure 7: An example of an object with four holes.

6 Results

In order to compute the number of holes and the Euler number, we show an example of an object of the real world: a piece of polyurethan. Polyurethanes are polymers composed of units of organic chains joined by carbamate links.
Flexible polyurethane foams are used as cushioning for a great variety of commercial products. In this kind of materials it is important to know the number of holes, the hole sizes, and their porosities. Fig. 8 shows the bubbles in a piece of polyurethan. Fig. 9 presents a slide of the piece of polyurethan shown in 8; this slide was obtained as a result of a previous processing. Now, using eqs. (8) and (9) we calculate $H = 31$ and $E = -30$. 

Figure 8: Bubbles in a piece of polyurethan.

Figure 9: A slide of the piece of polyurethan shown in Fig. 8.
6.1 Comparison of the proposed method for computing the Euler number via the SCC with others

Many authors have been proposing different techniques to compute the Euler number, such as: Dyer [15] presents the computation of the Euler number of an image from its quadtree; Bieri [2] defines the computation of the Euler characteristic of digital objects from their bintree representation; Chiavetta and Di Gesu [12] present a method of parallel computation of the Euler number via connectivity graph, Diaz-de-Leon and Sossa [14] present a method to obtain the Euler number of a binary object via its skeleton, the number of terminal points and the number of three-edge-points in the graph are used to compute this invariant; Bishnu et al. [3] define a pipeline architecture for computing the Euler number of a binary image; Bribiesca [10] uses the concept of the contact perimeter [9] to compute the Euler number, however, in this approach only unit-width objects are considered; and others.

Some authors have used chain coding to compute the Euler number, for example: Wulandhari and Haron [33] describe a fast algorithm to compute the Euler number via the Vertex Chain Code. However, this method only consider shapes with one hole; Liying and Xuejun [23] generate tree structures of contours and then based on the Vertex Chain Code computes the Euler number; Sossa-Azuela et. al. [29] count the number of vertices “1” and “3” of the Vertex Chain Code and compute the number of holes by a simple formula. Chain code techniques preserve information and allow considerable data reduction, they are another important tool to compute the Euler number in a fast way. To the best of our knowledge this is the first time that the SCC is used to compute the Euler number.

7 Conclusions

A number of definitions, corollaries, and theorems are presented, which allow us to find out interesting properties, such as: the computation of a noncircularity measure, arithmetic operations among convex shapes, analysis of the minimum and maximum values of the proposed noncircularity measure, the computation of the number of holes in a picture, and the computation of the Euler number. Finally, in order to prove the above-mentioned concepts, we presented an example of an object (a piece of polyurethan) of the real world. We have concluded that it is possible to obtain geometrical and topological information of any shape by means of its SCC description.

Suggestion for further work: extend the SCC and the above-mentioned concepts from 2D to 3D domain.

Acknowledgements. This research work was supported by IIMAS-UNAM
A contour-oriented approach to shape analysis

and SNI-CONACyT.

References


A contour-oriented approach to shape analysis


Received: September 11, 2015; Published: December 12, 2015