SHAPE ANALYSIS USING GLOBAL SHAPE MEASURES

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Abstract

The paper is devoted to the shape analysis with the global shape measures. Two global shape measures describing circularity and three global shape measures describing elongation of an object are presented in the paper. The global shape measures are calculated for nine polygons consisting of 64 polygon ventrices. The performance of the global shape measures to represent a shape is evaluated. The best global shape measure for each shape category is selected and presented in pairs for each polygon. The selected measure for elongation is the eccentricity and the selected measure for the circularity is the Haralicks measure of the circularity. It was found that is possible to differentiate between the polygons using this combination of the global shape measures.

1 Introduction

Nowadays, more and more digital images are used in many applications. There is a demand for image descriptors which could facilitate searching for images according to their content. One of the ways to extract these descriptors is to define shapes of objects in images. Defining the shape of an object can be very difficult. When people describe an object they use terms such as elongated, rounded, with sharp edges, etc. For computer use, these properties must be extracted from the digital objects and represented by numbers. Many approaches have been developed to describe these properties from very simple to very complicated and computationally expensive techniques. Global shape measures (also called global scalar transforms) are good shape descriptors with reasonable computational requirements. Global shape measures return a single value which describes the shape of an object. The description of an object with a combination of global shape measures (for example shape measure of circularity and elongation) should be enough to provide discrimination between different categories of shapes.

Many global shape measures are described in the literature, e.g. moments, Fourier descriptors, auto-regressive models. These measures have been proven to be effective, although a drawback is that their values are often not easily understandable. The paper presents the global shape measures with direct intuitive meaning. Two measures for circularity and three measures for eccentricity are presented and the possibility of shape differentiation with the measures is evaluated.

2 Definitions of Global Shape Measures

2.1 Circularity

The simplest formula to calculate circularity (also called compactness, shape factor, etc) [1, 2] is

$$Circularity = \frac{P^2}{A} \tag{1}$$

where P and A are the perimeter and the area of an object. Although this is a convenient formulation, there are problems caused by the digitization artifacts. These problems originate from the extreme sensitivity of the perimeter estimates to noise. Thus in case of digital objects, the non-circular shapes (e.g. octagons or diamonds) can be assigned lower values than digital circles [2].

2.2 Haralick's Measure of Circularity

An alternative to avoid aforementioned problem of digitization was suggested by Haralick [2, 3]. The Haralick's measure of circularity is defined as

$$Haralick's\_Circularity = \frac{\mu_R}{\sigma_R} \tag{2}$$

where R is the distance between the center and any point on the perimeter, μ is the expectation and σ is the standard deviation. The Haralick's measure of circularity has the following properties:

- As an object becomes more circular, the measure of its circularity increases.
- The values for digital objects follow the values for the corresponding continuous figures.
- It is orientation independent.
- It is area independent.

2.3 Eccentricity

Various measures that take into account the concept of aspects of ratio can be found in the literature [1, 2], these have several names such as eccentricity, elongatedness, etc. The easiest way of describing elongation is through the ratio of the length of the maximum chord A to the maximum chord B which is perpendicular to A (the ratio of major and minor axes of an object as in figure 1).

$$Eccentricity = \frac{A}{B} \tag{3}$$

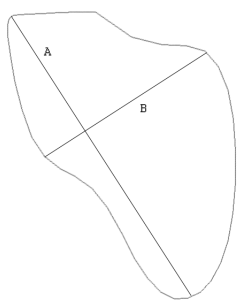

Figure 1: Visualization of the definition of eccentricity.

2.4 Elongatedness

Another frequently used convenient elongation measure used under the name of elongatedness works with the central moments μ_{pq} [2], and is calculated as the ratio of the lengths of the image ellipse axes

$$Elongatedness = \frac{\mu_{20} + \mu_{02} + \sqrt{(\mu_{20} - \mu_{02})^2 + 4\mu_{11}^2}}{\mu_{20} + \mu_{02} - \sqrt{(\mu_{20} - \mu_{02})^2 + 4\mu_{11}^2}} \tag{4}$$

which can be simplified as

$$Elongatedness = \frac{\sqrt{(\mu_{20} - \mu_{02})^2 + 4\mu_{11}^2}}{(\mu_{20} + \mu_{02})} \tag{5}$$

in order to provide a measure in the range between zero and one. In addition to the qualities of eccentricity elongatedness provides resilience to random spikes in the models.

2.5 Elongation

Elongation can be amongst others defined with the use of complex Fourier descriptors [2, 4]. If the boundary of a polygon is given by the points $(x(m), y(m))$ and the polygon is closed, the Fourier series of $x(m)$ and $y(m)$ are given by

$$x(m) = \sum_{n=-\frac{N}{2}+1}^{+\frac{N}{2}} a(n)e^{\frac{i2\pi nm}{N}} \quad and \quad y(m) = \sum_{n=-\frac{N}{2}+1}^{+\frac{N}{2}} b(n)e^{\frac{i2\pi nm}{N}} \tag{6}$$

where N is the number of points on the boundary. The sequences $a(n)$ and $b(n)$ are the complex Fourier coefficients of $x(m)$ and $y(m)$ respectively [4], and can be written as

$$a(n) = \frac{1}{N} \sum_{m=-\frac{N}{2}+1}^{+\frac{N}{2}} x(m)e^{\frac{-i2\pi nm}{N}} \quad and \quad b(n) = \frac{1}{N} \sum_{m=-\frac{N}{2}+1}^{+\frac{N}{2}} y(m)e^{\frac{-i2\pi nm}{N}} \tag{7}$$

The sequences $a(n)$ and $b(n)$ are used to derive a set of descriptors $s(n)$ defined by

$$s(n) = \frac{\sqrt{\mid a(n) \mid^2 + \mid b(n) \mid^2}}{\sqrt{\mid a(1) \mid^2 + \mid b(1) \mid^2}} \tag{8}$$

Descriptors $s(n)$ are invariant to translation, rotation and scaling. The descriptor $s(-1)$ can be used to measure elongation [5].

3 Method

Nine polygons were created to represent several types of shapes. Each polygon consist of 64 polygon vertices (x_k, y_k). The first three polygons represent basic shapes in order to demonstrate properties of the global shape measures. The rest of the polygons represent random shapes. The global shape measures are calculated for the polygons according to the formulas given in previous section. The performance of the global shape measures representing the circularity are evaluated first, then the performance of global shape measures describing eccentricity are evaluated. After evaluation the best global shape measure for each property is selected, and measures are paired. The pair of global shape measures is visually evaluated for possibility to differentiate between the shapes of the polygons.

4 Results

The calculated global shape measures for circularity are presented in figure 2 for each polygon. It can be seen that standard circularity return larger values for digital rectangles than digital circles. This is in agreement with theory presented in this article. The Haralicks circularity correctly returns bigger number for digital circles than for digital rectangles. But for eight and nine polygon the value bigger than for digital circle is assigned. It appears that Haralicks measure of circularity is disturbed by the polygons which consist of large concave and convex regions and assigned them bigger values than to the digital circles. Even with this property the Haralicks measure of circularity is superior to standard measure of circularity.

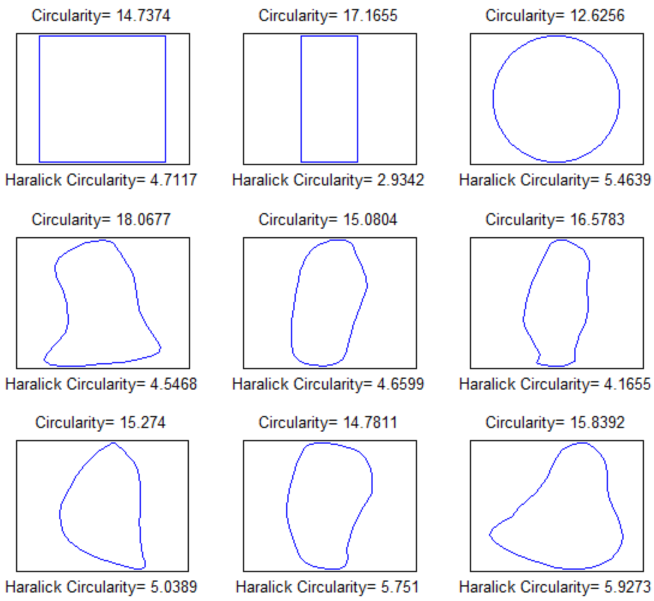

Figure 2: The circularity and the Haralick's circularity presented for each polygon.

The calculated global shape measures representing the eccentricity are presented in figure 3 for each polygon. As expected the elongatedness and the elongation is equal to zero, and the eccentricity is equal to one for the digital square and the digital circle. All global shape measures representing the elongation of polygons work sufficiently well. As the best global shape measure describing an elongation of the polygons the eccentricity is selected. Visually the eccentricity has the best performance for catching the elongation property of the polygons. Also the eccentricity have low computational requirements.

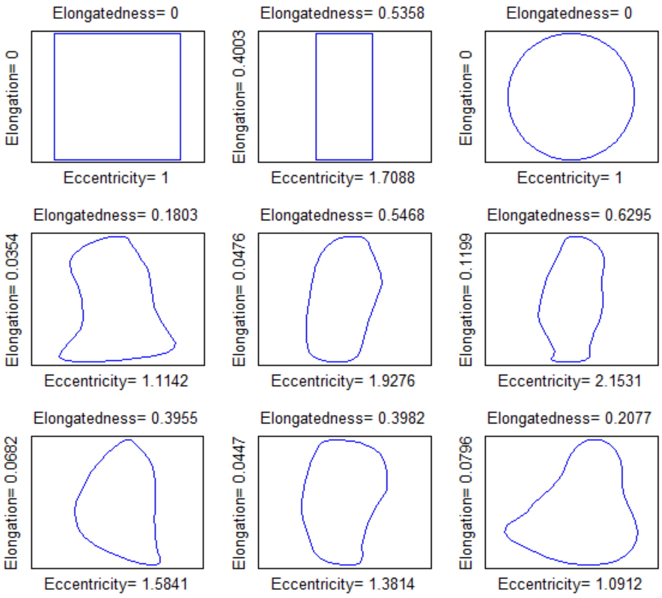

Figure 3: The eccentricity, the elongation, and the elongatedness presented for each polygon.

The polygons with the eccentricity and the Haralicks circularity are presented in figure 4. It is possible to differentiate between the polygons based on the values of the eccentricity and the Haralicks circularity. For example the digital square and the digital circle have the same eccentricity values but have different values of Haralicks circularity. This means that we can differentiate between the polygons if they have different elongation and circularity using the eccentricity and the Haralicks circularity measure.

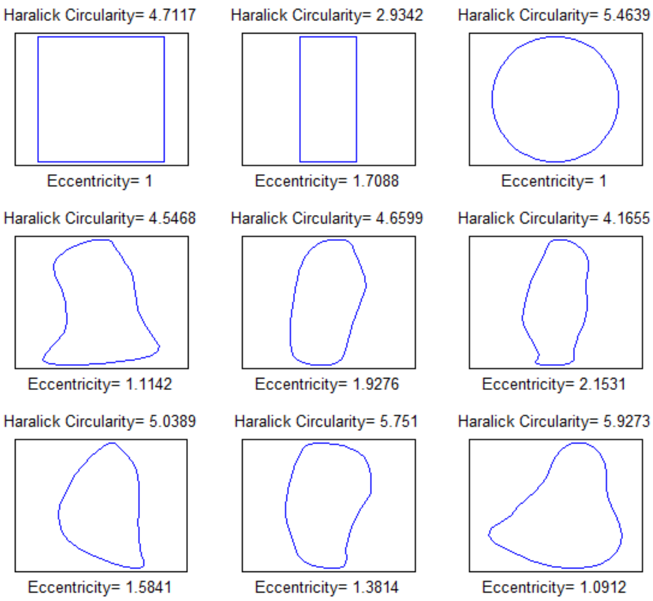

Figure 4: The eccentricity and the Haralick's circularity presented for each polygon.

5 Conclusion

Three global shape measures describing elongation and two global shape measures describing circularity of objects were presented. The global shape measures were calculated for nine polygons with different shapes. From the global shape measures the eccentricity was selected as the best global shape measure representing polygons elongation. The Haralicks circularity was selected as the best measure representing the circularity of polygons. The Haralicks circularity and the eccentricity were presented in pairs for each polygon. It was found that this pair of the global shape measures can differentiate between the shapes of the polygons.

References

[1] D. Zhang and G. Lu. *Review of shape representation and description techniques. Pattern Recognition, pages* 37(1):119, 2004.

[2] P. L. Rosin. *Computing global shape measures. Handbook of Pattern Recognition and Computer Vision, 3rd edition, page* 177:196, 2005.

[3] R. M. Haralick. *A measure for circularity of digital figures. IEEE Trans. on Systems, Man and Cybernetics, pages* 4:394396, 1974.

[4] G. H. Granlund. *Fourier preprocessing for hand print character recognition. IEEE Trans. on Computers, pages* 21:195201, 1972.

[5] E. T. Bowman, K. Soga, and T. Drummond. *Particle shape characterization using fourier analysis.Geotechnique, pages.* 51(6):545554, 2001

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