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AUGMENTING THE CONCEPT OF SHAPE NUMBERS FOR 3-D SHAPE RECOGNITION

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Abstract

Shape recognition plays a crucial role in image processing. This work proposes a method for object recognition, based on boundary detection by combining the concept of Fourier descriptors, wavelet transform and shape number. The main aim is to identify the shape of the object from the features that are drawn out from the boundary of the object. The boundary of the object of interest is extracted and then the shape number is obtained which would serve as the shape descriptor for recognition. Sometimes, the boundary pixels cannot truly represent the actual shape of the object due to the variations introduced during segmentation or edge detection process. So in order to remove the noise components in the boundaries, Fourier series concept is applied to decompose the shape into primary and secondary shapes. In this work, the focus is on primary or global shape. The 2-D shape number for this global shape is found out for 8 connectivity. The same concept is then extended for obtaining the 3-D global shape number to be used as descriptor for shape recognition using 64connectivity.

Introduction

The shape of an object in an image is one of the major characteristics when an eye recognizes an object. Shape recognition finds its applications in cancer cell detection, fingerprint analysis, machine vision, robotics, handwriting matching, face recognition, remote sensors etc [1]. Numerous methods for shape recognition and representation have been used, for example, shape context, dynamic programming, Curvature scale space (CSS), Fourier descriptor and wavelet descriptor [1]. Shape recognition is categorized into two main methods, boundary based technique and area based technique. In this paper we will only be considering the boundary based technique [1]. In area based technique, all the pixels that are within the region of image are considered to get the shape representation. The most generic area based technique uses the concept of moment descriptors to depict the shape. On the other hand the boundary based technique mainly lays focus on object boundary. The boundary based technique [2] depicts more details of the shape features of the object as compared to area based techniques [2]. It needs less computation and it is also fast in processing than area based technique. Therefore, the boundary based technique is widely used in real time and practical applications due to its fast processing and easy computation [2]. In this paper we will only take into consideration the boundary based technique.

Basic concepts of shape recognition

Chain codes

Chain codes are used to represent the boundary by connected sequence of straight line segment of nominal length and direction. 4 or 8 connectivity of pixels is used for chain codes as shown in the Fig 1.

But the chain code depends on the starting point location and also the rotational variance. We will be using 8 chain code in this paper since it requires a smaller length code [3]

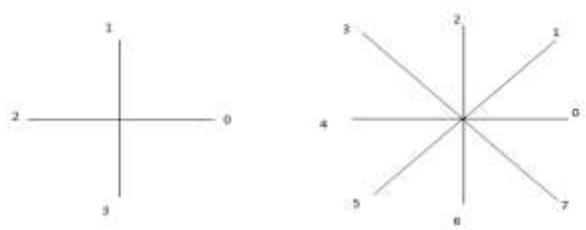

Fig. 1: 4 Connectivity and 8 Connectivity

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Differential chain codes

Differential chain codes are computed by taking the differences between two consecutive elements of the chain code. This makes it rotational invariant.

Shape number

Shape number of a boundary is defined as the first difference of the smallest magnitude [3].

Pre-processing technique

The main aim of the pre-processing is to remove the noise component from the image. This can be done using two techniques namely using wavelet transform or using Fourier descriptors.

Wavelet transform

The discrete wavelet transform is a mathematical tool used when the digital images are to be processed at multiple resolutions. The discrete wavelet transform gives information of the frequency characteristics and the spatial characteristics of the image [4].
The wavelet transform is applied to decompose the shape into primary and secondary shapes in order to remove the noise components in the boundaries [4].

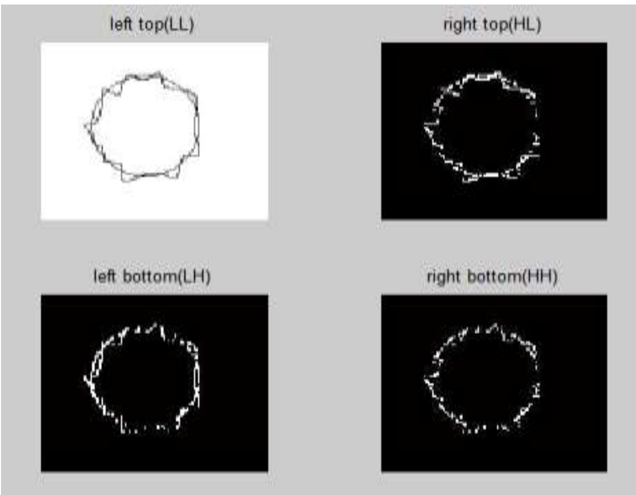

Fig. 2: Noisy circle image after wavelet decomposition

Fig. 2 decomposes the image into four distinct parts: LL(left-top), HL(right-top), LH(left-bottom) and HH(right-bottom). The HL band depicts the changes along the x-axis, the LH band depicts the changes along the y-axis and the HH band depicts the changes along both the x-axis and the y-axis. The HH band contains the high frequency components of the image. Thus, by subtracting the HH band from the LL band the global shape of the image can be obtained.

Fourier descriptors

Fourier descriptors are a type of boundary descriptors in which each point can be written as

$$s(k)=x(k)+jy(k) \quad ...(1)$$

where, x(k) and y(k) are the co-ordinates of the pixel.

The DFT of s(k) is as follows:-

$$\sum_{k=0}^{n-1} s(k).e\wedge(-j2\pi uk/K) \quad ...(2)$$

where, a(u) is the Fourier descriptor of the boundary [5]

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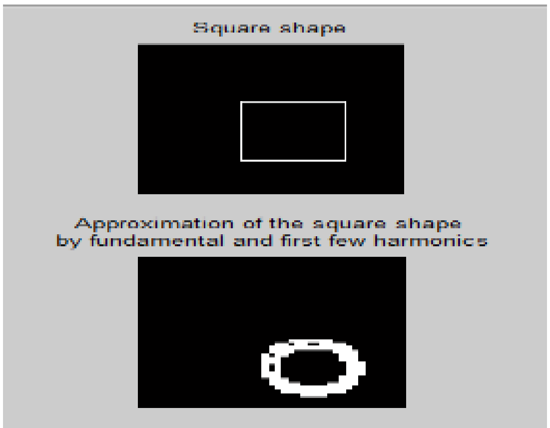

Fig. 3: Approximation of square using Fourier descriptors (using fundamental and first few harmonics)

Fig. 3 shows the approximation of a square using first few harmonics. Thus, the finer details are not present.

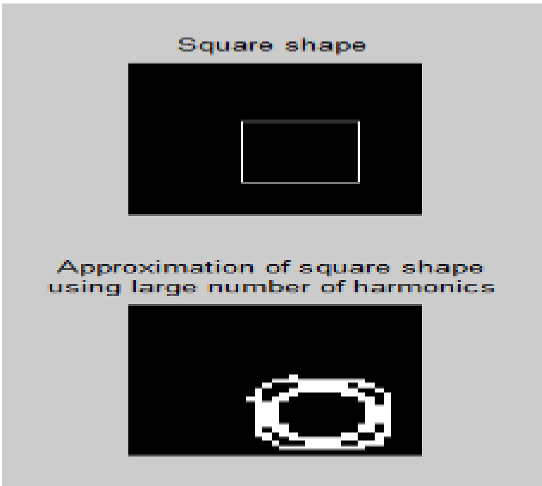

Fig. 4: Approximation of square using Fourier descriptors (using large number of harmonics)

Fig. 4 shows the approximation of a square using large number of harmonics. It shows slight further smoothing of the boundary but the finer details are not present. Thus, depending on the number of descriptors used to represent the figure the overall shape can be approximated.

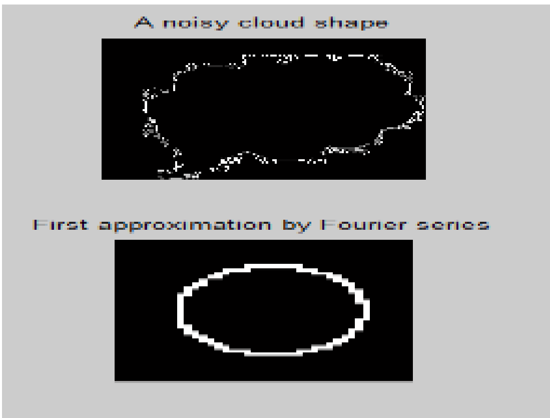

Fig. 5: First Approximation of noisy cloud shape using Fourier series

Fig. 5 shows the approximation of a noisy cloud shape using Fourier series. Thus, the overall shape of the cloud has been preserved by removing the harmonics from it i.e. the noise components.

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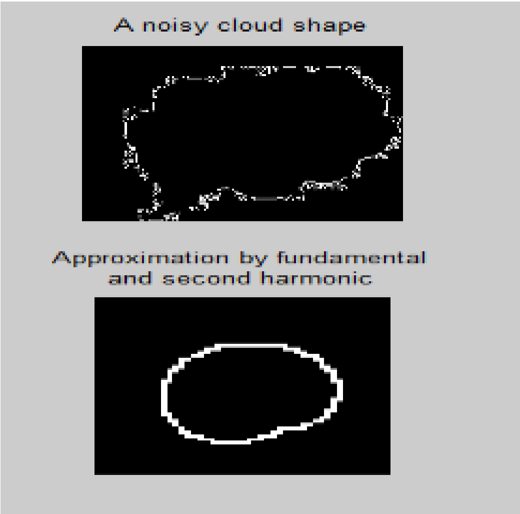

Fig. 6: Approximation by fundamental and second harmonic of noisy cloud shape

Fig.6 shows the approximation of a noisy cloud shape by fundamental and second harmonic. Thus, the overall shape of the cloud has been preserved by removing the noise components.

3-D directions and 3- D connectivity

Fig. 7 depicts the 32 directions in different planes in the 3-D shown so by traversing the surface boundary of the 3-D shape and the orientation of the next pixel with respect to the current pixel the corresponding chain code is obtained.

Depending on the number of connectivity required the value of θ is changed. For example, if a 64 connectivity is required the θ values vary with a step size of 22.5^{o} and if a 32 connectivity is required the θ values vary with a step size of 45^{o}.

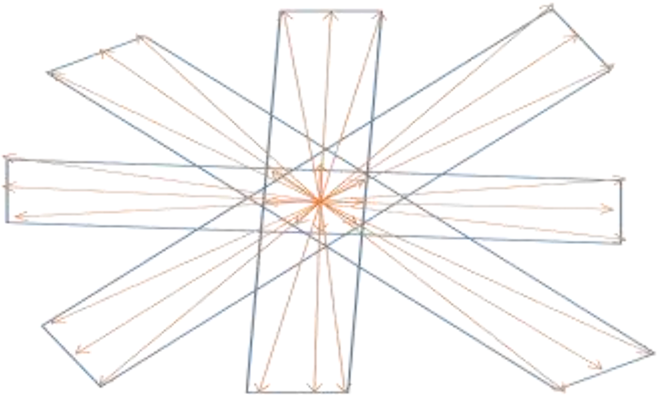

Fig. 7: 32 directions

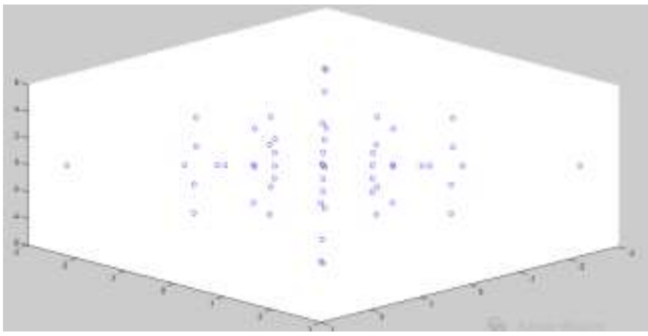

Fig. 8: 3-D Figure

The Fig. 8 shows the same for 64 directions in 8 different planes.

Results

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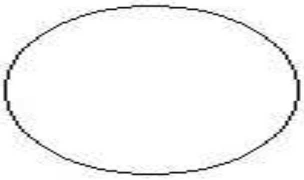

Fig. 9: 2-D Circle

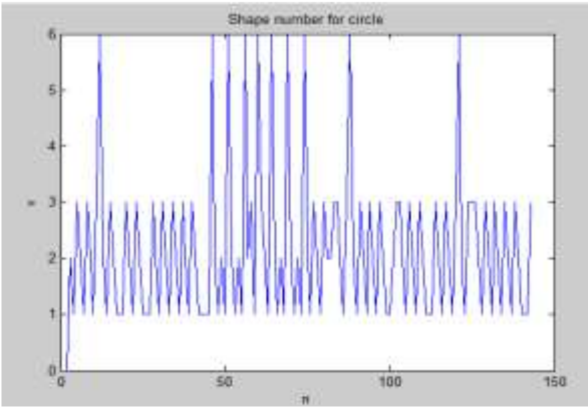

Fig. 10: Shape number of a Circle

Fig. 10 represents the shape number of a circle. This can be obtained by traversing on the boundary of the circle using the 8-connectivity concept.

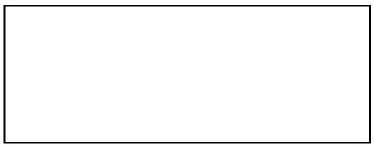

Fig. 11: 2-D Rectangle

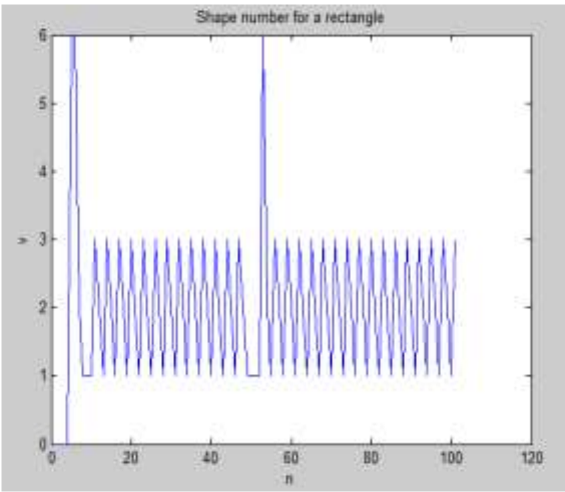

Fig. 12: Shape number of a Rectangle

Fig. 12 represents the shape number of a rectangle. This can be obtained by traversing on the boundary of the rectangle using the 8- connectivity concept.

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Fig. 13: 2-D Rectangle rotated by 90^0

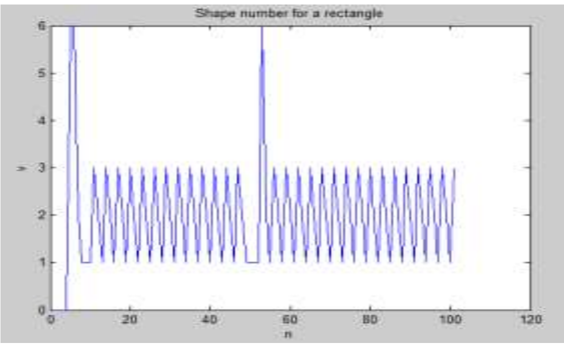

Fig. 14: Shape number of a Rectangle rotated by 90^0

Fig. 14 represents the shape number of a rectangle rotated by 90^0. Comparing, Fig. 12 and Fig. 14 we can observe that the shape number remains the same irrespective of the shape being rotated. Also, it is also independent of the starting point or translation.

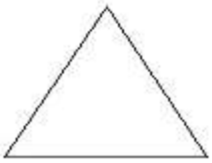

Fig. 15: 2-D Triangle

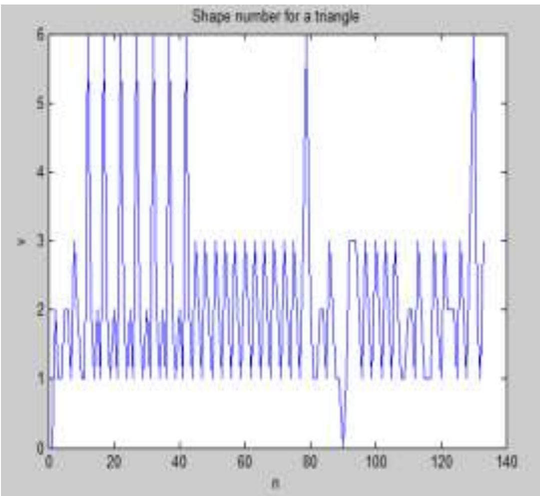

Fig. 16: Shape number of Triangle

Fig. 16 represents the shape number of a triangle. This can be obtained by traversing on the boundary of the triangle using the 8-connectivity concept.

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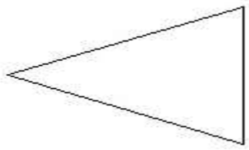

Fig. 17: 2-D Triangle rotated by 90^0

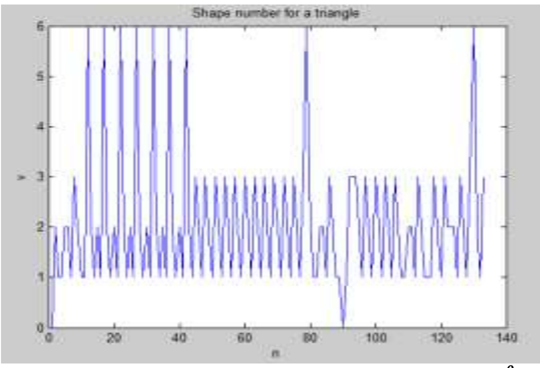

Fig. 18: Shape number of Triangle rotated by 90^0

Fig. 18 represents the shape number of a triangle. Comparing, Fig. 16 and Fig. 18 we can observe that the shape number remains the same irrespective of the shape being rotated. Also, it is also independent of the starting point or translation.

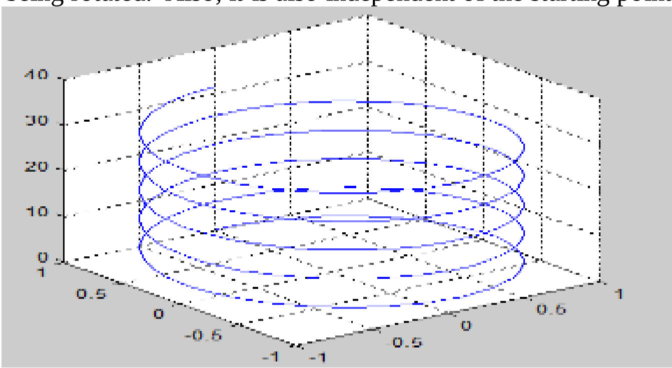

Fig. 19: 3-D helical shape

Fig. 19 shows a 3-D helical shape. The shape number for it can be calculated using the same technique that is used for a 2-D shape.

Conclusion

In this work a unique global shape number has been obtained for different 2- D shapes like circle, rectangle and triangle as shown in the figures above. Thus, it can be shown that every shape can be represented by a unique global shape number which is independent of the starting point as well as the boundary based rotation and translation. The decomposition of the images into its fundamental shape and its harmonics using both the Fourier descriptors and wavelet transform has also been investigated.

The challenges that are present in this work pertain to objects which have intersecting shapes or shapes contained inside shape. But with the concept of Fourier series it is possible to identify, the shapes of these kind of objects. These provide scope for further research and enhancement.

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