CIRCULAR OBJECT DETECTION USING GABOR FILTER

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by

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Certificate

This is to certify that this report entitled "Circular object detection using Gabor filter" is a bonafide record of the seminar presented by ***Mr. Robin CR, Roll No.RET17EC126*** *under our guidance towards the partial fulfilment of the requirements for the award of* ***Bachelor of Technology in Electronics & Communication Engineering*** *of the* ***APJ Abdul Kalam Technological University****.*

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Abstract

The detection of circular objects is of very importance in the area of digital image processing and recognition of some pattern of objects and also in the computer vision etc. Traditional technique for detection of circular objects is primarily focused on the use of well known Hough Transform for circular objects. This algorithm first of all find and draw the boundaries of the object and then uses the mathematical transformation for converting edge points into the parameter space with the help of center points and radius. In this research paper a novel technique based on deep learning network is proposed to detect circular objects present in the digital images. Circular and deformed circular objects of interest were efficiently extracted, and considerable resistance to noise and image degradation was achieved.

Contents

Chapter 1

Introduction

Texture analysis and texture detection are important methods for detecting objects in complex images and are among the most researched fields in image processing . Filtering an image with a Gabor filter is a simple procedure for extracting the spatially localized spectral properties of an image. Gabor filters are robust and are resistant to noise of various origins, and they provide good filtering results for images captured using lowquality, inexpensive devices.

The Gabor filter, named after Dennis Gabor, is a linear filter used in myriad of image processing application for edge detection, texture analysis, feature extraction, etc. The characteristics of certain cells in the visual cortex of some mammals can be approximated by these filters. These filters have been shown to possess optimal localization properties in both spatial and frequency domain and thus are well suited for texture segmentation problems. Gabor filters are special classes of band pass filters, i.e., they allow a certain 'band' of frequencies and reject the others.

Chapter 2

Gabor Filter

2.1 Working

It is a convolution filter representing a combination of gaussian and a sinusoidal term.Both signals are taken in 2-D plane.The gaussian component provides weights and the sine component provides the directionality.It is used to generate features that represent texture and edges.The 2D Gabor filters have certain optimal joint localization properties in the spatial domain and in the spatial frequency domain. They can describe the image texture features from different scales and orientations, therefore the changes of image statistical characteristics caused by steganography embedding can be captured more effectively. In the spatial domain, a 2D Gabor filter is a Gaussian kernel function modulated by a sinusoidal plane wave.

2.2 Equation

Gauss Function

In mathematics, a Gaussian function, often simply referred to as a Gaussian, is a function of the form for arbitrary real constants a, b and non zero c. It is named after the mathematician Carl Friedrich Gauss. The graph of a Gaussian is a characteristic symmetric " bell curve " shape. Gaussian functions are often used to represent the probability density function of a normally distributed random variable with expected value.

$$g(x, y, f, \phi, \sigma) = Ae^{-(\frac{(x-x_0)^2}{2\sigma_x^2}+\frac{(y-y_0)^2}{2\sigma_y^2})}e^{j(2\pi f(x\cos\phi+y\sin\phi)+\psi)} \tag{2.1}$$

f = spatial frequency

ϕ = Orientation of Gabor filter

σ = Standard deviation

ψ = Phase offset

A = Amplitude of the function

The first exponential function represents a 2D Gauss curve that is called an envelope and the second exponential function represents a complex sinusoid named a carrier with the initial phase ψ.

2.3 Graphical Representation

Response of Gabor filter

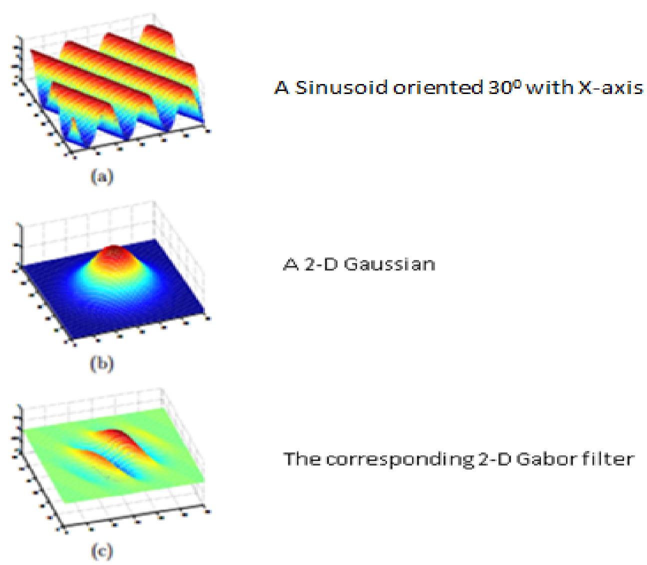

Figure 2.1: A 2-D Gabor filter obtained by modulating the sine wave with a Gaussian wave

Chapter 3

Circular Gabor Filter

3.1 Modified Equation

Gauss Function

$$G(x, y, F, \sigma) = Ae^{-(\frac{(x-x_0)^2}{2\sigma_x^2}+\frac{(y-y_0)^2}{2\sigma_y^2})}e^{j2\pi F(\sqrt{x^2+y^2})} \tag{3.1}$$

f = spatial frequency

ϕ = Orientation of Gabor filter

σ = Standard deviation

ψ = Phase offset

F = Central frequency

3.2 Derivation

Expanding equation (3.1) into real and imaginary

$$G = Re(G) + jImg(G) \tag{3.2}$$

Real part has cosine component

$$Re(G) = Ae^{-(\frac{(x-x_0)^2}{2\sigma_x^2}+\frac{(y-y_0)^2}{2\sigma_y^2})} \cos 2\pi F(\sqrt{x^2+y^2}) \tag{3.3}$$

Imaginary part has sine component

$$Img(G) = Ae^{-(\frac{(x-x_0)^2}{2\sigma_x^2}+\frac{(y-y_0)^2}{2\sigma_y^2})} \sin 2\pi F(\sqrt{x^2+y^2}) \tag{3.4}$$

Every image has sine, cosine and amplitude component.To analyse about its properties we need to plot the frequency and spatial response.

3.3 Graphical Representation

Response of Circular Gabor Filter

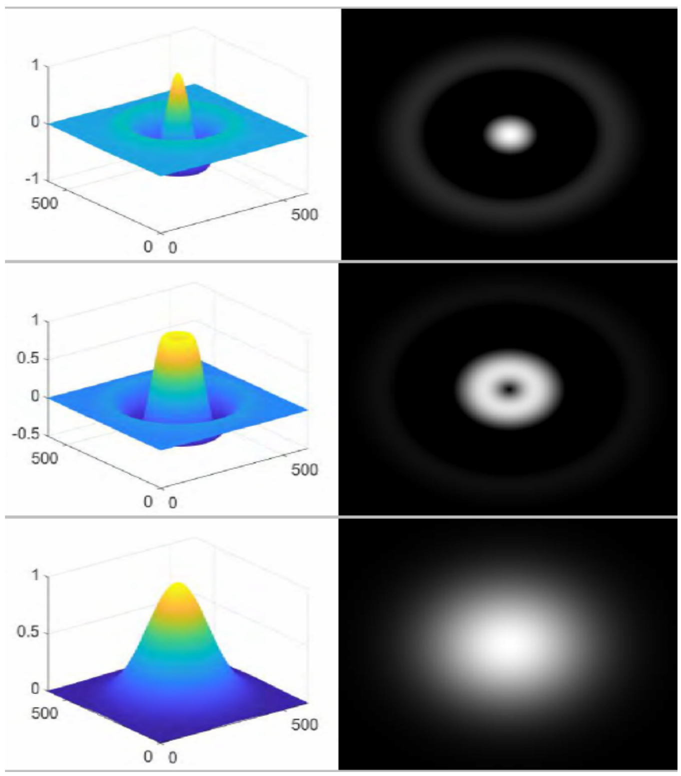

Figure 3.1: Spatial and frequency responses of (i)cosine (ii)sine (iii)amplitude

Comparing sine, cosine and amplitude response, cosine component has the strongest response that forms a full circle.

Chapter 4

Fuzzification of Circular Gabor Filter

4.1 Importance of Fuzzification

To obtain an appropriate response, it is most important to correctly select the parameters of the filter. The selection of Gabor parameters has been a long research focus in the field of Gabor based image processing. Sometimes the same parameter needs to be given a higher number of values that describe the nature of the problem equally well. One of the solutions to this issue is using filter banks, which allow for the use of a larger number of values for one or multiple parameters. The largest hurdle with this solution lies in the processing time and in the issue of insufficient memory during processing in certain extreme cases . Another major problem is that the selected values of the parameters are predefined. To remove this limitation, recent research has implemented fuzzy logic, i.e., fuzzy inference systems (FISs), because fuzzy techniques allow for greater flexibility and a gradual transition of the parameter values of interest. Essentially, this approach formalizes imprecise information. By using fuzzy logic, set membership can be described with a number in the interval [0,1].

4.2 Bell membership Function

A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is sometimes referred to as the universe of discourse, a fancy name for a simple concept.The bell membership function has one more parameter than the Gaussian membership function, so it can approach a non-fuzzy set if the free parameter is tuned. Because of their smoothness and concise notation, Gaussian and bell membership functions are popular methods for specifying fuzzy sets. Both of these curves have the advantage of being smooth and nonzero at all points. Bell membership function is formulated as ,

$$u(z) = \begin{cases} S(z, \sigma_x 1, \sigma_x 2) & z < \sigma_x 2 \\ S(2\sigma_x 2 - z, \sigma_x 1, \sigma_x 2) & \sigma_x 2 \leq z \end{cases} \tag{4.1}$$

4.3 Features of Fuzzified Gabor Filter

Fuzzy systems with standard deviations in the directions of x and y - axes is created. A different fuzzy system for wavelength is also defined. The resulting system was then used in filtering algorithm.This experiment has 55 features in total: 17 for σ_x, 17 for σ_y and 21 for wavelengths.It must be noted that the number of features can be changed easily, but a large number of features will result in increased processing time. With the help of the fuzzy systems, a series of circular Gabor filters and filter banks was created; this series was used to perform filtering in accordance with the properties of the created fuzzy system, whose collective response created the filtering result.

4.4 Process of Filtering

- The number of features can be changed easily, but large number of features will result in increased processing time.
- A series of circular Gabor filters and filter banks was created.
- This system provides the filtering result.
- It is to be noted that the series was used to perform filtering in accordance with the properties of the created fuzzy system.

4.5 Graphical Representation for a sample image

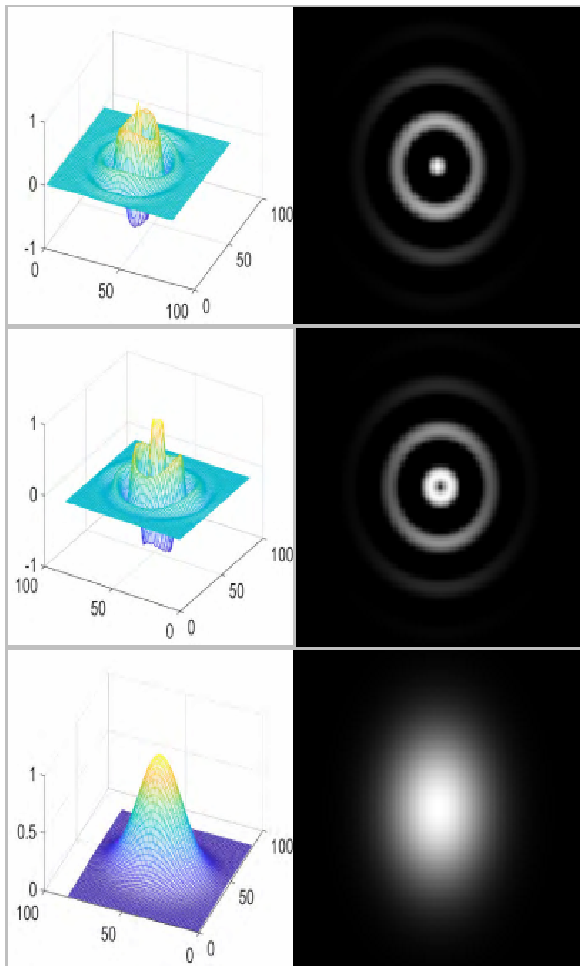

Figure 4.1: Fuzzified filter : Spatial and frequency responses of (i)cosine (ii)sine (iii)amplitude

Chapter 5

Experiment

5.1 Experimental Design

The basic procedure on executing fuzzified Circular Gabor filter is given below :

1. Prepare the training data set.
2. Data preprocessing.
3. Grayscale Conversion.
4. Fuzzificaton of Gabor Parameters wavelength.
5. Filtering with the cosine component of the fuzzified circular Gabor filter.

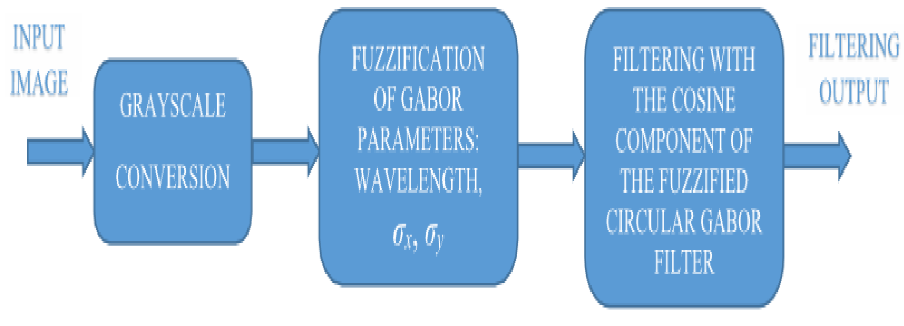

Figure 5.1: Block Diagram

5.2 Algorithm Evaluation Criteria

5.2.1 Assumptions

The images can be divided into four groups when identifying from a large data set :

1. Images that are relevant and identified by the system (TP)
2. Images that are irrelevant and identified by the system (FP)
3. Images that are relevant but not identified by the system(FN)
4. Images that are irrelevant but not identified by the system(TN)

5.2.2 Recall Rate

The number of related images identified is used as the numerator, with the total number of all related documents as the denominator.

$$RecallRate, R = \frac{TP}{TP + FN}$$

5.2.3 Accuracy Rate

The number of related images identified is used as the numerator, with the total number of all retrieved images as the denominator.

$$TruePositiveRate = \frac{TP}{TP + FP}$$

Chapter 6

Results

The efficiency of this new procedure was tested on test images specifically selected for this purpose. In this section, some of the results of using fuzzified circular Gabor filtersre presented to highlight the differences in the results of filtering compared to the case when a regular circular Gabor filter, and the filter proposed by Zhang et al. [3] are used for cropping image segment s of a regula rcircular shape.As mentioned earlier, only the cosine component of the fuzzified circular Gabor filter was used for filtering in all experiments since it produces a stronger response to the edges of objects that are of a circular or deformed circular shape.

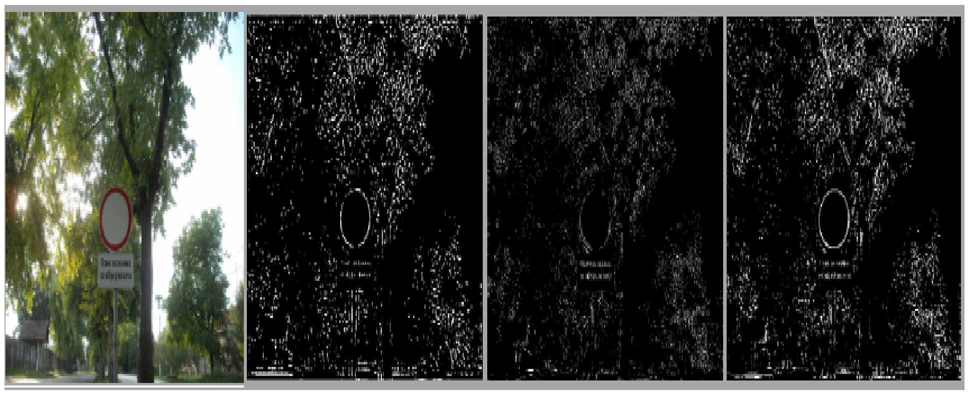

Figure 6.1: Comparison image

In Fig. 6.1, some examples of the images and the results of the experiments are shown. The first column (a) shows the original input images, the second column (b) highlights the results of filtering with the filter proposed by Zhang et al. [3], the third column (c) shows the results of filtering with a classic circular filter, and the fourth column (d) shows the results of filtering with a fuzzified circular Gabor filter.

FILTERS	ACCURACY (%)	RECALL RATE (%)
Filter proposed by Zhang[3]	75	72
Classic circular filter	65	68
Fuzzified Circular Gabor Filter	83	80

Figure 6.2: Comparison table (i)Accuracy(ii)Recall Rate

The comparison method involves multiple rounds of experimental comparisons and comparisons with different percentages of samples.

Chapter 7

Observations

The experimental results demonstrate that accuracy and recall rate are higher when using the Fuzzified Circular Gabor filter method than using the other methods. In the examples in Fig. 6.1, the efficiency of the fuzzified circular Gabor filter for detecting segments of images with circular or deformed circular shapes was obvious compared to that of the classic circular Gabor filter and the circular filter proposed by Zhang et al. [3]. The input images were of various origins, but the procedure presented in this paper proved to be efficient in all discussed examples.

Finally, Fig. 4.1 presents the fuzzification effects of different parameters on experiments with the first example from Fig.6.1. The first image shows the result of filtration only with fuzzified standard deviation σ_x along the x coordinate, the second x image shows the result of filtration only with fuzzified standard deviation σ_y along the y coordinate and the third image y shows the result of filtration only with fuzzified wavelengths. As it can be noticed, the filtering with fuzzified standard deviations yields good results, but the fuzzified wavelengths individually give a bad result. However, all three parameters together achieve an excellent filtering and detecting results as it can be seen in Fig 6.1 (d). A demerit which is found in this method is that at certain cases it enhances the noises.With additional processing, the results of filtering can be improved even further in terms of extraction of the target components, and it is also possible to eliminate unnecessary components from the image, which lies outside the scope of this paper.The aim of this paper was to show the efficiency of fuzzifying the parameters of a circular Gabor filter in relation to a classic circular Gabor filter.

Therefore, we can conclude that the fuzzified Circular Gabor filter can perform better circular object detection compared to other methods.

Chapter 8

Conclusions

Circular object detection is achieved through filtering by applying a new circular Gabor filter with fuzzified parameters, namely, wavelength and standard deviations in both coordinate directions. It has been experimentally proven that, by using the cosine component of the filter, more efficient extraction of the segments of interest can be achieved. It became evident on the test images that the fuzzified circular Gabor filter can more efficiently filter and detect the components of a circular or deformed circular shape in complex images of various origins.

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