A method for detection and extraction of circular shapes from noisy images using median filter and CHT

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Abstract: One of the challenging topics in image processing is extracting the shapes from noisy backgrounds. There are some methods for doing it from different kinds of noisy backgrounds. In this paper, we are going to introduce another method by using 4 steps to extract circular shapes from impulse noisy backgrounds. First step is applying median filter to disappear "salt and pepper" noise. This step causes edge smoothing. So, as the second step, a laplacian sharpening spatial filter should be applied. It highlights fine details and enhances the blurred edges. Using these two steps sequentially causes noise reduction in an impressive way. Third step is using Canny edge detection for segmenting the image. Its algorithm is talked during the paper. Finally, forth step is applying Circular Hough Transform (CHT) for detecting the circles in image. At the end of paper different use cases of this method is investigated.
[Masoud Nosrati, Ronak Karimi, Hamed Nosrati, Ali Nosrati. A method for detection and extraction of circular shapes from noisy images using median filter and CHT. Journal of American Science 2011;7(6):84-88]. (ISSN: 1545-1003). http://www.americanscience.org.

Keywords: Extracting circular shape; median filter; laplacian filter; Canny edge detection; Circular Hough Transform (CHT).

1. Introduction

Extracting shapes from noisy backgrounds was always been a challenging problem in image processing. Recent studies represented some solutions, but no one could give 100 percent guaranteed results.

In this paper, we are going to introduce another method which is a combination of different filters and techniques. Our purpose is to achieve a better result in detecting the circular shapes within an impulse noisy background. Due to this, 4 steps are listed to be applied to image. First step is using median filter for removing impulse points in the image. These points have an absolutely different color from their neighborhood pixels, and they can have bad effects in the result of edge detecting process. So, median filter will be applied to remove them. Other implicit effect of this filter is smoothing the edges. It can make the edge detection harder and the have bad effects on the result. So, another filter that should be applied as the second step, is laplacian sharpen spatial filter. This filter causes the details become more impressive and the edges become clearer. An implicit effect of this filter is noise increasing in image, but we don't worry about it, because the next step will neutralize this effect. Now, it is time to detect the edges. Due to it, some methods were introduced like Sobel and Canny edge detection. Here, we employ Canny edge detection as the third step, because it has a better performance in detecting the thin edges and when the edges are not very sharp and clear. As the edges were detected, it is time to extract the circular shapes. So, as the fourth step, we will employ Hough transform. In general it can be used for any type shapes. But this special form of this transform is called Circular Hough Transform (CHT).

We are going to investigate all of the mentioned steps in depth during the "Methodology" section. Then, special uses of this method will be talked in "Use cases", and finally "Conclusion" is placed at the end of the paper.

2. Methodology

In this section, we are going to explain the basic concepts of techniques which are used in this paper in details. Also, their application on the proposed image to extract the circular shapes will be investigated.

2.1 Median filter

One of the most efficient solutions for disappearing "salt and pepper" noises is applying median filter. Median filter belongs to the group of order static nonlinear filters. It could be easily used for erasing impulse noise. The process is that it replaces the value of a noise pixel with the median gray levels in the neighborhood of that pixel. It causes the impulse noise in the background be disappeared, but also an extra consequence is blurring the edges. This effect could be neutralizing impressively by applying the laplacian sharpening spatial filter [1].

2.2 Laplacian sharpening spatial filter

The purpose of using laplacian sharpening spatial filter is for highlighting fine details and enhance them which are blurred such as edges. As you know, laplacian is a linear and rotation invariant operator. Laplacian equation can be written for each dimension independently. Partial second-order derivatives in x and y directions could be calculated by (I) and (II).

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

$$\frac{\partial^2 f}{\partial x^2} = f(x+1, y) + f(x-1, y) - 2f(x, y) \qquad \text{(I)}$$

$$\frac{\partial^2 f}{\partial y^2} = f(x, y+1) + f(x, y-1) - 2f(x, y) \qquad \text{(II)}$$

$$\nabla^2 f = [f(x+1, y) + f(x-1, y) + f(x, y+1) + f(x, y-1)] - 4f(x, y)$$

$$g(x, y) = f(x, y) \pm \nabla^2 f(x, y)$$

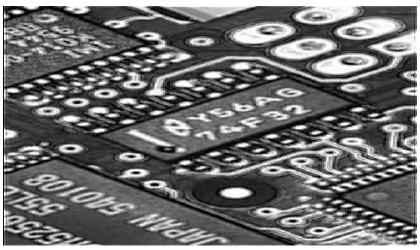
A 3x3 laplacian mask which could be obtained is as Figure 1.

-1	-1	-1
-1	9	-1
-1	-1	-1

Figure 1. One pass realization of 3x3 laplacian mask

Result of its application is indicated in Figure 2 [1].

(a)



(b)

Figure 2. (a) Original image, (b) Sharpen image

Laplacian filter by itself causes the increasing noise in the image. But using it in consequence of median filter avoids from occurring this problem. Since the major part of noise is reduced in median filtering process.

2.3 Canny edge detection

Edge detection is an important topic in the research area of image analysis [2]. The purpose of edge detection in general is to significantly reduce the amount of data in an image, while preserving the structural properties to be used for further image processing. Several algorithms exists, and this worksheet focuses on a particular one developed by John F. Canny (JFC) in 1986 [3]. Even though it is quite old, it has become one of the standard edge detection methods and it is still used in research [4] [5].

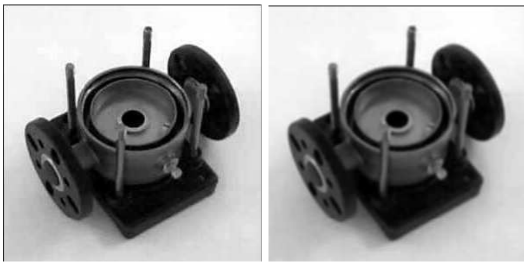
The aim of JFC was to develop an algorithm that is optimal with regards to the following criteria:

1. **Detection**: The probability of detecting real edge points should be maximized while the probability of falsely detecting non-edge points should be minimized. This corresponds to maximizing the signal-to-noise ratio.
2. **Localization**: The detected edges should be as close as possible to the real edges.
3. **Number of responses**: One real edge should not result in more than one detected edge (one can argue that this is implicitly included in the first requirement).

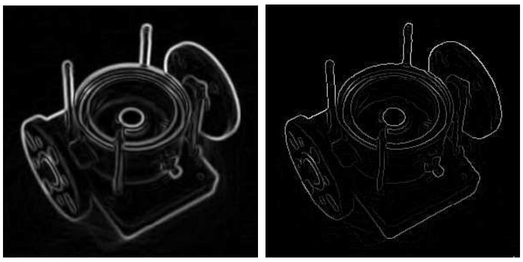
The algorithm runs in 5 separate steps:

1. **Smoothing**: Blurring of the image to remove noise.
2. **Finding gradients**: The edges should be marked where the gradients of the image has large magnitudes.
3. **Non-maximum suppression**: Only local maxima should be marked as edges.
4. **Double thresholding**: Potential edges are determined by thresholding.
5. **Edge tracking by hysteresis**: Final edges are determined by suppressing all edges that are not connected to a very certain (strong) edge.

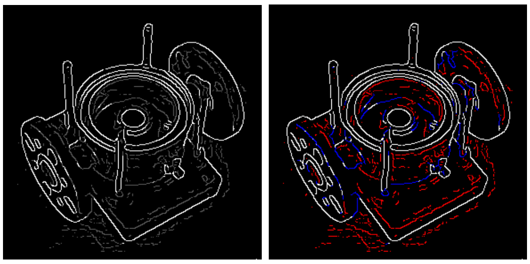
Figure 3 shows the result of applying this algorithm on an image [6].



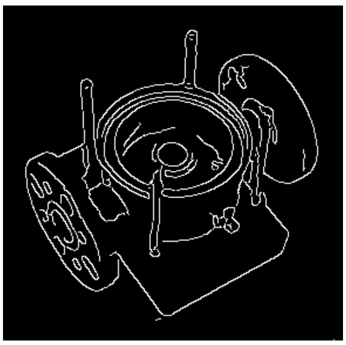
(a) Original (b) Smoothed



(c) Gradient magnitudes (d) non-maximum suppression



(e) Double thresholding (f) Edge tracking by hysteresis



(g) Final image

Figure 3. Applying Canny edge detection algorithm to example image

Even though Canny algorithm involves smoothing process, but it doesn't dispel the need for using median filter. Because smoothing step just blur the image and it causes the little noises to be smoothen. But median filter causes impulse noise to be disappeared.

2.4 Circular Hough Transform (CHT)

A commonly faced problem in computer vision is to determine the location, number or orientation of a particular object in an image. For example, recognizing of roads in an aerial image or detection of circles in the image are two samples of this problem. But it can be solved using Hough transform. Often the objects of interest have other shapes than lines, it could be parables, circles or ellipses or any other arbitrary shape. The general Hough transform can be used on any kind of shape, although the complexity of the transformation increase with the number of parameters needed to describe the shape [7].

The CHT has been recognized as robust techniques for curve detection. This method can detect object even polluted by noise. The CHT was sketched by Duda et al. [8]. The CHT is one of the modified versions of the HT. The CHT aims to find circular patterns within an image. The CHT is used to transform a set of feature points in the image space into a set of accumulated votes in a parameter space. Then, for each feature point, votes are accumulated in an accumulator array for all parameter combinations. The array elements that contain the highest number of votes indicate the presence of the shape. A circle pattern is described by (III).

$$(x_p - x_0)^2 + (y_p - y_0)^2 = r^2 \qquad \text{(III)}$$

Where x_0 and y_0 are the coordinates of the center and r is the radius of the circle. An example of conventional CHT is shown in Figure 4.

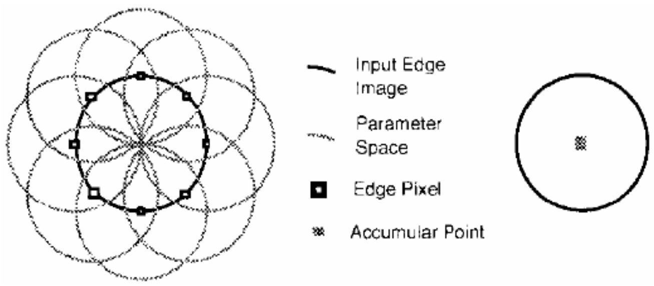


Figure 4. The contribution of the edge points to the accumulator space

The black circles indicate a set edge points within the image. Each edge point contributes a circle of radius R to an output accumulator space indicated by the grey circles. The output accumulator space has a peak where these contributed circles overlap at the center of the original circle. Modification to the CHT has been widely implemented to either increase the detection rate or reduce its computational complexity [9] [10].

The algorithm for Circular Hough Transform can be summarized to following steps [11]:

//HOUGH BEGIN

1. **For each edge point**
   Draw a circle with center in the edge point with radius r and increment all coordinates that the perimeter of the circle passes through in the accumulator.
2. **Find one or several maxima in the accumulator**

//HOUGH END

3. **Map the found parameters *(r,a,b)* corresponding to the maxima back to the original image.**

After applying the median and laplacian filter, Canny edge detection and CHT, circular shapes will be achieved efficiently.

3. Use cases

A question which may be asked is "What are the uses of this method?"

Following items can indicate just a small part of use cases of proposes technique:

- Building extraction: Most of building extraction methods can specify the buildings with polygonal rooftops and they have a weak performance in detecting circular buildings. For example look at the method which was introduced by Masoud S. Nosrati et al. [12].
- Digital filming: While taking film from sport matches like football and volleyball it can be possible to trace the ball by enhancing this technique. It means that a simple camera can take film automatically by using a developed form of this method.
- Biometric security: One way for identification of people is using their iris characteristics. For detecting the iris area this technique can be used. Eyelashes act like impulse noise and the filters which are used in this technique can make the detection process easier and more accurate.
- Astronomy: Proposed method can be used for detecting the planets surrounded by narrow clouds and recognizing the black holes in the special dim images.

Many other use cases can be found in chemistry, physics, biology, computer science and other fields of study. Also, with a little change in this method, other shapes in different noise styles can be extracted.

4. Conclusion:

In this paper, we introduced a method for extracting circular shapes from impulse noisy images. Due to this, 4 steps were nominated which were:

1. Applying median filter for erasing the impulse noise.
2. Applying laplacian sharpening spatial filter for neutralizing the blurring effect of median filter and sharpen the edges in the image.
3. Applying Canny edge detection.
4. Applying Circular Hough Transform for extracting the circular shapes in the image.

At the end of paper, different use cases of this method was investigated.

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5/7/2011