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Detecting Coins with Different Radii based on Hough Transform in Noisy and Deformed Image

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Abstract
Hough transform is a general technique for identifying the locations and orientations of certain types of features in a digital image and used to isolate features of a particular shape within an image. Because it requires that the desired features are specified in some parametric form, classical Hough transform is the most commonly used for the detection of regular curves such as lines, circles, ellipses, etc. A generalized Hough transform can be employed in applications where a simple analytic description of features is not possible. In this paper, Canny edge detector is used in conjunction with Hough transform to detect many coins with different radii. In this case, applying threshold make a significant and determinant factor in coins detection. Also, this paper shows that the Hough transform is an effective tool for coins detection even in the presence of noise such as salt and pepper, Gaussian and speckle noise. Also Hough transform succeeded in detecting blurring coins and deforming coins.

Keywords: *Hough transform, Edge detection, circle detection, image processing*

1. Introduction
The Hough transform was first introduced by Paul Hough [1] in 1962 to detect straight lines in bubble chamber data, the transform consists of parametric description of a feature at any given location in the original image's space. Duda and Hart [2] improved the Hough technique and extended it to detect other algebraic curves and they suggested that the detection of straight lines using Hough transform may most usefully parameterized by its normal form, i.e. an important advantage of the normal form over other parameterization methods is that the range of (ρ,θ) is bounded. Due to the above advantage, the (ρ,θ) form has become the most familiar parameterization method of line detection in using Hough transform, and the associated transform is termed the standard Hough transform. For the conventional (standard) implementation, the Hough transform essentially consists of two stages. The first is an increment stage based on the transform mapping and voting rule. The second stage is an exhaustive search for parameters in the accumulator array and the verification of the candidate shape associated with these parameters. Lam and Yuen [3] noted that the Hough transform is robust to noise, and can resist to a certain degree of occlusion and boundary effects. Akihiko Torii and Atsushi Imiya [4] proposed a randomized Hough transform based method for the detection of great circles on a sphere. Cheng Z. and Lin Y. [5] proposed a new efficient method to detect ellipses in binary or gray-scale images, called Restricted Randomized Hough transform. The key of this method is restricting the scope of selected points when detecting ellipses by prior image processing from which the information of curves can be obtained. Yip et al. [6] presented a technique aimed at improving the efficiency and reducing the memory size of the accumulator array of circle detection using Hough transform. The approach centers on the use of approximating a circular image(s) by a set(s) of line segment patterns. The Hough transform can be used to identify the parameters of a curve which best fit a set of given edge points. This edge description is commonly obtained from a feature detecting operator such as Canny edge detector [7] and may by noisy (i.e. it may contain multiple edge fragments corresponding to a single whole feature). Furthermore, as the output of an edge detector defines only where features are in an image, the work of the Hough transform is to determine both what the features are (i.e. to detect the feature(s) for which it has a parametric or other description) and how many of them exist in the image. Qi-Chuan Tian et. al. [8] used Hough transform in iris recognition system, where the inner boundary and the outer boundary of typical iris can approximately be taken as circles, so the two circles of iris can be obtained using Hough

transform. Also, Moukhtar E. et. al. [9] used circular Hough transform for detecting the iris and pupil boundaries. This involves first employing Canny edge detection to generate an edge map. Yu Tong et. al. [10] developed an efficient algorithm of Hough transform based fingerprint matching to overcome the difficulty in low quality fingerprint verification.
The rest of this paper is organized as follows: section (2) mention the advantage and disadvantage of Hough transform; section (3) classifies the Hough transform algorithms for straight line; section (4) discusses the Hough transform algorithm for detecting circle; section (5) the result of many coins detected after corrupted with different type of noise, and detected also blurred and deformed coins, and finally in section (6) the discussion and conclusion are given.

2. Advantage and disadvantage of Hough transform

Hough transform directly detects the object's edges using image global features; it can link every point to form a closed edge in image field. If the shape or edges of objects is known, using Hough transform edges can be detected and points can be linked together easily. The main advantage of the Hough transform technique is tolerant to the presence of gaps in feature boundary descriptions and is relatively unaffected by image noise. Also the Hough transform provides parameters to reduce the search time for finding lines based on a set of edge points, and that these parameters can be adjusted based on application requirements. The disadvantage of Hough transform is that the calculation quantity is very large. With image size increasing, the quantity of data will become too large and the processing quantity of data will be slow. However, there are two major drawbacks from the Hough transform; these drawbacks are the requirements for a large amount of storage and high cost in computation. To tackle these problems, many improvements have been suggested [6]. However, all the improvements are made with the cost of making certain assumptions or by sacrificing the degree of flexibility in the algorithm.

3. Classical representations of Hough straight line transform

The simplest form of the Hough transform is Hough line transform in Cartesian coordinate. Suppose we are attempting to describe lines that match edges in a two dimensional image. To use the Hough transform, we need a way to characterize a line. One representation of a line is the slope-intercept form, **y= m.x + c** where **m** is the slope of the line and **c** is the y-intercept. Given this characterization of a line, we can then iterate through any number of lines that pass any given point (x,y). By iterating through fixed values of **m**, we can solve for **c** by **c= y – m.x** However, this method is not very stable. As lines get more and more vertical, the magnitudes of **m** and **c** grow towards infinity.
The extended Hough transform can be applied to any geometric shape that can be described by an equation of the following form

$$F(x, y, \vec{p}) = 0 \qquad (1)$$

where the x and y are the raw and column based on the image's space.
In the case of the line finding Hough transform, the function is

$$\rho = x.\cos(\theta) + y.\sin(\theta) \qquad (2)$$

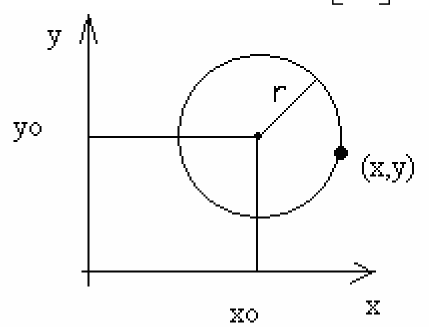
and the parameter $\vec{p} = \begin{bmatrix} \rho \\ \theta \end{bmatrix}$ (3)

4. Hough circle transform

The same procedure for line detection using Hough transform would follow to find the circle, but with an increased dimensionality to the search space, it is now a three dimensional parameter space (x_o, y_o, r) where x_o and y_o are the center coordinates of the circle and r is the radius of the circle as the following equation

$$(x- x_o)^2 + (y- y_o)^2 = r^2 \qquad (4)$$

The parameter vector is $\vec{p} = \begin{bmatrix} x_o \\ y_o \\ r \end{bmatrix}$ (5)



The pseudocode for Hough transform algorithm detecting circle as follows:

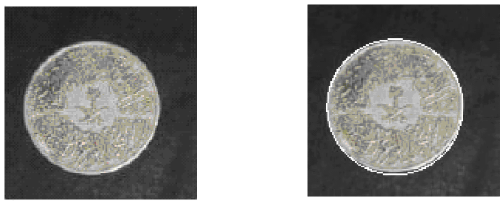
For each edge point (x_o,y_o)
For (x_o = x_o_min ; x_o<= x_o_max ; x_o++)
For (y_o = y_o_min ; y_o<= y_o_max ; y_o++)
r=sqrt((x-x_o)^2 + (y-y_o)^2) ;
Accumulator[r][x_o][y_o]++ ; // Voting
Find local maxima in accumulator [r][x_o][y_o] that higher than threshold.

This approach involves three basic parts. The first part is the edge detection. The purpose of the edge detection is to decrease the number of the points in the search space for the objects. Once the edge points are found by the edge detector, we apply Hough transform algorithm only on these points. For edge detection, we used the Canny edge detector which aims to maximize the signal to noise ratio and localization and minimize the false positives in edge detection [11]. The principal technique of Hough transform is voting and the accumulation of the voting to cells. The cells are generated by decomposing the dual parameter space based on the resolution of the original image. The discrete space constructed by the collection of cells is generally referred to as an accumulator, a voting or a Hough space. The detection of parameters of lines and conics is performed by detecting the peaks in the Hough space. Therefore the accumulation of voting is a fundamental tool for the simultaneous detection of many lines using the Hough transform.

5. Results

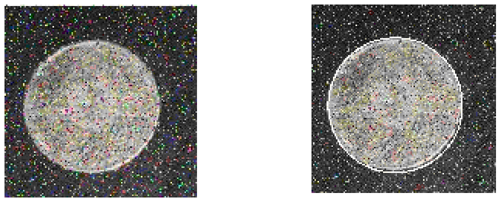
This paper is looking into feasibility of using the Hough transform to identify coins in an image. When coins are placed on a plain surface, the edges of the coins are easy to be picked up and the Hough transform has a much higher chance of success. On varied backgrounds, the patterns within the background can cause the Hough transform to be tricked into selecting incorrect edges. To illustrate the Hough robustness to noise, Canny edge description has been corrupted by 5% salt and 5% pepper noise as shown in figure (5-a). Also the original image is corrupted with Gaussian and speckle noise as shown in figure (7-a) and (8-a). Canny edge detector used with threshold 0.45 to remove most of the noise due to the texture and leave the edges of the coins. The Hough transform has been applied on these images after Canny edge detection, and then marked the circles of coins. The computational complexity highly depends on the number of edge pixel and the number of radii to be matched.

Figure (1-b) and figure (2-b) show that Hough transform succeeded in detecting one coin without noise and with salt and pepper noise respectively. Figure (3-c) shows that Hough transform detect one circle in the left coin and two overlapping circles in the right coin as a result of the brightness of the edge of the right coin, that is because Canny edge detector can detect one complete circle and half circle in the right coin as shown in figure(3-b). Different types of noise corrupted the image has 8 coins with different radii and Hough transform succeeded in detecting of 8 coins in case of Gaussian and speckle noise as shown in figure (7-b) and figure (8-b) respectively. In case of 8 coins image corrupted by 5% salt and 5% pepper noise, Hough transform succeeded in detecting 7 coins, the 8th coin has many overlapping circles as shown in figure (5-c). That is because the threshold value of Canny edge detector selected as 0.45, therefore this threshold value has not been enough to remove all noise in the image. When the threshold value is highly selected as 0.7, Canny edge detector eliminated the edges of 2 coins and the image has edges only for 6 coins as shown in figure (6-a) and Hough transform in this case detects only 6 coins as shown in figure(6-b). In case of blurring image using Gaussian with 2-dimentional Point Spread Function (PSF) mask, Hough transform succeeded in detecting 8 coins in the image as shown in figure (9). Last experiment done with deforming 8 coins in the image, the Hough transform succeeded in detecting 7 coins and the 8th coin has two overlapping circles as a result of the deforming of this coin as shown in figure (10).



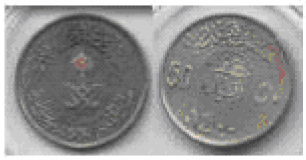
(a) Original image (b) Detected (Marked) image

Figure (1) Detecting one coin without noise

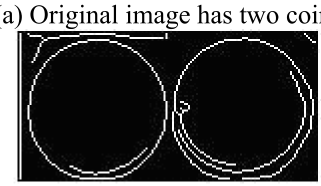


(a) Corrupted image with noise (b) Detected image

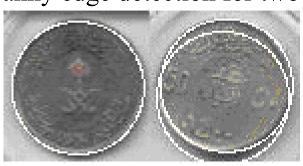
Figure (2) Detecting one coin after applying Salt and pepper noise



(a) Original image has two coins



(b) Canny edge detection for two coins



(c) Detecting two coins

Figure (3) Detecting two coins, the second coin has extra edge due to brightness

(a) Original image has 8 coins (b) Detected 8 coins

Figure (4) Detecting 8 coins with different radii

(a) Image corrupted with Salt and pepper noise image (b) Canny edge detector (threshold=0.45) (c) Detected 8 coins

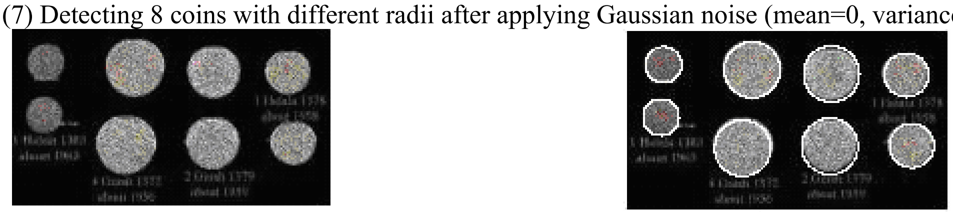
Figure (5) Detecting 8 coins with different radii after applying Salt and pepper noise using Canny edge detector with threshold = 0.45

(a) Canny edge detector (threshold=0.7) (b) Detected 8 coins

Figure (6) Detecting 8 coins with different radii after applying Salt and pepper noise using Canny edge detector with threshold = 0.7

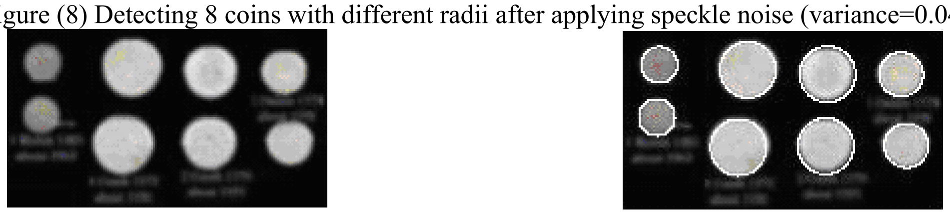
(a) Image corrupted with Gaussian noise (b) Detected 8 coins

Figure (7) Detecting 8 coins with different radii after applying Gaussian noise (mean=0, variance=0.01)



(a) Image corrupted with speckle noise (b) Detected 8 coins

Figure (8) Detecting 8 coins with different radii after applying speckle noise (variance=0.04)



(a) Image with blurred effect (b) Detected 8 coins

Figure (9) Detecting 8 coins with different radii after applying blurring effect

(a) Deformed image (b) Detected 8 coins

Figure (10) Detecting 8 coins with different radii after deforming image

6. Discussion and conclusion

The objective of this study is to use Hough transform to detect many coins with different radii in noisy environment. Canny edge detector was applied before Hough transform operation. Applying threshold makes a significant and determinant factor in coin detection because Hough transform is dependent on the edge pixels. For noisy image the edge detection is very critical and the threshold value should be chosen carefully. Very high threshold value might result in the elimination of correct edges (i.e. the less number of edges that can be detected), and a low threshold value might result in long execution time. In this paper, Canny edge detector used with threshold 0.45 to get the best result. Also, it can be concluded that the Hough transform is an effective tool for coins detection even in the presence of different types of noise such as salt and pepper, Gaussian and speckle noise. Hough transform can also detect blurring coins and deforming coins.

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