

# A Review Paper on Hough Transform and it's Applications in Image Processing

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**ABSTRACT:** The Hough transform is a feature extraction method that can be used in image analysis and digital image processing. The aim of this technique is to produce a computer vision system that can detect arbitrary shapes within a sample image. The main purpose of this method is finding imperfect instances of objects within a certain class of shapes by a voting procedure. The classical Hough transform was mainly introduced for the identification of lines in images, but later the Hough transform has been modified and extended to identify the positions of arbitrary shapes within an image, most commonly the extended version indulged itself in finding circles or ellipses. In that case appropriate parametric representation is needed. Nowadays there are a wide range of areas where the Hough Transform can be implemented successfully such as in medical visualization or in order to achieve high accuracy in face recognition etc. The characteristics of Pupil and Iris under Uncontrolled illumination can also be obtained by Hough Circle Transform. In Objective Spinal Motion Imaging Assessment system (OSMIA), it is required to locate marker that can be used in determining the positions of the vertebral bodies. The measurement of vertebral motion has been a challenge to the field of biomechanics for many years but now several automatic approaches to these problems have been developed. The Hough Transform has also been introduced in morphological image processing to detect and estimate the number of red blood cells in the blood sample image.

**KEYWORDS:** Hough Transform, Line detection, Medical visualization, Pupil detection, Vertebrae detection, Red blood cell estimation.

## I. INTRODUCTION

The Hough transform is a kind of technique used in image processing for extracting the features of an image. It finds the imperfect instances of an object within a group of shapes by a voting procedure. This procedure is done in a parameter space, where object candidates are obtained as local maxima in an accumulator space that is explicitly constructed by the algorithm for computing the Hough transform.

The Hough transform was invented by Richard Duda and Peter Hart in the year 1972, and they named it a "generalized Hough transform"[1] after the related 1962 patent of Paul Hough [2]. The transform got popularity in 1981 by Dana H. Ballard through a journal article titled "Generalizing the Hough transform to detect arbitrary shapes".

The most common case of using the Hough transform is the linear transform for detecting straight lines in an image. In the image space, the straight line can be described as  $y = mx + c$  where the parameter  $m$  represents slope of the line, and  $c$  represents the y-intercept. This form of representation is called the slope-intercept model of a straight line. The main idea behind using Hough Transform is considering the features of the straight line not as discrete image points  $(x_1, y_1)$ ,  $(x_2, y_2)$ , etc., but in terms of slope-intercept model. In general, the straight line  $y = mx + c$  can be denoted as a point  $(b, c)$  in the parameter space where  $b$  represents the slope of the line and  $c$  represents the intercept. However, problems arises in case of vertical lines as they are represented as  $x = a$  and would give rise to unbounded values of the slope parameter  $m$ . Thus for this computational phenomenon, Duda and Hart proposed using of a different pair of parameters, denoted by  $r$  and  $\theta$  (*theta*), for the lines in the Hough transform. These two values taken together as a whole define a point in the polar coordinate.

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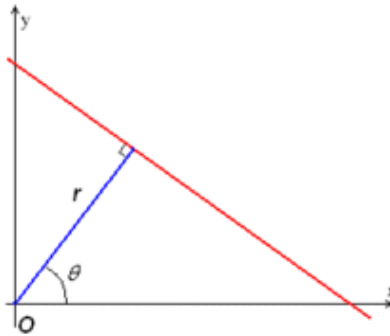


Figure 1: Slope-intercept model of straight line

The parameter  $r$  represents the algebraic distance between the line and the origin, while  $\theta$  is the angle of the vector. If the line is located above the origin,  $\theta$  is simply the angle of the vector from the origin to this closest point. Using this form, the equation of the line can be written as

$$y = \left( -\frac{\cos \theta}{\sin \theta} \right) x + \left( \frac{r}{\sin \theta} \right)$$

Which can be rearranged to  $r = x \cos \theta + y \sin \theta$ . It is therefore possible to associate with each line of the image a pair  $(r, \theta)$  which is unique if  $\theta \in [0, \pi)$  and  $r \in \mathbb{R}$ , or if  $\theta \in [0, 2\pi)$  and  $r \geq 0$ . The  $(r, \theta)$  plane is sometimes referred to as Hough space for the set of straight lines in two dimensions. This representation makes this transform very similar to the Radon transform. For an arbitrary point on the image space, e.g.  $(x_0, y_0)$ , the lines that go through this point are the pairs  $(r, \theta)$  with  $r(\theta) = x_0 \cos \theta + y_0 \sin \theta$ . Where  $r$  (the distance between the line and the origin) is determined by  $\theta \in [0, \pi)$ . If  $r$  is required to be positive, then  $\theta$  must vary in  $[0, 2\pi)$ . In other words,  $\theta$  is the angle of the vector from the origin and this closest point (if  $r \neq 0$ ), or the angle of the vector orthogonal to the line and pointing to the half upper plane (if  $r=0$ ). The lines that goes through  $(x_0, y_0)$  are the  $r(\theta) = |x_0 \cos \theta + y_0 \sin \theta|$ . These representations leads to a sinusoidal curve in the  $(r, \theta)$  plane [3], which is unique to that point. If the curves corresponding to the points are superimposed, then the location in the Hough space where they crosses each other corresponds to a line in the original image space that passes through both points. To be more general, a set of points that form a straight line will produce sinusoid curves that cross at the parameters for that line. Thus, the problem to detect collinear points can be converted to the problem of finding concurrent curves.

## II. DIFFERENT HOUGH TRANSFORMS

### A. LINE HOUGH TRANSFORM:

A suitable equation for describing a set of lines in a parametric form is:

$$x \cos \theta + y \sin \theta = r$$

Where  $r$  is the length of the normal from the origin to this line and  $\theta$  is the orientation of  $r$  with respect to the X-axis. A suitable way of describing this presentation is described in the figure 2 which shows an object taken as an example and the figure 3 shows the parametric representation of a line.

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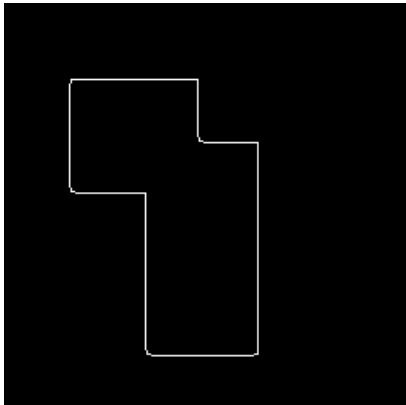


Figure 2: gradients of the example object

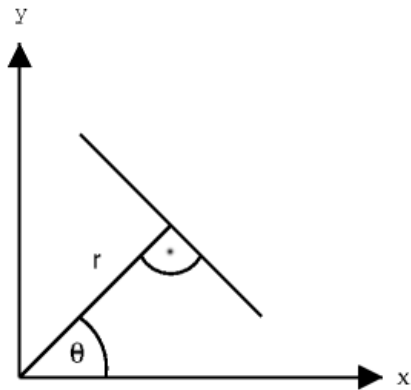


Figure 3: parametric representation of a line

When an image is analyzed the  $(x, y)$  parameters represents the well known pixels that are selected for analyzing. The pair of  $\theta$  and  $r$  used for parametric representation is inserted into an accumulator.

Another approach to think about this fact is that all the lines that go through the point  $(x, y)$  are transformed into parametric space  $(\theta, r)$  and then the relevant cell is increased by 1. Each and every single point present in the accumulator corresponds to certain line in the image. As this accumulator is discrete in nature it only consists of a set of all possible lines in  $R^2$ . It also corresponds to a set of sinusoid curves which intersects in some points. The white portions in the figure 4 show the intersection area.



Figure 4: Hough transformed image

A very useful thing of this algorithm is the robustness of this approach against noise and gaps present in the input image. This technique can be useful in real life applications such as in analyzing ultrasound images which contains some obvious noise that may causes problems in analyzing the features.

### B. CIRCLE HOUGH TRANSFORM:

To use the Hough Transform for detecting circles a suitable parametric representation is required. A circle can be represented as:

$$(x-ax)^2 + (y-ay)^2 = R^2$$

Where  $(ax, ay)$  denotes the center of the circle and  $R$  is the radius of the circle. A 3D accumulator array is also

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required for these three parameters used in representing the parametric equation. On the other hand if the radius of the circle is known in advance then the accumulator becomes two dimensional.

There is a very close similarity between the circle Hough Transform [4] and line Hough Transform but the difference come into existence where every set pixel proposes every circle that satisfies  $(ax, ay, R)$ . If there are many such pixels Proposes a certain circle or lie on the same circle a peak arises and it can be detected in the accumulator using thresholding.

This circle detection method can also be modified to identify other irregular shaped objects (e.g. ellipse) that can be represented in a parametric form. In that case the algorithm turns into a problematic one as the complexity of finding the object get increased. The accumulator  $r$  in the same way must be modified because it requires different set of parameters.

### C. GENERALIZED HOUGH TRANSFORM:

The use of GHT [5] becomes handy when the object cannot be expressed in a parametric form. A look-up table is used to define the relationship between the Hough parameters, boundary positions and orientations (see figure 5)

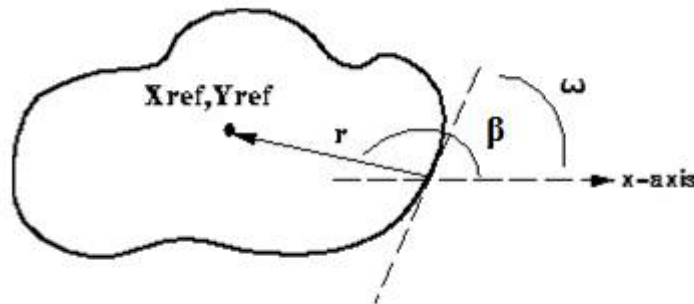


Figure 5: R-Table components

A point  $(x_{ref}, y_{ref})$  is taken as a reference in the shape. The look-up table sometimes also referred to as R-table. It collects the distance between the reference point and the edge points and the angle  $\beta$  of that distance. The angle is denoted as the gradient angle  $\omega$ . Now according to the look up table contents different reference point location collectively defines the hough space. For different possible position of the shape in the image the Hough Transform space is defined. This transformation can be represented as:

$$\begin{aligned} x_{ref} &= x - r\cos(\beta) \\ y_{ref} &= y - r\sin(\beta) \end{aligned}$$

For a particular angle  $\omega$ , the values of  $r$  and  $\beta$  are taken from the look-up table. The angle  $\omega$  is obtained by calculating the gradient vector around each point  $(x, y)$ . The angle is generally used as an index into the R-table.

### III. THE HOUGH TRANSFORM IN MEDICAL VISUALIZATION

Detection of some of the possible objects using Hough Transform has been discussed in the last sections. Now in the next section the real world applications of the aforesaid techniques by mainly focusing on the medical visualization will be discussed.

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In medical visualization there is a vast scope where the Hough Transform can be proved useful in extracting features from medical images. Some of these will be mentioned in the following sections of this paper.

### IV. VALID REGION RECOGNITION IN X-RAY IMAGES

A problem that is often encountered in medical imaging system sometimes referred to as PACS (Picture Archive and Communication System) [6]. It is mainly used for image transmission. An important part of the PACS system is the processing of X-ray images.

Figure 6 shows the image taken as an input to the algorithm. The valid region is first separated from the invalid region by using seed-growing algorithm. The result image is shown in figure 7.

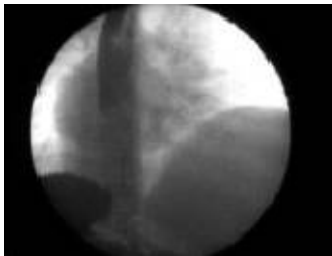


Figure 6: Medical X-ray image

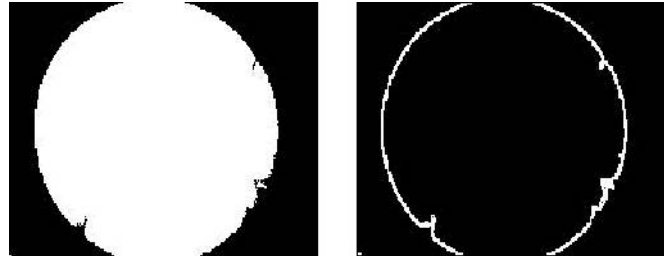


Figure 7: Image after seed and sobel operators

The sobel operator is used to determine the edges of the bi-level result image. This image is then taken as the input image to the Circular Hough Transform (CHT) but limited range of radius is estimated before applying Hough Transform. To minimize the computational expenses the set pixels in the seeded image are counted first and then used in estimating the radius range. For further information on this algorithm and some experimental results that have been made, refer to [7].

### V. DETECTING PUPIL AND IRIS UNDER UNCONTROLLED ILLUMINATION

There have been many studies about detecting the pupil and iris but most of these works done under the controlled illumination conditions. By using fixed radius CHT the characteristics of iris and pupil can also be obtained under uncontrolled illumination.

A lot of researchers are currently working on iris and pupil detection [8]. Each of this work has different methods for feature extraction. The algorithm for finding the pupil and iris is based on few steps. In the first step the frontal face image is distinguished on the basis of the colour of the skin. The RGB image is converted into YCbCr for colour segmentation. This segmentation is done on the basis of the threshold value which is obtained by the histogram components Cb and Cr. The components area are then combined to strengthen the luminance effect and these image information is further stored into the original image. In the second step the eye region is detected by assuming that the eyes are located at 1/3 of the whole facial image in the box [9] which is used for storing the entire image pixel. In the next step the focus is on the detection of pupil. The RGB image is converted into LAB image as it is more capable of displaying the brightness properly. The noise in the LAB image is reduced on the same time for easy processing through Circle Hough Transform by using canny edge detection operator. CHT is used to trace this image and this technique is used to create the looping making circle at each point which leads in finding the end point, which will be considered as the center of the new circle (see figure 8). This circle is then considered as the candidate pupil. A line is then created on the basis of center that has been found. The straight line is drawn from the center of pupil to the pupil radius and then rotated by  $360^\circ$  to get a circle described in figure 9. As the center of the desired is found, the next step is to locate the iris. In general the radius range of the iris is assumed to be in the range between 80 - 130 pixels while

the best value for pupil radius considered as 20 pixels. The ratio of the pupil and iris is assumed to be 1:4 as shown in figure 10. Refer to 10 for more information.



Figure 8: Candidate of Pupil Center



Figure 9: Pupil Circle



Figure 10: Iris Circle

#### VI. LUMBAR VERTEBRAE SEGMENTATION

The modified HT can be used to mark the portions in determining the positions of the vertebral bodies. Several approaches have been developed in this area. The combination of the genetic algorithm and HT was introduced by Michael Wohlfart in his paper journal titled “Hough transforms applications in Computer Graphics (With focus on medical visualization)”. An image from videofluorescence device has been taken as input in this approach (see figure 11). Phase congruency [11] is used to gain the edge information. It is a quantity that is invariant in changing the image brightness or contrast. It provides a useful measure that allows using a universal threshold value that can be applied over a vast range of images. Figure 12 shows the different results of the canny and phase congruency applied to the



Figure 11: image of lumbar spine

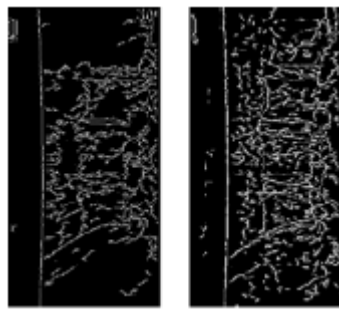


Figure 12: Canny and Phase Congruency



Figure 13: Results of vertebrae detection

Same source image. A generalized version of HT is used in this approach which represents the vertebrae through Fourier descriptors [12]. Each edge point vote in this array and the parameters are determined by locating the maximum in the array. Figure 13 shows the result of feature detection.

#### VII. RED BLOOD CELL ESTIMATION

In diagnosing the blood diseases the number of red blood cells plays an important role. There are four basic steps in counting the red blood cells. These are acquisition, segmentation, feature extraction and estimation. The morphological technique is used for the segmentation and feature extraction part while the estimation is done by using Hough Transform [13]. The counting process of red blood cells is shown by flow chart in figure 14.



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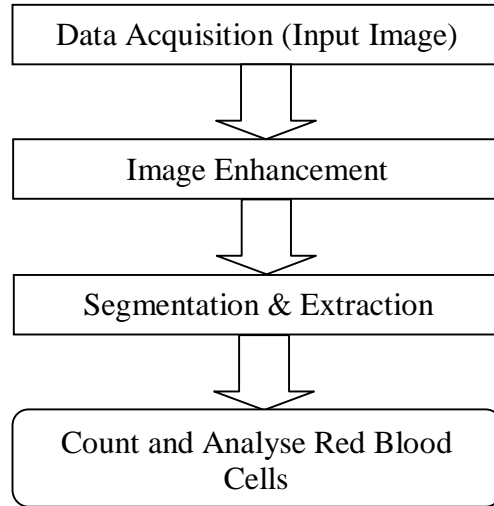


Figure 14: Flow chart of the red blood cells counting process.

The sample image, collected from the online medical library is taken as input as shown in figure 15. This image is then enhanced as a pre-processing step before applying segmentation process. The segmentation and extraction is done by applying the thresholding process. Any point  $(x, y)$  for which  $f(x, y) > T$  is called an object point; otherwise the point is called background point. The operation can be expressed as;

$$g(x, y) = \begin{cases} 1 & \text{if } f(x, y) > T \\ 0 & \text{if } f(x, y) \leq T \end{cases}$$

XOR operation and area opening with disk structural element applied after morphological on lower and higher pixel image and the result is shown in figure 16. In order to counting the red blood cells using Hough transform [14]; the radius is obtained by using the MATLAB function, "IMDISTLINE". The result is shown in Figure 17.



Figure15: Image of blood cells



Figure16: Result of XOR operation

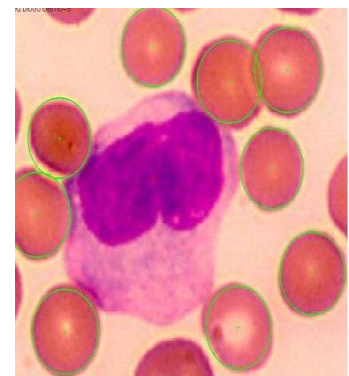


Figure 17: Red blood cells estimation

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## VIII. CONCLUSION

Based on the information the reader should have an idea of the function and the possible applications of the Hough Transform. The advantage of the SHT is that all the pixels that belong to a certain object in the source image maps to a single point in parameter space. Several extensions to this approach are also explained. For detecting arbitrary shapes in gray level images GHT has been used. For parameterization it uses the look-up table or R-table. It has been shown that this technique has a vast potential in detecting features of nearly any type of shape in image processing which makes it a good approach to be used in medical visualization.

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