4.6 Progressive Probabilistic Hough Transform

The simplest case of Hough transform is the linear transform for detecting straight lines. In the image space, the straight line can be described as $y = mx + b$ and can be graphically plotted for each pair of image points (x, y). In the Hough transform, a main idea is to consider the characteristics of the straight line not as image points (x_1, y_1), (x_2, y_2), etc., but instead, in terms of its parameters, i.e., the slope parameter m and the intercept parameter b. Based on that fact, the straight line $y = mx + b$ can be represented as a point (b, m) in the parameter space. However, one faces the problem that vertical lines give rise to unbounded values of the parameters m and b. For computational reasons, it is therefore better to use a different pair of parameters, denoted as ρ (rho) and θ (*theta*), for the lines in the Hough transform. These are the Polar Coordinates.

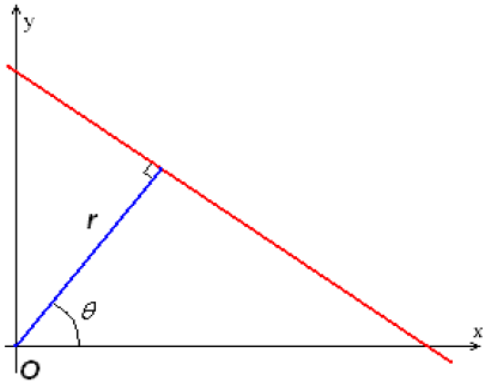

Figure 9: Polar form for line representation.

The parameter ρ (rho) represents the distance between the line and the origin, while θ (*theta*) is the angle of the vector from the origin to this closest point (see fig.9).Using this parameterization, the equation of the line can be written as,

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

It is possible to associate with each line of the image a pair (ρ,θ) which is unique and referred to as Hough space for the set of straight lines in two dimensions. For an arbitrary point on the image plane with coordinates, e.g., (x_0, y_0), the lines that go through it are

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

where (the distance between the line and the origin) is determined by θ. This corresponds to a sinusoidal curve in the (ρ,θ) plane, which is unique to that point. If the curves corresponding to two points are superimposed, the location (in the Hough space) where they cross corresponds to a line (in the original image space) that passes through both points. More generally, a set of points that form a straight line will produce sinusoids which cross at the parameters for that line. Thus, the problem of detecting collinear points can be converted to the problem of finding concurrent curves. But the problem with standard Hough transform is that it detects the complete line segment. The application requires that only line segment must be detected not the complete line. Therefore, in this paper progressive probabilistic Hough transform has been used [10]. The algorithm for PPHT is as follows,

Begin.
1. Check the input image, if it is empty then finish.
2. Update the accumulator with a single pixel randomly selected from the input image.
3. Remove pixel from input image.
4. Check if the highest peak in the accumulator that was modified by the new pixel is higher than threshold l. if not go to 1.
5. Look along a corridor specified by the peak in the accumulator, and find the longest segment of pixels either continuous or exhibiting a gap not exceeding a given threshold.
6. Remove the pixels in the segment from input image.
7. Unvote from the accumulator all the pixels from the line that have previously voted.
8. If the line segment is longer than the minimum length adds it into the output list.
9. Go to 1.

End

The resulting image obtained by applying PPHT is given in figure 10 below.

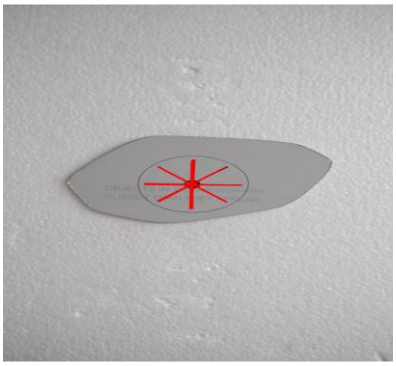

Figure 10: Line segment detected image.

The line segment detected by PPHT gives the length of line in terms of pixels. The length of line required for the application is in units of mm (mille meters). The conversion of pixel length into mm is done by multiplying the number of pixel with a scalar mm/pixel. The scalar is calculated by first taking an image of line, whose length is known. The camera used is same and the angle for taking the image is also same as for the experimental setup. The line length is then calculated in terms of pixels and as the actual length of line is known in terms mm, we can calculate the scalar in mm/pixel. This scalar is then multiplied with the pixel length of lines shown in fig.10 to get the length of lines in mm.

5. Results

Four mirrors have been taken to verify the proposed method used for calculating Distortion factor. The output of proposed method is compared with the values of previous method. In case of previous method, the experimental setup was same but the image taken by camera was printed and distortion was calculated manually. Below table 3 describes the performance of the proposed method by percentage accuracy obtained when compared with the standard manufacturer values.

$$percentage\ accuracy\ (\%) = \frac{proposed\ method\ value}{standard\ value} \times 100$$

If the accuracy obtained by above formula is 100, then subtract it by 200 to get normal % accuracy. The results for Distortion test is given in table 1 below. The scalar factor is 0.197mm/pixel.

Table 1: Results for Distortion test

Mirror	*Manufacturer value(mm)*	*Previous manual method*	*Proposed method*	
		(Value) %	*(Value) %*	*% Accuracy*
Truck	<4%	0.74	0.73	98.64
Car	<4%	0.51	0.51	100
Bike	<4%	0.92	0.91	98.91
Non gear	<4%	0.54	0.54	100

6. Conclusion

Input image is taken from experimental setup and the proposed methodology is applied over it to get the respective results. The accuracy obtained for distortion factor test is over 98%. The proposed system takes approximately 10 seconds to give results of Distortion test which is quite less as compared to previous manual method. Proposed system is very time efficient and free from human error.

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