Performance Evaluation of Different Line Detection Algorithms

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***Abstract*—Line detection is an important task in the field of image processing. Line detection has lot of applications in the field of military and other important areas. So fast and accurate line detection is required. This paper evaluates the performance in terms of its speed and accuracy of different line detection algorithms.**

***Index Terms*—Hough, line, mid-point, performance, transactions.**

I. Introduction

The line detection from an image is one of the basic task of computer vision and image processing. Knowledge about the lines in an image is useful in many applications. This paper evaluates the performance of Standard Hough Transform (SHT), Randomized Hough Transform (RHT) and Mid-Point Hough Transform in terms of its speed and accuracy of this algorithms.

Hough Transform (HT) [1] is a powerful global method for line detection. It transforms between the image space and parameter space, in which a straight line can be defined. In the method, one pixel of the image space is transforming to a parameterized curve of the parameter space. So, a point in the image plane will be a curve in the parameter space. In this manner all feature or edge points of an image are transforming from image space to parameter space. Each transformed point in the parameter space is considered as a candidate and accumulated in the corresponding cell of the accumulator. Finally, a cell with local maximum of scores is selected, and its parameter coordinates are used to represent a line segment in the image space.

Randomized Hough Transform (RHT) [2] is an advance version of Standard Hough Transform (SHT) for line detection. The basic idea behind the Randomized Hough Transform is, instead of transforming one pixel from image space to parameter space, randomly select more than one pixel and map them in to one point in the parameter space. So far, Randomized Hough Transform with two points is only discussed. This paper, evaluate the performance of Randomized Hough Transform with more than two points.

Mid-Point Hough transform [3] is a modification of Standard Hough Transform and RHT. In this method, two points are randomly selected and calculate its mid point. If it is also a ON or bright point, calculate ρ and θ of this points and map in to parameter space.

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Richard Duda and Peter E. Hart [1] introduced a method (Hough Transform) to detect the line segments from an image. In this, all feature points of the image space are transforming to a parameterized curve of the parameter space. Lei Xu, Erkki Oja and Pickka Kultanen [4] proposed a new method for line detection and it is known as Randomized Hough Transform (RHT). In this, more number of points are transforming from image space to parameter space at a time. Q. Ji and Y. Xie [5] proposed a method for line detection and circle detection based on Randomized Hough Transform based on error propagation. The curve detection robustness and accuracy improvement is achieved by analytically propagating the errors with image pixels to the estimated curve parameters. Chan-Ta Ho and Ling-Hwei Chen [6] introduced a high speed method for line detection. In this paper, through the use of geometric property of pair of parallel lines, the parameter set of those lines possible on the image can be obtained immediately. R.S.Stephen [7] proposed a method for line detection based on a Hough transform based on probabilistic approach. This paper shows that there is a strong relationship between the Hough Transform and the Maximum Likelihood method. Ranga Rodrigo, Wenxia Shi and Jagath Samarabandu [8] proposed an energy based line detection. In this paper, they consider the straight line detection task as an energy minimization problem.

II. Different Line Detection Algorithms For Line

Any straight line can be represented as

$$x\cos\theta + y\sin\theta = \rho \tag{1}$$

Here the parameter ρ represents the perpendicular distance from the origin to the line and θ represents the angle of the vector from the origin to the closest point on the line. It is therefore possible to associate with each line of the image, a couple (ρ, θ) which is unique if $\theta \in [0, \pi]$ and $\rho \in R$ or if $\theta \in [0, 2\pi]$ and $\rho > 0$. The (ρ, θ) plane is referred to as the Hough space.

A. Standard Hough Transform

Every pixel in the image is mapped to the Hough space for all values of θ. This leads to a sine wave in the Hough space for each individual pixel. The detection using Hough Transform is based on a voting procedure. This voting procedure is carried out in a parameter space or accumulator.

In Standard Hough Transform method each pixel is mapped into the Hough space and the accumulator value for the corresponding parameters are updated. By finding the bins with the highest values in the accumulator space the most likely lines can be extracted and their geometric definitions read off. The advantage of Hough Transform based detection is that lines need not be continuous thus enabling detection even in presence of noise. The main disadvantage is the high computational and memory overhead with the size of the accumulator and the parameter space being the limiting factors.

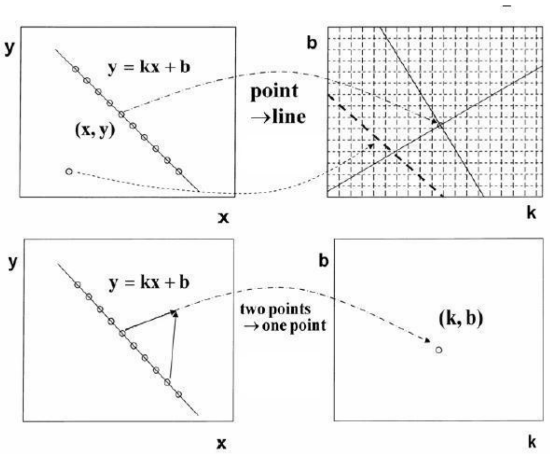

Fig. 1. Randomized Hough Transform [2]

A. Randomized Hough Transform

In the case of Randomized Hough Transform, randomly pick two or more pixels and map them in to one point in the parameter space. In comparison with Hough Transform, this new method has the advantages of the small storage, high speed, infinite parameter space and arbitrarily high resolution. The Randomized Hough Transform is as shown in Fig. 1

A straight line can be expressed by $y = mx + c$. In this equation the parameters of the line are *m* and *c*. If two pixels are in the same line, its *m* and *c* values will be same in the parameter space. We know the parametric equation of line is $\rho = x cos\theta + y sin\theta$. So, if two points ($x_1$, y_1) and (x_2, y_2) are on the same line, it's (ρ, θ) values will be same in the parameter space.

Randomized Hough Transform picks two points simultaneously to detect lines. It can use *n* points to find an *n* parameter curve. The method being to solve the *n* parameters for curve from the *n* linear equations using the *n* points selected at random. A modification for the line detection algorithm can also be attempted using more number of random points simultaneously. In RHT with 3 points (RHT-3), select three points simultaneously at random from the set of ON pixels from the image. Taking any two sets out of those we transform them to the (ρ, θ) space. We get two discrete points in the (ρ, θ) space. If the three points that we selected were collinear then all possible combinations of them would map to the same point in (ρ, θ) space. The idea given above for RHT- 3 can be extended by taking four points (RHT-4) at a time. Four points would give six possible pair selections. The (ρ, θ) values for each of them has to be found out. Then a voting procedure is followed. If three or more pairs evaluate to the same (ρ, θ) value that particular accumulator bin is updated.

B. Mid-Point Hough Transform

The new method calculates the mid-point of the two selected random points from binary image. If the mid-point is also an ON pixel we map the random points to the parameter space else we do not map any of those pixels at all. By mapping we mean that for each value of θ we find the corresponding ρ value for the pixel under consideration. We then proceed to pick the next pair of random pixels and apply the same logic on them. The main disadvantage of this algorithm is the missing of small line segments which is a common drawback among all randomized algorithms.

Since only one point is mapped for every pair of points taken, the estimation of parameter (ρ, θ) is prone to errors. This can be alleviated at the cost of added processing by mapping the selected pair also along with the midpoint. This modified Mid-Point Hough Transform will smooth out the estimation errors in the parameter space as more number of points are now mapped to the parameter space. Mid-Point Hough Transform algorithm and modified mid-point algorithms are named as MP1 and MP2 respectively.

III. Performance Evaluation

The performance evaluation done on the basis of speed and accuracy of the different line detection algorithms. A number of images with known (ρ, θ) values are selected as input images. The line is detected using the different algorithms. The mean square error between the parameters of the actual and detected line is computed. This is repeated for different signal to noise ratios (SNR). Different SNRs are obtained by synthetically adding white Gaussian noise to the image.

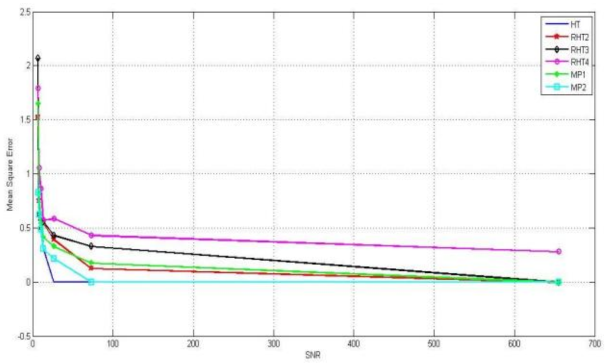

Fig. 2. Comparison of various algorithms in terms of Mean Square Error

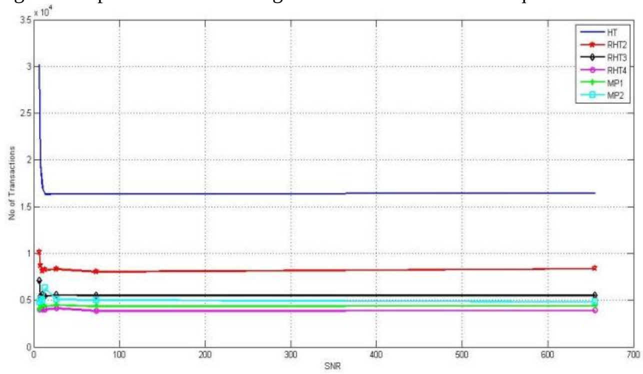

Fig. 3. Comparison of various algorithms in terms of No of Transaction

TABLE I: STANDARD HOUGH TRANSFORM (SHT) PERFORMANCE

SNR	Actual		Detected			Number of Transactions	Time (sec)
	ρ	θ	Number of Lines	ρ	θ		
INF	50	63	1	50	63	15257	1.83
655.36	50	63	1	50	63	15155	1.84
72.82	50	63	1	50	63	15154	1.85
26.21	50	63	1	50	63	15151	1.79
18.20	50	63	1	51	64	15033	1.85
13.37	50	63	1	51	64	14984	1.87
10.24	50	63	1	51	64	17772	1.75
8.09	50	63	1	52	64	26772	1.98
6.55	50	63	1	53	66	67789	3.06

TABLE II: RANDOMIZED HOUGH TRANSFORM WITH TWO POINTS (RHT2) PERFORMANCE

SNR	Actual		Detected			Number of Transactions	Time (sec)
	ρ	θ	Number of Lines	ρ	θ		
INF	50	63	1	50	63	7358	1.02
655.36	50	63	1	50	63	7827	1.05
72.82	50	63	1	50	63	6947	1.07
26.21	50	63	1	51	64	7987	0.94
18.20	50	63	1	51	64	7918	0.93
13.37	50	63	1	52	62	7279	1.03
10.24	50	63	1	51	64	6603	1.03
8.09	50	63	1	51	64	9193	1.02
6.55	50	63	1	56	55	10235	1.05

TABLE III: RANDOMIZED HOUGH TRANSFORM WITH THREE POINTS (RHT3) PERFORMANCE

SNR	Actual		Detected			Number of Transactions	Time (sec)
	ρ	θ	Number of Lines	ρ	θ		
INF	50	63	1	50	63	5155	0.87
655.36	50	63	1	50	63	5178	0.88
72.82	50	63	1	50	64	5149	0.82
26.21	50	63	1	52	62	5127	0.81
18.20	50	63	1	51	64	4974	0.79
13.37	50	63	1	52	62	4792	0.78
10.24	50	63	1	51	64	4980	0.80
8.09	50	63	1	51	64	4902	0.78
6.55	50	63	1	57	74	11363	1.25

In the test image, a line segment with known ρ and θ is present. In the different tables, the transaction number from image space to parameter space and the total time for the execution are given. The best algorithm will detect more number of lines in less number of transactions and time. If the transaction from image space to parameter space is high, then that algorithm should require high memory.

Fig. 2 shows the mean square error in various SNR for different algorithms. Fig. 3 shows the number of transactions at various SNR for different algorithms. The number of transactions is the number of computational operations, which is essentially a measure of time consumed for estimation of the parameters. Notations SHT and RHT*n* represents the Standard Hough Transform and Randomized Hough Transform with *n* points.

TABLE IV: RANDOMIZED HOUGH TRANSFORM WITH FOUR POINTS (RHT4) PERFORMANCE

SNR	Actual		Detected			Number of Transactions	Time (sec)
	ρ	θ	Number of Lines	ρ	θ		
INF	50	63	1	50	63	3600	0.80
655.36	50	63	1	51	64	3692	0.79
72.82	50	63	1	51	64	3502	0.82
26.21	50	63	1	51	64	3775	0.79
18.20	50	63	1	51	64	3622	0.80
13.37	50	63	1	51	64	3773	0.80
10.24	50	63	1	52	62	3585	0.79
8.09	50	63	1	52	64	3220	0.78
6.55	50	63	1	42	59	2760	0.82

TABLE V: MID-POINT HOUGH TRANSFORM I (MP1) PERFORMANCE

SNR	Actual		Detected			Number of Transactions	Time (sec)
	ρ	θ	Number of Lines	ρ	θ		
INF	50	63	1	50	63	3666	0.75
655.36	50	63	1	50	63	3795	0.77
72.82	50	63	1	50	63	4085	0.80
26.21	50	63	1	50	63	4153	0.79
18.20	50	63	1	51	64	3539	0.82
13.37	50	63	1	51	64	3755	0.83
10.24	50	63	1	52	62	4048	0.80
8.09	50	63	1	52	64	3786	0.82
6.55	50	63	1	44	71	2316	0.81

TABLE VI: MID-POINT HOUGH TRANSFORM II (MP2) PERFORMANCE

SNR	Actual		Detected			Number of Transactions	Time (sec)
	ρ	θ	Number of Lines	ρ	θ		
INF	50	63	1	50	63	4503	0.77
655.36	50	63	1	50	63	4804	0.78
72.82	50	63	1	50	63	3982	0.82
26.21	50	63	1	50	63	4769	0.79
18.20	50	63	1	51	64	4782	0.80
13.37	50	63	1	49	64	5366	0.80
10.24	50	63	1	52	62	3852	0.81
8.09	50	63	1	49	61	4810	0.80
6.55	50	63	1	47	64	2784	0.80
6.05	50	63	1	44	64	2115	0.80

IV. CONCLUSION

Here Standard Hough Transform performance is compared with different Randomized Hough Transform algorithms and two Mid-Point Hough Transform algorithms. The Mid-Point Hough Transform algorithm (MP1) is giving better results than Randomized Hough Transform and Standard Hough Transform in terms of its accuracy, number of transactions and time required for the calculation. The modified Mid-Point Hough transform (MP2) is giving better results than MP1 in terms of its accuracy; Its number of transactions and time are more than that of MP1 and lesser than that of other algorithms

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