Comparative analysis of Radon and Fan-beam based feature extraction techniques for Bangla character recognition

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Summary
This paper presents a comparative analysis of two projection based feature extraction techniques namely Radon and fan-beam. Fan-beam technique is a variation of Radon transform and usually used in tomography. In this work, Radon and fan-beam projections are used to compute feature vectors of Bangla characters. Extracted features are simulated for recognition and the recognition rates are compared for both of the methods.

Key words:
Feature extraction, Radon transform, Fan-beam projection, k-nearest neighbor classifier.

1. Introduction

Devijver and Kittle define feature extraction as the problem of "extracting from the raw data the information which most relevant for classification purposes, in the sense of minimizing the within-class pattern variability while enhancing the between-class pattern variability" [1]. Features are unique characteristics that can represent an image, i.e. a character in this case. Each character is represented as a feature vector, which becomes its identity. The goal of feature extraction is to extract a set of features, which maximizes the recognition rate with the least amount of elements. In this paper, we are going to discuss two projection based feature extraction methods named Radon and fan-beam. Projection is a way to represent a two-dimensional region. It is the one dimensional representation region. Projection is simply the sum of the run lengths of 1s along a straight line oriented at a certain angle. In this sense a projection is simply a histogram that provides the number of pixels that project into a bin.

There are a number of techniques available for feature extraction [2-6]. Selection of a feature extraction method is the single most important factor in achieving high recognition performance of Optical Character Recognition (OCR) systems. Radon transform is used as one of the feature extraction methods [7]. Here the image of a character is Radon transformed and the result is used as features after passing through principal component analysis. Whereas the Fan-beam projection is a variation [8] of Radon transform. The fan-beam function computes projections of an image matrix along specified directions except that the projections are taken in a different way from that of Radon transform. This paper presents a comparative analysis of these two methods.

The theory and difference of fan-beam from Radon are discussed in section 2. In section 3, computation and formation of feature vector is explained, section 4 deals with the simulation and finally section 5 contains the results.

2. Radon and Fan Beam projection

The Radon transform of a function *f(x,y)*, denoted as *r(s, θ)*, is defined as its line integral along a line inclined at an angle *θ* and at a distance *s* from the origin [9]. Fig. 1 shows the geometry of Radon transform. The geometry of the Radon transform can be expressed by the following equation:

$$r(s,\theta) = \iint_{-\infty}^{\infty} f(x,y)\delta(x\cos\theta + y\sin\theta - s)\,dx\,dy;$$
$$-\infty < s < \infty, 0 \le \theta < \pi \qquad (1)$$

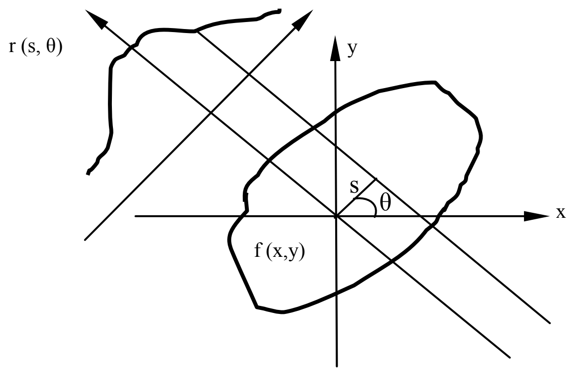

Fig. 1 Geometry of Radon transform.

The Radon transform computes the line integrals from multiple sources along parallel paths, or beams spaced 1 pixel unit apart, in a certain direction. Here multiple, parallel-beam projections of the image from different angles are taken by rotating the source around the center of the image to represent an image. The following figure shows parallel beam projection at a specified rotation angle *θ*.

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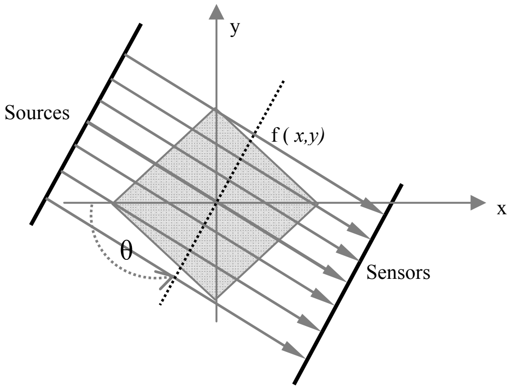

Fig. 2 Parallel beam projection of Radon transform at rotation angle θ.

Often the projection data is collected using fan-beams rather than parallel beams. This is more practical method because it allows rapid collection of projections compared to parallel beam scanning. These diverging beams are just like a fan and hence it is named as fan-beam geometry. In Fig. 3, the source *S* emits a thin divergent beam of X-rays, and a detector receives the beam.

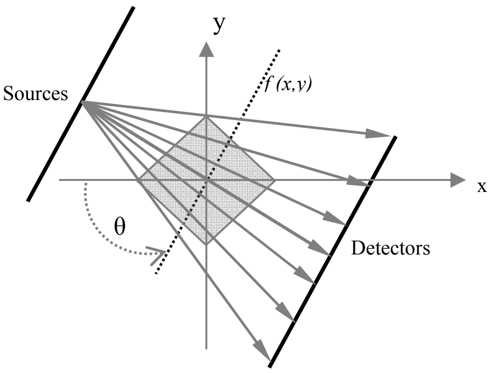

Fig. 3 Fan-Beam projection at rotation angle θ.

The source position is characterized by the angle β, and each projection ray is represented by the coordinates (σ, β); $-\pi/2 \leq \sigma \leq \pi/2$, $0 \leq \beta < 2\pi$. The rays are related to the parallel beam coordinates (s, θ) as indicated in equations 2 and 3 [9]. Here D is the distance of the source from the origin of the object. Fig.4 shows the Fan-beam geometry.

$$s = D \sin\sigma \qquad (2)$$
$$\theta = \sigma + \beta \qquad (3)$$

3. Projection features

Features were computed using Radon and fan-beam geometry discussed above. For Radon transform, 111 parallel beams are taken while 83 diverging beams are taken for Fan-beam.

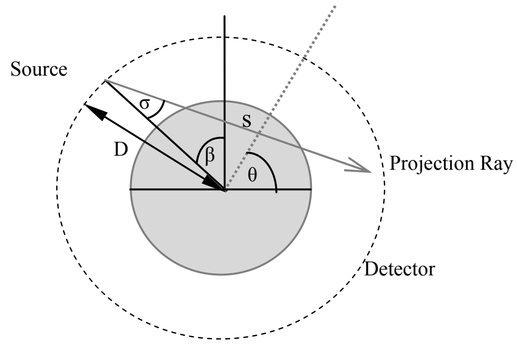

Fig. 4 Fan-beam geometry.

The distance D from the fan-beam source to the center of rotation has to be determined first (Fig. 4). D must be large enough to ensure that the fan-beam source is outside of the image at all rotation angles. D is taken a few pixels larger than half the diagonal image distance, where the diagonal image distance is, $d = \sqrt{i^2 + j^2}$, where i and j are rows and columns of the image respectively. Radon and Fan-beam takes projections at different angles by rotating the source around the center pixel at θ degree intervals. These projection data is considered as feature vector.

The accumulator of Radon transform is shown in Fig. 5. It can be seen from the figure that after 180 degree the signal repeats itself in the reverse direction. This is because projections taken from 0 to 180 degree are exactly equal to the projections taken from 181 to 360 degree. Similar thing happens for Fan-beam in Fig. 6.

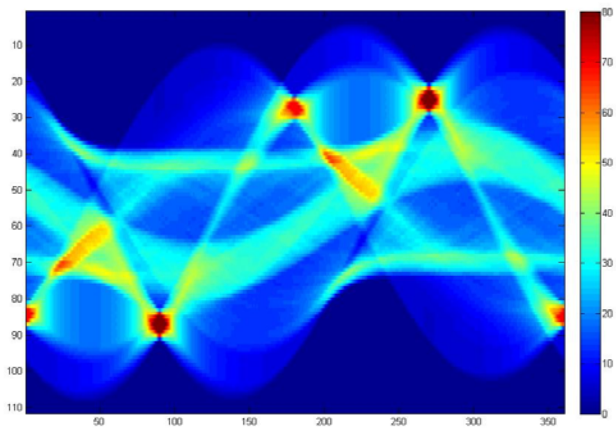

Fig. 5 Accumulator data of Radon transform (repeating after 180 degree)

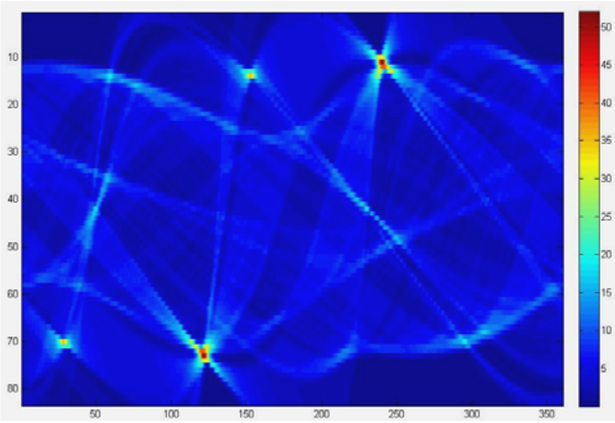

Fig. 6 Accumulator data of Fan-beam (repeating after 180 degree)

Once, we get the projection data we take average value to build the feature vector. For Fan-beam the average of the projections of one direction was taken which is the average of 83 parallel projections. Hence size of feature vector for one character is 1×360. In case of Radon, however, average was taken for 180 degree rotation of angle theta, unlike beam wise stated in Fan-beam. So, size of feature vector for one character is 111×1. Fig. 7 shows the plot to feature vector generated using Fan-beam for one character. Similar plot of feature vector is shown in Fig. 8 generated by Radon transform for the same character.

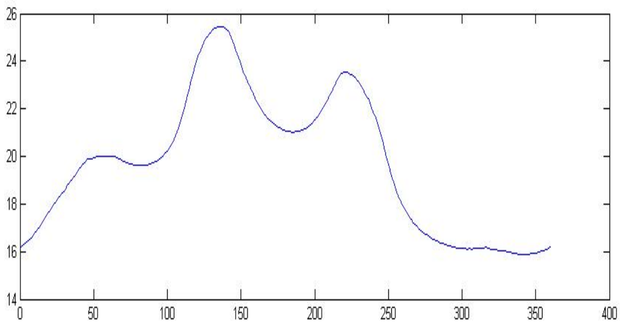

Fig. 7 Plot of feature vector generated by Fan-beams.

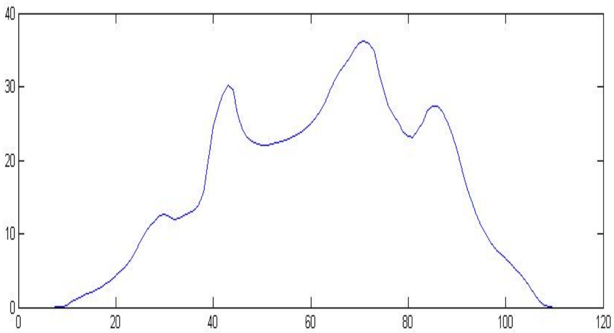

Fig. 8 Plot of feature vector generated by Radon transform.

4. Results

Table I contains the results for the techniques stated above. The feature vectors were generated from 4 different types of fonts. These fonts are the most used fonts of Bangla printed text. There were two types of classifiers used, namely Artificial Neural Network (ANN) Multi-layer Perceptron and k-nearest neighbor (KNN) classifier. It was seen that KNN is the best classifier for these two types of feature extraction techniques. Also time required by KNN is less than ANN.

Table I

	KNN		**ANN**	
	Accuracy	*Time*	*Accuracy*	*Time*
Fan-beam	99%	0.01 s	76%	60.78 s
Radon	99%	0.02 s	98%	24.05 s

5. Conclusion

Radon transform gives more consistent result than Fan-beam. For both classifiers, Radon gives same accuracy while Fan-beam fails to do so. As the experiment was done on different types of fonts, it can be stated that these features are style invariant. More strictly, Radon transform features are more style invariant than those of Fan- beam.

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