

Handwritten Digit Recognition - Masters Thesis Summary Report

By Mike Del Rose

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14. ABSTRACT Pattern recognition/classification of handwritten digits were performed on a random sample of 3000 digits. Each class was trained with 200 digits and tested with 100 digits. Each digit was normalized to a 32x32 matrix representation of the digit. Four methods were used to classify each digit: Directional Vectors, Profiles, Curvatures, and Profile Curvatures. In addition to each method used, a wavelet transform was also performed on the digits to see if any better results could be obtained. The goal of this project was to investigate less common methods that might be useful in pattern recognition of digits while keeping the generality of these algorithms. It was not the intent of this project to base methods off certain digits and combine them together to create an algorithm used for classification; each method was used on its own as a classifier. In each method the classification is done using the Mahalanobis distance function. Either the covariance's are used or a number of eigenvectors (based from the largest eigenvalues) are used. Each method may use a different number of eigenvectors.					
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1.0 Introduction

Pattern recognition/classification of handwritten digits were performed on a random sample of 3000 digits. Each class was trained with 200 digits and tested with 100 digits. Each digit was normalized to a 32x32 matrix representation of the digit.

Four methods were used to classify each digit: Directional Vectors, Profiles, Curvatures, and Profile-Curvatures. In addition to each method used, a wavelet transform was also performed on the digits to see if any better results could be obtained.

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2.0 Direction Vector Classification

There were two types of direction vectors used on the contours of the digit image. The 4 point directional vector and the 8 point directional vector. A 4 point directional vector uses numbers 1, 2, 3, and 4 to represent the direction of the last pixel with respect to the current one. {1 represent an angle of 0° or 180° , $2 = (45^\circ, 225^\circ)$, $3 = (90^\circ, 270^\circ)$, and $4 = (135^\circ, 315^\circ)$ }. An 8 point directional vector uses the numbers 1, 2, ..., 8 to represent the direction ($1 = 0^\circ$, $2 = 45^\circ$, $3 = 90^\circ$, $4 = 135^\circ$, $5 = 180^\circ$, $6 = 225^\circ$, $7 = 270^\circ$, $8 = 315^\circ$).

The image of the digit was cut into either 4 or 16 groups and a histogram of the values were used for each group. Both covariance matrices and eigenvectors were used to classify the image. A wavelet was also used to see if better results could be obtained from the transform. The following results are read as % correct/% reject.

- 4 point directional vector with 4 groups
 - covariance: 79.2/26.3
 - eigenvectors: 73.9/0.5
- 4 point directional vector with 16 groups
 - covariance: 86.2/3.8
 - eigenvector: 94.5/5.0 and 92.7/0.9
- 8 point directional vector with 4 groups
 - covariance: 82.0/3.7
 - wavelet/covariance: 72.0/18.0
- 8 point directional vector with 16 groups
 - eigenvectors: 95.1/8.4 and 93.2/1.7

As the results show:

- The wavelet transform reduces the chance of correct classification while increasing the rejection percentage.
- The eigenvectors do a better job classifying digits than the covariance matrix.
- The 8 point directional vector classifier has a slightly higher classification percentage then the 4 point direction vector; however, the rejection rates are also increased.

3.0 Profiles

4 different profiles were compiled of each image: a left profile is the column value of the first 'on' pixel in each row, a right profile is the column value of the last 'on' pixel in each row, a top profile is the row value of the first 'on' pixel in each column, and a bottom profile is the row value of the last 'on' pixel in each column.

The widths of each right/left or top/bottom profiles were also used to classify digits. After the profiles are found, wavelet transforms of the data was computed. The following results are read % correct/% reject where R - right profile, L - left profile, T - top profile, B - bottom profile, and W - width.

- Covariance matrix
 - R, L, and W: 81.6/0.2
 - T, B, and W: 65.0/0.8
- eigenvectors:
 - R, L, and W: 80.8/0.1
 - R, L, T, B, and Ws: 83.4/2.7

These results are not as useful as I had originally thought they would be. From previous papers, it shows the use of profiles without wavelet transforms are mainly used as a second set of a dual classification algorithm using fuzzy logic. Here, only distance classifications were used to keep the generality of the algorithms.

4.0 Curvatures

Curvature matrices seemed the same as directional vectors except being more lenient on local noise to the image. A curvature was computed for each point by calculating the curve of two vectors. One vector is made from the current point and 3 points back and the other vector is made from the current point and 3 points ahead.

Curvature matrices seemed like good candidates for wavelet transforms, but only 65.0 percent of the digits were correctly classified. Without the transform, classification results didn't do much better.

5.0 Profile-Curvature

The profiles of the digit were compiled of the curvature of the image to get a right/left curve profile of the digit. The classification was obtained from both a wavelet transform and the straight eigenvectors. Using eigenvectors or covariance matrices didn't help in the distance function to classify digits. The results were 58.9% correct with a rejection rate of .3%.

Wavelet transforms of the profiles gave strange classification results. They seemed to classify most all the digits as either a zero or a six. Similar results were found when using wavelets in other classification methods.

6.0 Conclusion

Directional vectors were, by far, the best classifier used in this study. The difference between 4 point directional vectors and 8 point directional vectors was negligible. The results of the remaining classification methods do not justify further study in these areas. Wavelet transforms on these methods only made classification rates lower while increasing the rejection rates. Similar methods of directional vectors (curvature) that were supposed to remove local noise did not; errors turned out higher. Profile classification results showed that profiles could only be useful in dual classification algorithms. Many of these methods could probably be improved by adding syntactical measures, but this would decrease the generality of the method.