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HIGH EFFICIENCY PATTERN RECOGNITION

University of California at San Diego

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This contract had two main goals: (1) the improvement and comparison of optical pattern recognition filter algorithms and (2) the improvement of the optical or Horner efficiency in order to allow smaller lower powered lasers for pattern recognition systems. The first goal was achieved by studying and comparing the performance results of three generic classes of filters: the Fukunaga-Koontz, the Hotelling, and the Foley-Sammon filter. All of these are of the classical statistical feature extraction type. In addition the effect of white noise on the recognition of a 2 class problem employing the LSLMT algorithm was evaluated. The second goal was apparently not achieved, as the simulated optical efficiency and classification reliability remained about the same as the full phase and amplitude filters. This may have been due to non-standard definition of Horner efficiency used by the contractor, and the fact that a limited database was used. However, the phase-only filters did show increased peak correlation intensity and SNR.

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1. Introduction

The research performed at UCSD for the AF RADC Contract had two main goals.

a) The improvement of optical pattern recognition reliability. This was to be achieved by incorporating new recognition algorithms into the design of pattern recognition filters, thereby allowing the combination of the speed of optics with the reliability of algorithms usually reserved for digital processing [1,2].

b) The improvement of the optical efficiency of spatial filters, in order to allow the use of smaller, lower power lasers for pattern recognition.

In this report we will review and summarize the research done at UCSD from March 1985 to February 1987. The degree to which the two goals were met will be evaluated.

2. Algorithm Study

A) Optical Implementation of New Algorithms

1) Database creation

Two new image data bases were generated. This was done in order to incorporate both interclass as well as intraclass statistical variation in our training and test image sets for the first database and rotationally varying samples of two classes for the second database. The first database consisted of 512 ×512 gray tone (0 to 255) images of 10 tanks and 10 trucks. (See Status Report: March-April, 1985.) In the second, rotationally variant database two airplanes were rotated by increments of 5 and 10 degrees to obtain 72 and 36 respectively samples for each class. (See Status Report: December 1985-January 1986.)

2) Implementation of new statistical algorithms

In addition to previously studied feature extraction algorithms (e.g., Fukunaga-Koontz (F-K) [1] and Hotelling Trace Criterion (HTC) [2]) we studied and implemented the Foley-Sammon (F-S) transform which was applied to the older birds-and-fish database with good results: 100% correct classification with both the training and test data. (See Status Report: March-April 1985 and Publication #1.)

3) Pattern recognition of images submerged in noise

The effect that the addition of white noise had on the recognition of a 2-class problem employing the least squares linear mapping technique (LSLMT) algorithm [3] was evaluated. The white noise was treated as third class object. Good recognition results were demonstrated for a signal-to-noise ratio as low as 0.2. (See Status Report: March-April 1985 and Publication #2.)

B) Comparison study of linear mapping and eigenvector-based algorithms.

Most statistical pattern recognition algorithms can be grouped into two classes: linear mapping methods and feature extraction methods. The LSLMT, Simplified LSLMT (SLSLMT), [4] and Synthetic Discriminant Function [5] (SDF) are examples of linear mapping methods, while the F-K, F-S, HTC, Linear Discriminant Function (LDF) [6] and Generalized Matched Filter (GMF) [7] are examples of eigenvector-based feature extraction methods of pattern recognition. (See Status Reports: May-June, July-August, September-November 1985 and Publications #3 and 4.)

1) Linear mapping methods

In this study we formulated the generalized linear mapping (GLM) method, which for special cases can be reduced to the LSLMT, SLSLMT and SDF algorithms. When the number of training images is smaller than the number of image pixels, i.e., the underdetermined case, the GLM, LSLMT and SDF algorithms were shown to be identical. For the overdetermined case when the number of training images is larger than the number of image pixels, the LSLMT and GLM were found to be identical, whereas the SDF algorithm was undefined for that case. This was then verified experimentally using the birds-fish and tank-truck database. (See Status Report: May-June, 1985.)

In addition, the GLM was compared on a theoretical basis with the Caulfield-Maloney filter (CMF) [8], the equal correlation peak (ECP) [9] technique, and the SLSLMT. The CMF and ECP again were shown to be special cases of the GLM. The SLSLMT was shown to be identical to the GLM for images of Markov-1 process. It was also noted that the SLSLMT has a computational advantage over both the LSLMT and SDF algorithms. (See Status Report: July-August, 1985 and Publication #3.)

2) Eigenvector based methods

A theoretical comparison of eigenvector-based algorithms such as the FS, HTC, FK, LDF and GMF was also performed. It has been shown that all the eigenvector based methods can be represented in the generalized eigenvector form. However, the calculations of the discriminant vectors are different for different algorithms (summaries on how to calculate the discriminant functions for the FS, HTC and FK transforms are provided in publication #4). We also compared theoretically the classification effectiveness of the discriminant functions generated from the FS, HTC and FK algorithms with those generated with the LDF and GMF as well as the discriminant functions generated from the linear mapping based algorithms with those using eigenvector based methods. The experimental comparison was performed using the birds-fish and the tank-truck database. (See Publication #4.)

C) Comparison of algorithm sensitivity to image rotation

The statistical pattern recognition algorithms LSLMT, SLSLMT, FS, HTC and FK were applied to the rotation varying database. We found that the linear mapping based algorithms were not as sensitive to rotation as the eigenvector based algorithms, needing only 12 rotated images to correctly classify the test set compared to 72-180 for the eigenvector based algorithms. The linear mapping based algorithms are more robust when faced with rotation than the eigenvector based algorithms. (See Status Report: February-March, 1986.)

3. Phase Only Filtering

Phase only (PO) filtering was also investigated [8,9]. The effects of PO filtering on such characteristics as the Horner efficiency of the filter, the correlation peak intensity, the correlation spot size, and the signal-to-noise ratio of the correlation function were evaluated.

For linear mapping-based algorithms, e.g., the LSLMT and SLSLMT, the PO filtering increased the peak correlation intensity and the signal-to-noise ratio. The Horner efficiency did not seem to be improved and the classification realiability remained about the same as compared to amplitude and phase (AP) filtering. (See Status Reports: July-August, 1986, September-October, 1986.)

For eigenvector-based algorithms, e.g., the HTC, FS and FK algorithms, the PO filtering decreased the spot size while increasing the peak correlation intensity. The signal-to-noise ratio and the Horner efficiency did not seem to be improved while the classification reliability again remained about the same as for the AP filtering. (See Status Report: November-December, 1986.)

A point needs to be made concerning the classification reliability of phase only filtering. While it is true that the classification realiability was not overly degraded by the use of phase only filters, a limited database was used. The results for the tank-truck database may not be applicable to other and larger database.

4. Summary and Conclusion

To meet the goal of improvement of optical pattern recognition, we have studied and experimentally verified new computation methods for the FS algorithm, and extended the LSLMT algorithm to the case of images corrupted by additive noise. We also theoretically and experimentally studied the algorithms based on solutions to linear mapping and generalized eigenvalue problems. The robustness of these algorithms with respect to statistical variations and rotations of training data was investigated using the tank-truck and rotated airplane database respectively. The two groups of algorithms were also employed to compare their performance characteristics in using PO versus AP filtering.

5. List of Publications during the granting period.

1. Z. H. Gu and S. H. Lee, "Classification of multiclassed stochastic images buried in additive noise," *J. Opt. Soc. Am.* A:**4**, pp. 712-719, 1987.
2. Q. Tian, M. Barbero, Z. H. Gu and S. H. Lee, "Image classification by Foley-Sammon transform," *Opt. Eng.*, **25**, pp. 834-840, 1986.
3. Q. Tian, Y. Fainman, Z. H. Gu and S. H. Lee, "Comparison of statistical pattern recognition algorithms for hybrid processing. Part I: Linear mapping algorithms," submitted to *J. Opt. Soc. Am.*, Dec. 1986.
4. Q. Tian, Y. Fainman and S. H. Lee, "Comparison of statistical pattern recognition algorithms for hybrid processing. Part II: Eigenvector-based algorithms," submitted to *J. Opt. Soc. Am.*, Dec. 1986.

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