IMPROVED FOURIER DESCRIPTORS FOR 2-D SHAPE REPRESENTATION

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I. INTRODUCTION

Compact shape representation is important for segment coding, coding of medical signals, etc. Compact shape representation is not only interesting for the purpose of data compression, but also for pattern recognition, where it helps to overcome the curse of dimensionality. The required accuracy of representation is lower for these applications, but the power to discriminate between different shapes is more important. Typical applications are classification, recognition of shapes in images, retrieving similar shapes from databases, motion analysis, posture analysis, etc.

II. SHAPE DESCRIPTORS

A. *Fourier Descriptors*

A class of contour descriptors which are widely used, are Fourier descriptors (FD's). If we consider the contour in the complex plane, then each coordinate of the contour is expressed as a complex number. We can represent the contour by scanning all the contour points, i.e., $s(t) = x(t) + jy(t)$, where $x(t)$ and $y(t)$ are the euclidean coordinates of point "t". The contour $s(t)$ can be approximated using a trigonometric polynomial, i.e.,

$$s_N(t) = \sum_{n=-N}^{N} B_n e^{jnt} \tag{1}$$

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Where the coefficients B_n minimize the mean squared distance between s and s_N. The B_n coefficients are called Fourier descriptors.

If the shape undergoes a translation, rotation and or scaling, the FD's change in an easy way. This has made it possible to derive descriptors which are invariant to these transformations. This has made the FD's very popular in a wide range of applications [1].

B. *Improved Fourier Descriptors*

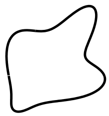
Even though the coefficients B_n are unique, the representation using FD's is not. This is because the parameterization $s(t)$ is not unique. Scanning the contour a little bit faster or slower at certain parts of the contour results in another parameterization of the contour. So $s(\theta(t))$ represents the same contour, where $\theta(t)$ "warps" the scanning speed. By approximating $s(\theta(t))$ by a trigonometric polynomial, a new set of FD's for the contour are calculated. The approximation of the FD's can be improved by optimizing the warping function. The FD's of the optimal warped contour are called the improved Fourier descriptors (IFD's). Since the IFD's are a generalization of FD's, they can also be made invariant for certain transformations.

III. ERROR METRICS

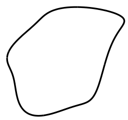
To measure the difference between the original image and the approximation, two metrics are defined. For every point on one contour, the closest point on the other contour is matched. The Hausdorff distance is the maximum of all the distances between matched contour points.

(a) the original shape

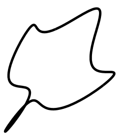
(b) the original shape



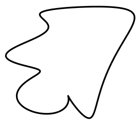
(c) 10 FD



(d) 10 FD



(e) 10 IFD



(f) 10 IFD

Figure 1. Examples of the representation using FD's and IFD's. In the first row the shape we want to approximate is shown. In the second and third row the approximations are shown.

The modified Hausdorff distance is the average of all the distances between matched contour points.

IV. Results and Discussion

To test the ability of IFD's to represent shapes, a database with pictures of leaves was used. This database contains pictures of isolated leafs from six different plant species. The database contains over 400 shapes, which were all approximated using 10, 20, ...,50 descriptors.

As an example, two shapes were approximated using both improved and regular Fourier descriptors descriptors. In Fig. 1, the results are shown. The first row shows the leafs we want to approximate. In the second and third row there approximation using respectively 10 FD's and IFD's can be seen. In these examples, it is clearly visible that the IFD's approximate the original shape better than the FD's. For both examples, the IFD approximation shows more clearly the leaf incisions. In the first example also the long extension of the leaf stalk is clearly captured by the IFD approximation.

To get quantitative results, the Hausdorff and modified Hausdorff distance were used as error metrics. For both metrics, using the IFD's results in an average improvement of over 10% over approximation using regular FD's.

V. Conclusion

In this paper shape approximation by IFD's was thoroughly tested. It is shown that these shape descriptors are not only theoretically better, but that they also have a significant better performance in practice. Since their good performance, they seem interesting descriptors for pattern recognition.

VI. Acknowledgments

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References

[1] T. McLellan and J.A. Endler, "The relative success of some methods for measuring and describing the shape of complex objects," *Systematic Biology*, vol. 47, no. 2, pp. 264–281, 1998.

[2] W. Philips, "Adaptive warped polynomial contour descriptors," *Proceedings of 1995 IEEE International Conference on Systems, Man and Cybernetics*, vol. 5, pp. 4638–4643, October 1995.