Comparing Feature Extraction Techniques for Binarized Content-Based Image Retrieval

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Background

- Historians use watermarks in paper to relate documents to each other.
- Searching for similar watermarks by hand is time-consuming.
- A prototype system was created to automate the search [1].
- Further improvement is still needed.

Research Question

What image features are the most effective for retrieving similar, binarized watermarks from a set of historical documents?

- What types of features are relevant for recognition of binarized watermarks?
- Which specific image features may perform well, and how do they actually perform at watermark retrieval?
- What impact do the parameters of the techniques have, and how can they be optimized?
- How can different techniques be combined to further improve performance of the system?

Methodology

There are two relevant types of image features.

- Texture features quantify the texture in an image in its entirety.
- For example, Gabor filters model mammalian eye cells by isolating frequency and orientation information.
- **Gabor features:** Each image is filtered, and the mean and standard deviations are used as a feature vector.

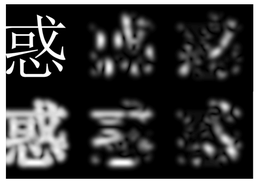

Figure 1: Image after various Gabor filters. Johndoe154, Public domain, via Wikimedia Commons

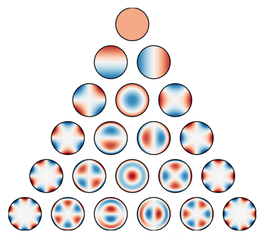

Figure 2: First 21 Zernike polynomials. Nschloe, CB BY-SA 4.0, via Wikimedia Commons

- Image moments compare the image to many "base images" based on different polynomial orders
- Cartesian: simple to compute, but sensitive to rotation
- Polar: Rotation invariance, but more complex to compute
- **Zernike and Legendre moments** first suggested in 1980 [2]
- **Bessel-Fourier and Tchebichef moments** improve on them [3, 4]

Methodology Continued

- Two combined techniques: **Gabor-Zernike** and **Gabor-Legendre**
- Instead of mean and standard deviation, Zernike and Legendre moments

- 146 images: 81 training, 65 evaluation
- 3 synthetic datasets: rotated, sheared, both
- Apply technique, then rank with Euclidean distance
- Precision: percentage retrieved that is relevant
- Recall: percentage of relevant images retrieved
- Mean Average Precision: area under precision-recall curve

- Preliminary experiment: decide on moment orders

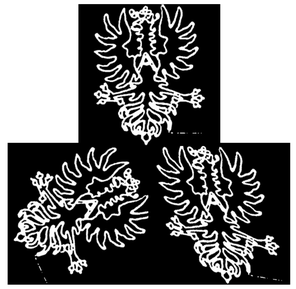

Figure 3: Original eagle watermark (top), after rotation (bottom right), after shearing (bottom left). Figure created by the author.

	Maximum moment order				
	6	8	10	12	14
Zernike	0.630	0.641	**0.697**	0.679	0.672
Bessel-Fourier	0.646	**0.659**	0.641	0.620	0.592
Legendre	0.670	**0.764**	0.745	0.708	0.684
Tchebichef	0.630	0.706	0.742	**0.764**	0.756
Gabor-Zernike	0.762	**0.772**	0.754	0.766	0.765
Gabor-Legendre	0.766	**0.818**	0.803	0.770	0.765

Results

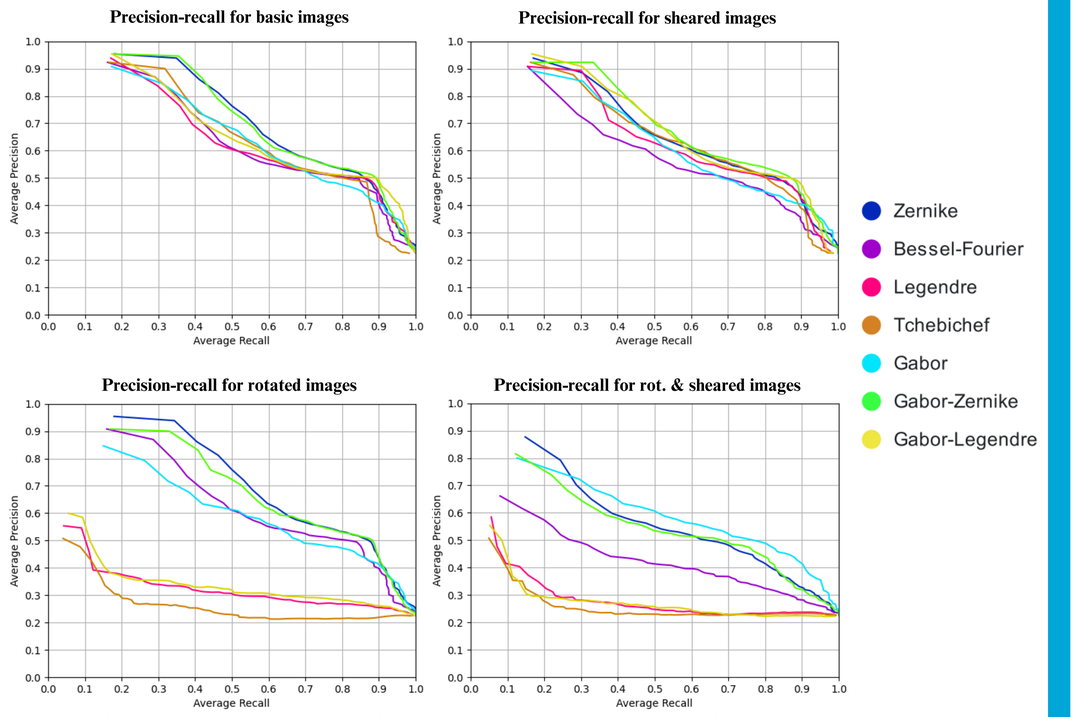

Figure 4: Precision-recall curves for each technique when the images are unchanged, sheared, rotated, and both sheared and rotated. Precision and recall both range from 0 to 1 and are dimensionless.

Conclusions and Future work

- Zernike and Gabor-Zernike both viable
- Zernike is better under rotation, Gabor-Zernike under shearing
- For low-quality datasets, texture features are better

- Bessel-Fourier and Tchebichef are supposed to to improve on Zernike and Legendre, but don't for binarized images
- Moments with orders higher than ~12 don't improve performance

References

Figure 1: Johndoe154, Public domain, via Wikimedia Commons https://commons.wikimedia.org/wiki/File:Gabor-ocr.png
Figure 2: Nschloe, CC BY-SA 4.0, via Wikimedia Commons https://commons.wikimedia.org/wiki/File:Zernike_polynomials_with_read-blue_cmap.png
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[2] Michael Reed Teague, "Image analysis via the general theory of moments*," J. Opt. Soc. Am. 70, 920-930 (1980)
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[4]R. Mukundan, S. H. Ong and P. A. Lee, "Image analysis by Tchebichef moments," in IEEE Transactions on Image Processing, vol. 10, no. 9, pp. 1357-1364, Sept. 2001, doi: 10.1109/83.941859.