Research on the Theory and Application of New Image Orthogonal Moments

Dissertation Submitted to

Liaoning Normal University

in partial fulfillment of the requirement

for the degree of

Master of Science

in

Computer Science and Technology

by

QI Shuren

Dissertation Supervisor : Professor YANG Hongying

June, 2020

Research on the Theory and Application of New Image Orthogonal Moments

Abstract

Image representation is an important topic in computer vision and pattern recognition. It plays a fundamental role in a range of applications towards understanding visual contents, *e.g.*, image classification, instance retrieval, object detection, semantic segmentation, copyright authentication, and forgery detection. Moment-based image representation has been reported to be effective in satisfying the core conditions of descriptor, due to their beneficial mathematical properties, especially geometric invariance and independence. However, moment-based image representation models often suffer from several open problems, including the lack of invariance to any geometric transformation, the unsatisfactory speed and accuracy of calculation, the difficulty in capturing spatial structure information of image, *etc.*

Starting from real-world applications, we abstract several basic conditions that an efficient moment-based descriptor should satisfy: the invariance to affine transformation, the robustness to signal corruption, the discriminability to a large number of patterns, and the reasonable complexity and accuracy. Based on such observations, this thesis will focus on the three open problems of moment-based image representation models, and propose several corresponding solutions. Specifically, the main contents of this thesis are as follows:

1. Optimization of scaling invariance: Log-Polar Exponent-Fourier Moments. We define a class of scaling and rotation-invariant orthogonal moments, named Log-Polar Exponent-Fourier Moments, by extending the classical Exponent-Fourier Moments to the log-polar coordinates. Moreover, we develop a new framework for computing the Log-Polar Exponent-Fourier Moments with better time complexity, accuracy and numerical stability. In short, the proposed approach has four advantages: scaling invariance, speed, accuracy and stability.

2. Optimization of speed and accuracy: fast and high-precision computation strategy for Generic Polar Complex Exponential Transform. We design a fast, accurate and numerically stable generic calculation algorithm, associated with the Generic Polar Complex Exponential Transform and other well-known harmonic function-based moments. In addition, we define Quaternion Generic Polar Complex Exponential Transform for color image representation. As for application, we propose a color image zero-watermarking approach based on the above powerful tools. It achieves better comprehensive performance than state-of-the-art methods.

3. Optimization of robustness and discriminability: Mixed Low-order Moment Feature based on Fractional-order Jacobi-Fourier Moments. We innovatively point out that, by strengthening the spatial structure information, it is expected to mitigate the contradiction between the robustness and discriminability of moment-based descriptor. We first define a new set of generic orthogonal moments, called Fractional-order Jacobi-Fourier Moments, which is a generic version of many existing classical and fractional-order moments. We then develop a novel framework to improve both the robustness and discrimination power of image representation, named Mixed Low-order Moment Feature, by fully exploiting the time-frequency analysis property of Fractional-order Jacobi-Fourier Moments. According to the extensive theoretical analysis, experimental results and a real-world application, the superior performance of our proposed scheme for robust and discriminative image representation is clearly proved.

One major contribution of this thesis lies in the generic nature of the proposed methods. Our research provides several new clues for researchers on the related research fields. At the same time, these methods have strong application potential in many important applications of computer vision and pattern recognition.

Key Words： Digital Image; New Orthogonal Moments; Geometric Invariance; Fast Computation; Zero-Watermarking