Moment–Based Image Watermarking Principles, Perspectives, and Challenges

E.D. Tsougenis
Democritus University of Thrace, Greece

G.A. Papakostas
Eastern Macedonia and Thrace Institute of Technology (EMaTTech), Greece

D.E. Koulouriotis
Democritus University of Thrace, Greece

INTRODUCTION

The unprecedented raise of the digital media distribution caused by the wide use of mobile devices and cyber space generates numerous concerns strongly connected with media *security* and copyright protection. The authenticity of all kinds of media such as image, video, sound or text remains a hot topic of rising interest. Researchers are highly motivated especially by the daily untrusted exchange/sharing of huge number of images lacking of protection and try to bring forth solutions that partially cover specific needs. During the last decade, the progress in image *security* area is increasing by the significant discovery of the watermarking process. Watermarking aims to ensure the integrity, authority and authenticity of images by incorporating information for further identification. According to Hartung & Kutter (1999) a watermark is a non-removable digital code, robustly and imperceptibly embedded in the original (host) data, which contains information about the origin, status, and/or destination of the data.

The present article focuses on *image watermarking* that tries to adopt and takes advantage of the transform domain coefficients' properties, regarding to a successful image protection and authentication. The major question that rises through this area is why a watermarking method should use the transform domain coefficients to "seal" their significant information within the media. The basic reason is that the specific domain manages to better capture the characteristics of the Human Visual System (HVS) (Moon et al., 2007) leading to high visual quality watermarked images. Specifically, the low order coefficients describe the coarse part of the content in contrast with the higher order that describe the image details. As a matter of fact, middle order coefficients constitute a safe solution (Ahmidi & Safabakhsh, 2004) for information embedding reducing the risk of original content's manipulation.

The selection of the proper coefficients is strongly connected with the basic requirements of a successful *image watermarking*. An advanced ideal *image watermarking* method should satisfy all four basic requirements of robustness, imperceptibility, capacity and complexity. As a matter of fact, a simple implemented/fast (low complexity) watermarking method should incorporate the maximum allowed amount of information (high capacity) to the host image according to the perceptual redundancy (high imperceptibility) surviving also any geometric or signal processing attacking condition (high robustness). As illustrated in Figure 1, an interrelationship within the pre-mentioned requirements exist in watermarking algorithms i.e. a simple raise of the embedded information (capacity) may lead to degradation of the image quality (imperceptibility) or method's defense against malicious tasks (robustness). The specific representative example partially describes the traditional tradeoff existing in *image watermarking* community where uncontrollable manipulations regarding to one requirement's enhancement possibly leads to an alongside degradation of another one. Therefore, a fair solution to this conflict lies between the alongside satisfaction of the basic requirements (Figure 1) and since now is considered as a quite challenging task. Nevertheless, a high qualified

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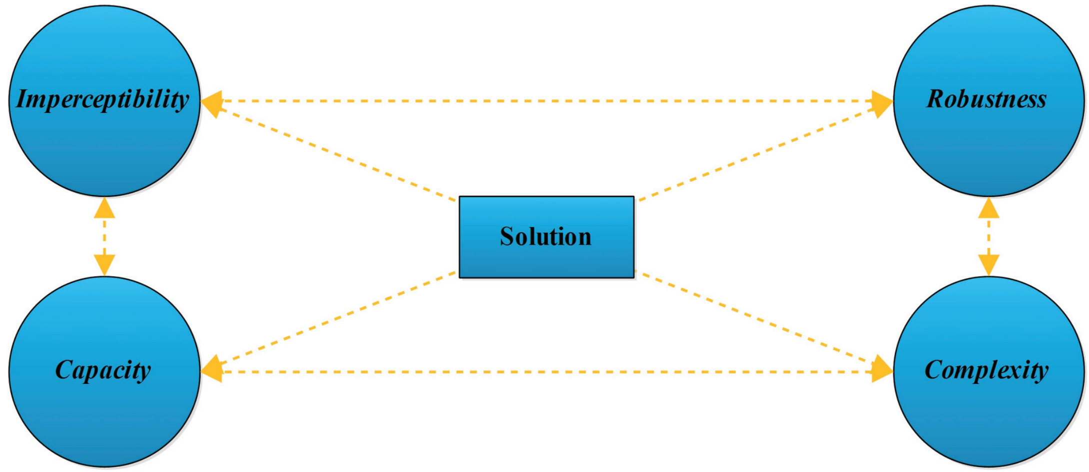
Figure 1. A tradeoff between basic watermarking requirements



domain proved during the last decades (Tsougenis et al., 2012), named as "*image moments*" may alongside satisfy all requirements and constitute the future trend in image *security*.

The present article manages to strictly examine the moment-based watermarking prospects by different perspectives including performance, open issues and latest trends/applications. The article is organized as follows: Section 2 presents the background of the most traditional and recently introduced moment families. In Section 3, a number of significant moment-based *image watermarking* methods are briefly discussed. During Section 4, a typical moment-based method is analyzed through its basic steps. In Section 5 the open issues in moment-based watermarking topic are presented. Finally, conclusions and proposals for future work are discussed in Section 6.

BACKGROUND

Image moments are region-based descriptors that correspond to the projection of the image on a specific polynomial base, where the type of the polynomials gives the name to the specific moment family. The computation of a single moment comprises a repetitive process of polynomials evaluation for each image's pixel (Equation 1). Theoretically, the inverse process should lead to a reconstructed image identical to the original one with respect to the maximum order value (Equation 2). The major categories of the commonly applied moment families are presented hereafter.

Geometric Moments

The first introduced family generation consists of the geometric moments where their projection base is defined by "xy" monomials of several orders. However, their base is not orthogonal and therefore their information redundancy is very high.

Continuous Moments

Teague (1980) introduced the Zernike (ZMs), Pseudo-Zernike (PZMs) and Legendre (LMs) moments which are orthogonal and manage to overcome the geometric moments' drawback of redundancy and stay invariant under flipping and rotation attacks. Nevertheless, their computational instabilities (Liao & Pawlak, 1998) especially in higher order values lead to undesirable behaviors. ZMs, PZMs and LMs along with the Fourier-Mellin (OFMMs) moments introduced by Sheng & Shen (1994) are the most widely referred in the literature moments which are defined in the continuous space. Meanwhile, Polar Harmonic Transforms (PHTs), one of the most recently introduced transformations (Yap et al., 2010), have the ability to generate rotation invariant features with no numerical instabilities through higher order values, in a simplified computation framework. PHTs are further divided into three categories, the Polar Complex Exponential Transform (PCET), the Polar Sine Transform (PST) and the Polar Cosine Transform (PCT).

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