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Towards adaptivity of image watermarking in polar harmonic transforms domain

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ABSTRACT

A successful image watermarking method is identified by the high performance in a number of basic requirements such as robustness, imperceptibility, capacity and complexity. Enhancement could be achieved through an adaptive process that handles individually the embedded information to each coefficient. The specific need for adaptivity is justified through this work by a set of experiments applied to the traditional moment families (Zernike, Pseudo-Zernike, Tchebichef), where more optimum results are produced. The extensive study of Polar Harmonic Transforms' (PHTs) significance parameters (order, magnitude) along with the use of a generalized embedding strength calculation process, easily applied to circularly orthogonal transformations, leads to a promising solution of the adaptivity issue. Experimental results justify that the proposed image watermarking scheme clearly outperforms the compared methods in terms of robustness, capacity and complexity and promotes the traditional schemes to a next generation of moment-based image watermarking.

1. Introduction

Nowadays, information security is a cutting edge research field where crucial issues arise and researchers try to bring forth solutions through the development of advanced and effective systems. The scientific community came up with watermarking process in order to satisfy information security requirements. Therefore, a watermark constitutes a non-removable digital code, robustly and imperceptibly embedded in the original (host) data providing information about the origin, status, and/or destination of the data [1]. In order to highly secure the important information through a watermarking process, a number of requirements should be taken into consideration, analyzed hereafter.

1.1. Preliminaries

An advanced successful image watermarking method should satisfy the basic requirements of robustness, imperceptibility, capacity and complexity. The interrelationship of the specific requirements (Fig. 1) leads to a tradeoff which can be easily comprehended by their basic corresponding definitions. Robustness deals with the property of the watermark resisting to multiple geometric or signal transformations applied on the watermarked image. However, the watermark insertion process should affect the pixel values (intensities) based on the Human Visual System (HVS) [2] satisfying the requirement of imperceptibility. Capacity refers to the maximum amount of information the algorithm can embed into the host image reaching the imperceptibility limit. The capacity factor is still an open issue with researchers trying to determine and raise it [3–6], since the existence of applications (e.g. medical image watermarking [7]) that secure large amounts of information demands it. All the pre-mentioned requirements should be alongside satisfied with the least computational effort and time, keeping the complexity in low levels.

The tradeoff produced by the interrelationship of the basic requirements is a crucial issue to both spatial [8] and transform domain (gyrator transform [9], Fourier transform [10], bandelet transform [11]) watermarking methods. For example, high capacity levels can be achieved by the spatial domain methods [12,13] in contrast to the transform domain methods that satisfy robustness. Although the aforementioned basic requirements are interrelated and quite conflicted, the present work manages to simultaneously enhance their performance.

1.2. Related work

A new era has begun in image watermarking field with the use of image moments by the innovative method of Alghoniemy and Tewfik [14]. They incorporated Hu's seven moment invariants in watermarking systems in order to achieve robustness to RST

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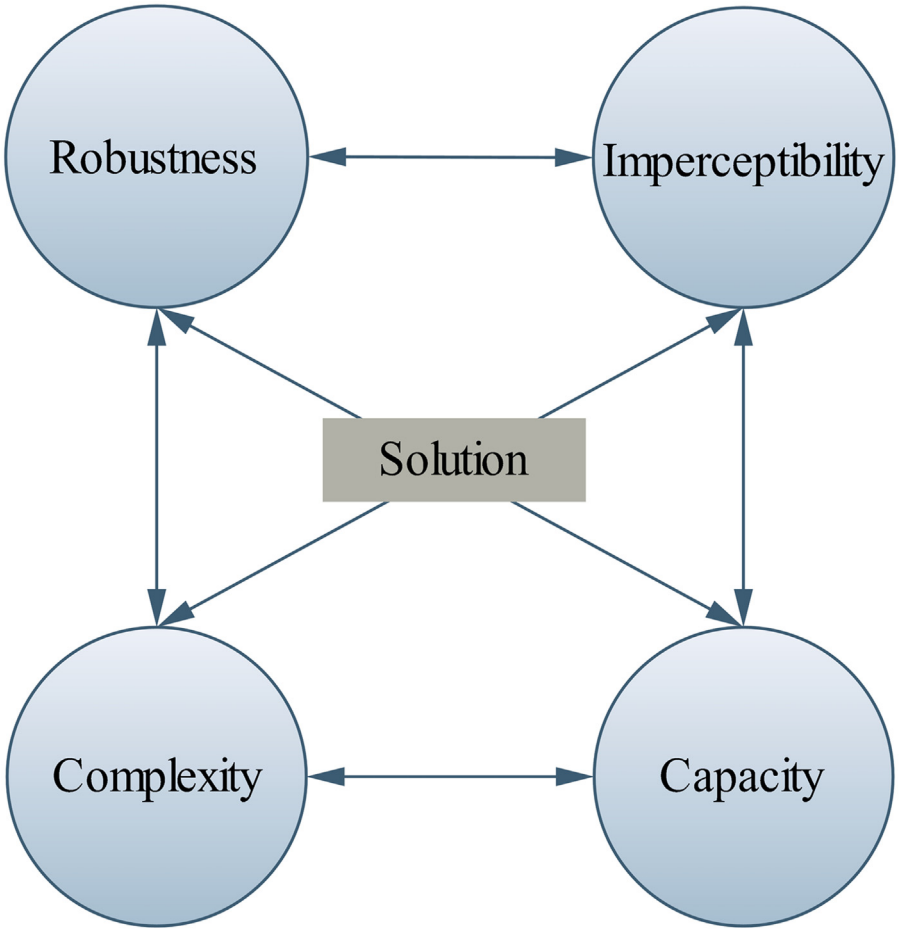

Fig. 1. A tradeoff display of basic watermarking requirements.

(Rotation, Scale and Translation) attacks. Xin et al. [15] inspired lots of recently published works by introducing the Dither Modulation (DM), a special form of quantization index modulation [16], which could assign one bit to one moment. Since then, numerous methods applying different moment families along with DM process have been designed [15–19] in order to satisfy the basic watermarking requirements previously analyzed. However, the majority of the moment-based watermarking methods applying DM do not take into consideration moments' significance or any HVS models resulting to significant deterioration of the image content or even lack of security.

Recently, researchers studying the HVS models managed to simulate the human mechanism applying it to image watermarking schemes. Numerous spatial domain methods applied the Noise Visibility Function (NVF) in order to identify embeddable regions (textures) avoiding edged areas where alterations are more recognizable [20]. Although, the specific schemes satisfied the imperceptibility requirement, they could not deal with flat areas [21]. Delaigle [22] built a HVS masking based on Fourier Transform (FT) and managed to locally embed information by calculating the area energy. However, the quality of the specific watermarked images stays at low levels due to appearance of the ring effect at regions where edges exist. Apart from FT, the rest of two-dimensional domains needed a process that takes into consideration the HVS in order to embed their information. Watson [23] proposed a mathematical model that identifies the noise detection thresholds by estimating the Just Noticeable Differences (JND) of the original and the watermarked image. Although, the specific model was applied in DWT [24] and DCT [25], regarding to further enhancement of the imperceptibility requirement, still the specific watermarking methods lack of robustness under geometric distortions.

The development of a robust watermarking scheme that could adaptively embed information remains an open issue in image watermarking field. To the best of our knowledge, no state-of-the-art moment-based method [15–19] takes into consideration the adaptivity issue. Commonly, the watermark information is embedded by adjusting empirically the Δ parameter (embedding strength) of DM,), an approach that does not produce the optimum results. The proposed work manages to handle the adaptivity issue from a completely different kind of mathematical and experimental point of view. Inspired by the traditional moment watermarking processes applying the DM, this novel proposed scheme presents a calibration process for quantization step Δ in combination with the recently introduced PHTs. The specific combination not only manages to control the embedding strength of the watermark but also takes into consideration the significance of the specific coefficients.

The adaptivity issue for moment-based watermarking methods is experimentally justified with the use of a Genetic Algorithm (GA) in Section 2. In Section 3, a solution to this existent systems' weakness along with the corresponding experiments is presented. In Sections 4 and 5, the proposed watermarking method is introduced step by step and its performance is investigated under common signal processing and geometric attacks along with a results' analysis based on crucial parameters, respectively. In Section 6, a discussion on limitations and restrictions of the proposed method is also presented. Finally, the main conclusions are being summarized in Section 7.