Introduction to the Special Issue on Authentication, Copyright Protection, and Information Hiding

THE PROLIFERATION of digital documents, multimedia processing tools, and the worldwide availability of Internet access have created an ideal medium for copyright fraud and uncontrollable distribution of multimedia content. To deal with this problem, conventional analogue watermarking technology has been adapted to digital media as a tool to achieve copyright protection, ownership trace, authentication, or information hiding. Over the last few years, mathematical models, signal processing algorithms, and methods from information theory have been used to generate a gamut of watermarking schemes targeting one or more of these tasks.

Although this is a relatively young and, as of yet, a largely unexploited field, digital watermarking has emerged as a fundamental technology leveraging developments and trust in multimedia applications. After an initial wave of excitement, which led to the development of many techniques, some of them making overoptimistic claims, the research community has arrived at a point where the limitations and properties of these methods have been well studied and understood. As a consequence of careful examination of the technical requirements for specific applications, new schemas tailored to user needs and with ability to survive attacks better have been developed.

The objective of this Special Issue is to report recent achievements of researchers working on watermarking for different applications and under well-specified requirements. The Special Issue is organized in five parts according to the properties of the proposed methods and the addressed applications, followed by a Transactions Letters section.

The first part contains six papers targeting one of the most challenging applications: that of robust watermarking for copyright protection of images and video. The first paper, by Simitopolus *et al.*, uses two generalized Radon transformations to deal with geometric attacks. The proposed technique resists rotation and scaling exploiting the invariance properties of the transform. Translation invariance is achieved through localization and estimation of feature points in the image. Wong *et al.* present a framework comprising three watermarking techniques for still images: single watermark embedding using two secret keys, multiple watermark embedding targeting minimization of the induced distortion, and iterative watermark embedding which is robust against JPEG compression. The technique proposed by Zheng *et al.* also addresses robustness against geometric transformations. The watermark is embedded in the log-polar mapping of the magnitude of the Fourier coefficients of the original image. Image quality is preserved by avoiding the computation of the inverse log-polar transformation and exploiting phase correlation in the watermark extraction step. The paper by Kim *et al.* also focuses on invariance to rotation, translation, and scaling using Zernike moments. The properties of their watermarking approach correspond in several aspects to the invariance properties of the Fourier–Mellin transform. However, it offers higher flexibility for specific applications. The paper by Kang *et al.* describes a method robust to both affine transforms and JPEG compression. A discrete-wavelet-Fourier composite scheme is used to embed synchronization templates in the Fourier domain while the actual watermark signal is embedded in the qavelet domain. Alattar *et al.* present an advanced framework based on state-of-the-art technology to achieve robust watermarking in low bit-rate video. Their approach embeds watermarks in MPEG-4 streams and is suitable for video transmitted over broadband Internet.

Complementing these papers, the second part of the Special Issue consist of a paper dedicated to audio watermarking. Liu and Inoue use a small number of sinusoids as watermarks. The sinusoids are modulated with bipolar pseudorandom sequences. As a consequence, it is straightforward to use psycho-acoustic shaping for the sinusoids and control them according to the targeted application.

One important aspect of digital watermarking is the capacity or amount of data that can be embedded into a host signal. Most data-hiding techniques exploit perceptual masking to optimize capacity. Clearly, a higher capacity is achieved considering the inherent properties of different media when applying perceptual masking. The information contained in compressed media like JPEG images is strongly decorrelated. Thus, the capacity of compressed and uncompressed media is different and consequently perceptual masking is performed using different properties of the host data. The third part of the Special Issue presents two papers on this aspect. Wong and Au describe an approach to estimate capacity in JPEG-to-JPEG image watermarking. They use the human visual system model to estimate the JPEG-to-JPEG data hiding capacity. Their capacity-estimation technique does not assume any specific watermarking method. The paper by Wu tackles one of the main problems of quantization-based information hiding: namely, the problem of security. If a data-hiding technique is not secure, an adversary could change the embedded information rendering the approach useless. In their paper, an efficient quantization-based information-hiding scheme is described. High security is achieved using look-up table mapping and robustness is achieved through distortion compensation.

A completely different application of watermarking technology is verification of the authenticity of media. This application looks at the other extreme of the robustness-imperceptibility curve. The watermark should appear invisible but fragile, i.e., it should be destroyed by any attempt to modify the watermarked data. In the fourth section, the paper by Izquierdo and Guerra targets authentication. It is based on a

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rather unconventional approach: the extremely high sensitivity of ill-posed operators to any change in the input data is turned into the tool to achieve fragile watermarking for secure image verification. The ill-posed operator of concern is based on a highly ill-conditioned matrix interrelating the watermark and the original image. Authentication is achieved by solving the least-squares problem associated with the underlying linear operator.

The fifth part of the Special Issue contains two papers dealing with the watermark of non-conventional content. In their work, Garcia and Dugelay introduce a texture-based watermarking technique for 3-D video objects. The embedded watermark can be recovered if the 3-D object and the lighting conditions are known by the watermark detector. Their approach opens new ways to watermark 3-D objects adding even more diversity to the application of watermarking technology. This part closes with a paper describing a low-complexity noise-balanced error diffusion technique to watermark error-diffused images. In their paper, Pei and Guo propose a kernels-alternated error diffusion to watermark halftone images. They use a cumulative squared Euclidean distance criterion to decode the watermark. Additionally, a lookup table technique is proposed to speed up the decoding process.

The last section of this Special Issue includes two Transactions Letters which revisit the properties of the second and fourth sections, respectively. In the first letter, Kim and Choi describe an echo-hiding technique based on double kernels. Complementary to previously reported echo-hiding schemes, they embed virtual echoes that violate causality. The double echoes with forward and backward kernels have a more dominant cepstral peak than those with single kernels. This property is exploited to achieve higher robustness and imperceptibility than conventional methods. In the second letter, Tian targets authentication and reports a technique for reversible data embedding in digital images. He uses difference expansion to achieve high capacity while keeping distortion low. His technique can be used for authentication applications when the original undistorted image needs to be recovered.

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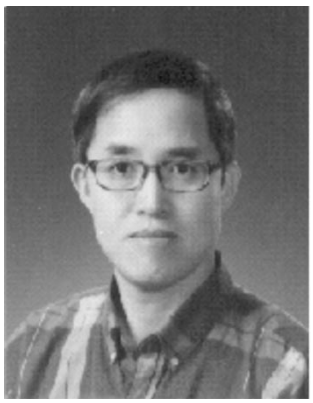

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Dr. Kim has served as a Guest Editor of the IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY. He was also the founder of the International Workshop on Digital Watermarking (IWDW) and a Co-Chair of the Technical Program Committee of the workshop in 2002.

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