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Hiding Color Watermarks in Halftone Images using Maximum-Similarity Binary Patterns

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Abstract

This paper presents a halftoning-based watermarking method that enables the embedding of a color image into binary black-and-white images. To maintain the quality of halftone images, the method maps watermarks to halftone channels using homogeneous dot patterns. These patterns use a different binary texture arrangement to embed the watermark. To prevent a degradation of the host image, a maximization problem is solved to reduce the associated noise. The objective function of this maximization problem is the binary similarity measure between the original binary halftone and a set of randomly generated patterns. This optimization problem needs to be solved for each dot pattern, resulting in processing overhead and a long running time. To overcome this restriction, parallel computing techniques are used to decrease the processing time. More specifically, the method is tested using a CUDA-based parallel implementation, running on GPUs. The proposed technique produces results with high visual quality and acceptable processing time.

Keywords: Color embedding, Halftone, Color Restoration, Watermarking, Enhancement

1. Introduction

Printing an image consists of performing a conversion from digital to analog, while scanning an image involves a conversion from analog to digital. These two processes may add several types of distortions to the original content, which include geometric distortions (rotation, scaling, cropping, etc.), color distortions, and noise. These distortions are a consequence of several factors, like, for example, the process of conversion from digital images to halftone representations performed just before printing [1].

The halftone representation is generated using a mathematical model that produces the illusion of colors by using a combination of colored dot patterns [2]. Due to the low-pass property of the Human Visual System (HVS), halftone images are perceived as continuous tone images when viewed from a distance. Many different halftoning methods have been developed over the years, like for example Direct Binary Search (DBS) [3, 4], Ordered Dithering (OD) [5, 6], Error Diffusion (ED) [7, 8, 9], and Dot Diffusion (DD) [10, 11, 12]. Although there is a great diversity of image halftoning methods, these methods insert distortions during the quantization process that converts multi-level images (color or grayscale) into binary (halftone) images.

Scanner devices read the printed halftone and restore a multi-level image via an inverse halftoning algorithm [13, 14]. Therefore, the scanning process corresponds to the inverse of the printing process. Although the inverse halftoning algorithm is able to recover an approximation of the intensity levels of the original image, the reconstructed image often presents distortions like noise [15] and blurring [16].

Although digital watermarking is a well-established area that mostly targets color and grayscale images (wide range of intensity levels) [17, 18, 19], *hardcopy* watermarking is still a challenging area. In particular, distortions introduced by the print-and-scan (PS) process make the task of transmitting data using hardcopy watermarking more

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