Fuzzy Inference Rule Based Reversible Watermarking for Digital Images

Ruchira Naskar and Rajat Subhra Chakraborty

Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur
{ruchira,rschakraborty}@cse.iitkgp.ernet.in

Abstract. The last couple of decades have seen rapid growth of research interest in the field of reversible watermarking of multimedia data. The primary aim of reversible watermarking is to restore the original cover data content, with zero residual distortion, after watermark extraction. Such a feature is desirable in industries dealing with highly sensitive data, e.g. in military, medical and legal industries. In this paper we propose a reversible watermarking algorithm for grayscale images, based on fuzzy inference mechanism based pixel prediction method. We apply a thresholding technique on the prediction errors to embed the watermark bits. Our experimental results show that the quality of the watermarked cover data, produced by the proposed method, is considerably high compared to the other state–of–the–art schemes.

Keywords: Digital watermarking, fuzzy inference rules, pixel correlation, pixel prediction, reversible watermarking.

1 Introduction

Digital watermarking [1] is the act of embedding some valuable information, into some form of digital multimedia data, such as, text, image, audio or video. The purpose of digital watermarking is content protection and authentication of multimedia data. The valuable information, known as the *watermark*, is usually a secret information which is hidden into the *cover data* in form of a binary bitstream. Some of the application domains of digital watermarking are copyright control, content authentication, ownership proof, broadcast monitoring etc.

In this paper we deal with a special class of digital watermarking, called *reversible watermarking* [2–6]. Reversible watermarking belongs to the class of *fragile watermarking*, where the watermark is used for authentication of the cover data. A fragile watermark is destroyed even due to minimal modification of the watermarked cover data, and hence the authentication of the cover data fails at the receiver side. Digital watermarking, in general, causes the cover data to get distorted due to watermark embedding. Although this cover data distortion is perceptually negligible in ideal cases, it is unacceptable in industries dealing with highly security sensitive data, such as medical, military or legal industries. In *reversible watermarking*, the distortion of the cover data caused due to watermark embedding can be removed entirely after watermark extraction. The cover

V. Venkatakrishnan and D. Goswami (Eds.): ICISS 2012, LNCS 7671, pp. 149–163, 2012.

data can be restored back to its original form, bit–by–bit, thus allowing zero residual distortion after watermark extraction.

In this paper we propose a reversible watermarking technique for digital images based on *fuzzy inference mechanism* [7]. Although a few watermarking schemes [8–10] have utilized fuzzy logic for their implementation in the past, none of them were meant to achieve reversibility of cover data. Fuzzy reasoning has been widely used for more than a decade to process image data [11–13]. In [11], the author has presented a study of FIRE (Fuzzy Inference Ruled by Else–action) operators, used to evaluate and hence process image data, to enhance a noisy image. FIRE operators are special fuzzy models, working on the principle of fuzzy if–then–else reasoning. In [12], the author has proposed fuzzy rulebases for image denoising using a non–linear filter, as well as for edge detection in an image. Other notable fuzzy inference rule based image processing techniques can be found in [13, 14].

In all standard images, the neighboring pixels usually exhibit high degree of spatial correlation in grayscale values. This feature of standard images has been utilized in the proposed reversible watermarking algorithm to predict some of the pixel values from their neighboring pixel values, using fuzzy reasoning. The pixel predictions give rise to *prediction errors*, which are used to embed the watermark. In any reversible watermarking algorithm, the most desirable feature apart from cover image reversibility is *watermark transparency*, i.e. low distortion of the watermarked image [3–6]. To keep the watermarked image distortion low, in any prediction based reversible watermarking algorithm, the prediction technique needs to be accurate enough to obtain very low (close to zero) prediction errors. Our experimental results prove that the proposed *fuzzy inference mechanism based prediction* is an extremely accurate pixel prediction technique for a standard image. In addition, the watermarked image distortion is considerably low, compared to the state–of–the–art.

Rest of the paper has been organized as follows. In Section 2 we have presented the theory behind fuzzy inference mechanism based pixel prediction. The proposed reversible watermarking algorithm has been presented in details in Section 3. Experimental results have been presented in Section 4. Finally, we conclude in Section 5.

2 Fuzzy Inference Mechanism Based Prediction

In the proposed reversible watermarking algorithm we predict the cover image pixel values from their surrounding pixel values, using fuzzy inference mechanism, and embed the watermark bits into the prediction errors.

To predict the value of a pixel x from its surrounding, we first compute its differences with its neighboring pixels $n_1, n_2, \ldots$:

$$\Delta x_1 = n_1 - x;\ \Delta x_2 = n_2 - x;\ \cdots \tag{1}$$

Then, we add a *correction term* Δx to x:

$$x' = x + \Delta x \tag{2}$$