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Hardware implementation of a novel water marking algorithm based on phase congruency and singular value decomposition technique

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ABSTRACT

The effortless accessibility of digital information and the simplicity of the digital systems have left the contents over the digital media extremely insecure. Digital watermark based information hiding is a prospective means for copyright protection, authentication, integrity verification and intellectual property right protection. Phase congruency technique works on the principle that perceptually significant image features have effect at spatial locations, where the essential Fourier components are maximally in phase with one another. An adaptive digital watermarking algorithm for better performance in multi-parametric solution space is developed here for hiding the copyright information by means of phase congruency and singular value decomposition supported information hiding technique. Performance evaluation of the algorithm is performed using simulation in Matlab in terms of Peak Signal to Noise Ratio, Structural Similarity Index Metrics, and Normalized Cross correlation index. Hardware realization up to the register transfer logic schematic level has been performed using high performance field programmable gate array board. The device utilization is 26% only, the dynamic power consumption of the circuit is 5.029 mW and delay after clock is 1.539 ns only. The experimental analysis establishes better robustness of the proposed algorithm as it stands against various attacks along with better data hiding capacity.

1. Introduction

The enormous popularity of Internet along with digital consumer devices as digital cameras, scanners etc, has become an indispensable part of people's living. At the same time as the popularity increases, access and storage of digital information become very easier. The need for mechanisms to protect such information is undeniable. From viewpoint of copyright protection, authentication and integrity verification of digital information, the digital watermarking is a very important technique which embeds watermark information into a digital signal in such a manner that it must be intricate to exterminate [1]. The aim of this work is to develop an innovative algorithm which has sufficient resistance against various attacks and to implement it by hardware. The requirements of watermarking schemes mainly focus on imperceptibility, robustness and embedding capacity. But they continuously conflict with each other [2]. It means that simplistic algorithm/watermarking methods are no longer adequate and it has become necessary to develop new ideas and algorithms to avoid conflicts. The phase congruency, which works on the principle that 'perceptually significant image features have effect at spatial locations where the essential Fourier components are maximally in phase with one another', is a prospective technique for copyright protection, authentication and integrity verification as well as intellectual property right protection [3,4].

Experiments on various attacks have been reported to be effective against watermarking methods. Geometric distortion is known as one of the most difficult attacks to resist. In such special cases, much attention is required to reconfigure the image and extract the watermark information from the watermarked location in the correct order. In that crucial case, proposed phase congruency scheme has proved itself to be very useful tool. R.Z. Liu et al. have also explained about SVD based image watermarking scheme, which gives secure and robust owner identification [5]. The main properties of SVD image processing are the singular values of an image have good stability and Singular values represent intrinsic algebraic image properties. The incorporation of newly introduced concept, phase congruency helped to reduce the payload and enhanced the capacity maintaining the standard correlation with the watermark. The phase congruency is a useful means for the edge and corner detection [6]. The corner map refers to a strict subset of the edge map, which is an important

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feature of this method. The highly phase congruent position are the most suitable position for the watermark to embed as it is less prone to be affected by noise attack [7]. Peter Kovesi et al. has described the measure of phase congruency and developed it in their research paper [4]. They have used the term factor that presents the weights for frequency spread. Phase-congruency is used in this work to minimize the number of data for watermarking. Feature points that are found by the phase congruency corner detector are used to locate the positions of watermark [3]. Hardware, based on the watermarking unit can be easily integrated with digital camera, graphics processing units and other necessary electronic devices [9–12]. Hardware implementation of watermarking algorithm also aims an optimized design to incorporate a small, fast, and potentially cheap watermarking unit. FPGA based watermark unit consumes lesser power than software, which requires a general purpose processor. For small power applications, hardware based watermarking unit is ideal. The hardware has been implemented as a soft core expressed in the high syntax structural hardware description language, VHDL. The soft core can be modified as algorithm changes and can be reconfigured into new silicon technology without any delay, as it is technology independent design code. Inclusion of any modification in design due to modification in algorithm is very simple and can be easily integrated without changing the present developed hardware which justifies the name 'adaptive'. Rest of the paper is organized as: Section 2 describes the phase congruency scheme for detection of corner and edges of an image. In Section 3, Experimental results from Matlab environment are included. Design and VLSI Implementation using FPGA have been described with suitable test bench waveforms and RTL schematics in Section 4. Finally, we conclude in Section 5.

2. The phase congruency scheme for detection of corner and edges of an image

In Phase congruency, the feature points are more related to phase than the amplitude of a signal. Hence, phase congruency reflects the frequency domain behavior of an image. The phase congruency results in variant quantities to measure the image feature and it remains constant throughout the image. The dimensionless value of Phase Congruency varies between 0 and 1, where 1 indicates most significant feature and 0 indicates not significant. Local energy model [3,4] postulates that features are perceived in the location of high phase congruency. The watermark data in this project is an image of a fingerprint which is assumed to be a unique watermark data. The watermark data is embedded using well known SVD technique in the phase congruency mapping points on the host image. It is perceived that the visual quality of the image has not deteriorated to an unacceptable level on embedding the data. The watermark is invisible and the algorithm is categorized as a non-blind digital watermarking algorithm as original image is used during the detection process to detect the watermark. A highly robust phase-congruency and SVD based digital watermarking algorithm has been implemented in this work. SVD is basically a factorization of a real or complex matrix. Usually, for an $m \times n$ real or complex matrix the singular value decomposition, M is the factorization of the form, $M = USVT$, Where U is an $m \times m$ real or complex unitary matrix, S is an $m \times n$ rectangular diagonal matrix with non-negative real numbers on the diagonal and VT is an $n \times n$ real or complex unitary matrix. The operational block diagram for the embedding mechanism is shown in Fig. 1. We have designed phase congruency block to incorporate the feature point extraction algorithm and the watermark embedding block incorporating the watermark embedding algorithm.

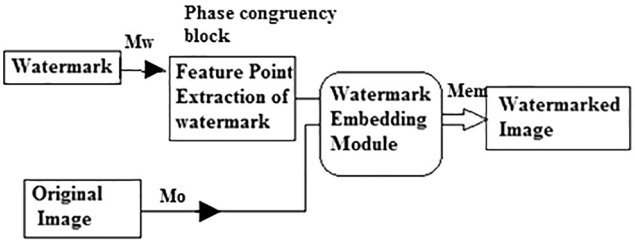

Fig. 1. Proposed watermark embedding scheme.

2.1. Feature point extraction algorithm

We determine the feature points of the original watermark image for embedding purpose, henceforth instead of the original image; watermark is the feature region of the original watermark. This procedure is adopted to reduce the amount of bits required for watermarking on the original image. Our algorithm is mostly suitable for fingerprinting application as different fingerprints have their own unique features. So, it can be applied for copyright protection of multiple owners, having their unique watermark. The detailed method for choosing the points or regions for hiding the information is based on the following steps:

Algorithm:

Step 1:	Find the phase congruent map having same dimension of the watermark
Step 2:	Find the total number of non-zero points of the phase congruent map
Step 3:	Let n^2 number of non-zero points are determined. Now these non-zero locations are utilized to fetch gray scale values in particular order from the original watermark into a matrix M_w of dimension $n \times n$
Step 4:	If $n \times n$ is the order of the watermark matrix, then n^2 number of points in the original image is required to embed the data. Feature map of the original image is determined. Numerical value of n^2 is within limit and justified
Step 5:	The particular value of phase congruency of the host image which is mapped between 0 and 255 is determined above which the number of points are exactly or just exactly above the n^2 value. [Initialize a Phase congruency value G = 128]
Step 6:	If the number of points is greater than n^2, then n^2 number of locations are fetched in a particular order which increases the security. It depends on the amount of feature points of the host
Step 7:	The Gray Scale data of the host image from this n^2 number of locations are fetched to a matrix, M_o

For calculating phase congruent map we have used Peter Kovesi method [3,4]. After finding the phase congruent map we are calculating the total number of non zero points of the phase congruent image where all the points in the phase congruent map vary from '0' to '1'. In Step 3, we create a closest square matrix for the watermark non zero points taking from the phase congruent image of the original watermark in a particular order. Let, n^2 number of points are determined. Now these particular locations of non zero points are utilized to fetch gray scale value from original watermark in the same order. Now, if $n \times n$ is the order of the watermark matrix then n^2 number of points in the original image is required to embed the data. For that, feature map of the original image is determined.