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11th International Work-Conference
on Artificial Neural Networks, IWANN 2011
Torremolinos-Málaga, Spain, June 8-10, 2011
Proceedings, Part I

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Preface

We are proud to present the set of final accepted papers for the eleventh edition of the IWANN conference "International Work-Conference on Artificial Neural Networks" held in Torremolinos (Spain) during June 8–10, 2011.

IWANN is a biennial conference that seeks to provide a discussion forum for scientists, engineers, educators and students about the latest ideas and realizations in the foundations, theory, models and applications of hybrid systems inspired by nature (neural networks, fuzzy logic and evolutionary systems) as well as in emerging areas related to the above items. As in previous editions of IWANN, this year's event also aimed to create a friendly environment that could lead to the establishment of scientific collaborations and exchanges among attendees. Since the first edition in Granada (LNCS 540, 1991), the conference has evolved and matured. The list of topics in the successive Call for Papers has also evolved, resulting in the following list for the present edition:

1. **Mathematical and theoretical methods in computational intelligence**: Mathematics for neural networks; RBF structures; Self-organizing networks and methods; Support vector machines and kernel methods; Fuzzy logic; Evolutionary and genetic algorithms
2. **Neurocomputational formulations**: Single-neuron modelling; Perceptual modelling; System-level neural modelling; Spiking neurons; Models of biological learning
3. **Learning and adaptation**: Adaptive systems; Imitation learning; Reconfigurable systems; Supervised, non-supervised, reinforcement and statistical algorithms
4. **Emulation of cognitive functions**: Decision making; Multi-agent systems; Sensor mesh; Natural language; Pattern recognition; Perceptual and motor functions (visual, auditory, tactile, virtual reality, etc.); Robotics; Planning motor control
5. **Bio-inspired systems and neuro-engineering**: Embedded intelligent systems; Evolvable computing; Evolving hardware; Microelectronics for neural, fuzzy and bioinspired systems; Neural prostheses; Retinomorphic systems; Brain–computer interfaces (BCI) nanosystems; Nanocognitive systems
6. **Hybrid intelligent systems**: Soft computing; Neuro-fuzzy systems; Neuro-evolutionary systems; Neuro-swarm; Hybridization with novel computing paradigms: Qantum computing, DNA computing, membrane computing; Neural dynamic logic and other methods; etc.
7. **Applications**: Image and signal processing; Ambient intelligence; Biomimetic applications; System identification, process control, and manufacturing; Computational biology and bioinformatics; Internet modeling, communication and networking; Intelligent systems in education; Human–robot interaction. Multi-agent systems; Time series analysis and prediction; Data mining and knowledge discovery

At the end of the submission process, we had 202 papers on the above topics. After a careful peer-review and evaluation process (each submission was reviewed by at least 2, and on average 2.4, Program Committee members or additional reviewer), 154 papers were accepted for oral or poster presentation, according to the recommendations of reviewers and the authors' preferences.

It is important to note that for the sake of consistency and readability of the book, the presented papers are not organized as they were presented in the IWANN 2011 sessions, but classified under 21 chapters and with one chapter on the associated satellite workshop. The organization of the papers is in two volumes and arranged following the topics list included in the call for papers. The first volume (LNCS 6691), entitled *Advances in Computational Intelligence. Part I* is divided into ten main parts and includes the contributions on:

1. Mathematical and theoretical methods in computational intelligence
2. Learning and adaptation
3. Bio-inspired systems and neuro-engineering
4. Hybrid intelligent systems
5. Applications of computational intelligence
6. New applications of brain–computer interfaces
7. Optimization algorithms in graphic processing units
8. Computing languages with bio-inspired devices and multi-agent systems
9. Computational intelligence in multimedia processing
10. Biologically plausible spiking neural processing

In the second volume (LNCS 6692), with the same title as the previous volume, we have included the contributions dealing with topics of IWANN and also the contributions to the associated satellite workshop (ISCIF 2011). These contributions are grouped into 11 chapters with one chapter on the satellite workshop:

1. Video and image processing
2. Hybrid artificial neural networks: models, algorithms and data
3. Advances in machine learning for bioinformatics and computational biomedicine
4. Biometric systems for human–machine interaction
5. Data mining in biomedicine
6. Bio-inspired combinatorial optimization
7. Applying evolutionary computation and nature-inspired algorithms to formal methods
8. Recent advances on fuzzy logic and soft computing applications
9. New advances in theory and applications of ICA-based algorithms
10. Biological and bio-inspired dynamical systems
11. Interactive and cognitive environments
12. International Workshop of Intelligent Systems for Context-Based Information Fusion (ISCIF 2011)

During the present edition, the following associated satellite workshops were organized:

1. **4th International Conference on Computational Intelligence in Security for Information Systems (CISIS 2011)**. CISIS aims to offer a meeting opportunity for academic and industry-related researchers belonging to the various vast communities of computational intelligence, information security, and data mining. The corresponding selected papers are published in an independent volume (LNCS 6694).
2. **International Workshop of Intelligent Systems for Context-Based Information Fusion (ISCIF 2011)**. This workshop provides an international forum to present and discuss the latest scientific developments and their effective applications, to assess the impact of the approach, and to facilitate technology transfer. The selected papers are published as a separate chapter in the second volume (LNCS 6692).
3. **Third International Workshop on Ambient-Assisted Living (IWAAL)**. IWAAL promotes the collaboration among researchers in this area, concentrating efforts on the quality of life, safety and health problems of elderly people at home. IWAAL papers are published in LNCS volume 6693.

The 11th edition of IWANN was organized by the Universidad de Malaga, Universidad de Granada and Universitat Politecnica de Catalunya, together with the Spanish Chapter of the IEEE Computational Intelligence Society. We wish to thank to the Spanish Ministerio de Ciencia e Innovacion and the University of Malaga for their support and grants.

We would also like to express our gratitude to the members of the different committees for their support, collaboration and good work. We specially thank the organizers of the associated satellite workshops and special session organizers. Finally, we want to thank Springer, and especially Alfred Hofmann, Anna Kramer and Erika Siebert-Cole, for their continuous support and cooperation.

June 2011

Joan Cabestany
Ignacio Rojas
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Hani Hagras	The Computational Intelligence Centre School of Computer Science and Electronic Engineering, University of Essex, UK
Francisco Herrera	Head of Research Group SCI2S (Soft Computing and Intelligent Information Systems), Department of Computer Science and Artificial Intelligence, University of Granada, Spain
Tom Heskes	Head of Machine Learning Group, Intelligent Systems Institute for Computing and Information Sciences (iCIS) Faculty of Science Radboud University Nijmegen, The Netherlands

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New Applications of Brain–Computer Interfaces

Francisco Pelayo	University of Granada
M.A. López Gordo	University of Granada
Ricardo Ron	University of Malaga

Optimization Algorithms in Graphic Processing Units

Antonio Mora	University of Granada
Maribel García-Arenas	University of Granada
Pedro Castillo	University of Granada

Computing Languages with Bio-inspired Devices

M. D. Jimenez-Lopez	University of Rovira i Virgili
A. Ortega De La Puente	Autonomous University of Madrid

Computational Intelligence in Multimedia

Adriana Dapena	University of A Coruña
Julio Bregáins	University of A Coruña
Nicolás Guil	University of Malaga

Biologically Plausible Spiking Neural Processing

Eduardo Ros	University of Granada
Richard R. Carrillo	University of Almeria

Video and Image Processing

Enrique Domínguez	University of Malaga
José García	University of Alicante

Hybrid Artificial Neural Networks: Models, Algorithms and Data

Cesar Hervás	University of Cordoba
Pedro Antonio Gutiérrez	University of Crdoba

Advances in Machine Learning for Bioinformatics and Computational Biomedicine

Paulo J.L. Lisboa	Liverpool John Moores University
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Leonardo Franco	University of Malaga

Biometric Systems for Human–Machine Interaction

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Data Mining in Biomedicine

Julián Dorado	University of A Coruña
Juan R. Rabuñal	University of A Coruña
Alejandro Pazos	University of A Coruña

Bio-inspired Combinatorial Optimization

Carlos Cotta Porras	University of Malaga
Antonio J. Fernández Leiva	University of Malaga

Applying Evolutionary Computation and Nature-Inspired Algorithms to Formal Methods

Ismael Rodríguez	Complutense University of Madrid

Recent Advances on Fuzzy Logic and Soft Computing Applications

Inma P. Cabrera	University of Malaga
Pablo Cordero	University of Malaga
Manuel Ojeda-Aciego	University of Malaga

New Advances in Theory and Applications of ICA-Based Algorithms

Addison Salazar	Polytechnic University of Valencia
Luis Vergara	Polytechnic University of Valencia

Biological and Bio-inspired Dynamical Systems

Vladimir Rasvan	University of Craiova
Daniela Danciu	University of Craiova

Interactive and Cognitive Environments

Andreu Catalá	Polytechnic University of Catalonia
Cecilio Angulo	Polytechnic University of Catalonia

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Biological and Bio-inspired Dynamical Systems

Interactive and Cognitive Environments

International Workshop of Intelligent Systems for Context-Based Information Fusion (ISCIF'11)

On the Use of Genetic Algorithms to Improve Wavelet Sign Coding Performance

Ricardo García[1,⋆], Otoniel López[1], Antonio Martí[2], and Manuel P. Malumbres[1]

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Abstract. Compression of wavelet coefficient sign has been assumed to be inefficient for a long time. However, in the last years several proposals have been developed and, in fact several image encoders like JPEG 2000 include sign coding capabilities. In this paper, we present a new sign coding approximation using a genetic algorithm in order to efficiently predict the sign of wavelet coefficients. We have included that prediction in a fast non-embedded image encoder. Preliminary results show that, by including sign coding capabilities to a non-embedded encoder, the compression gain is up to 17.35%, being the Rate-Distortion (R/D) performance improvement up to 0.25 dB.

Keywords: sign coding, wavelets, image coding, genetic algorithms.

1 Introduction

Wavelet transforms have proved to be very powerful tools for image compression. Many state-of-the-art image codecs, including the JPEG2000 standard [1], employ a wavelet transform in their algorithms. One advantage is the provision of both frequency and spatial localization of image energy. The image energy is compacted into a small fraction of the transform coefficients and compression can be achieved by coding these coefficients. The energy of a wavelet transform coefficient is restricted to non-negative real numbers, but the coefficients themselves are not, and they are defined by both a magnitude and a sign. Shapiro stated in [2] that a transform coefficient is equally likely to be positive or negative and thus one bit should be used to encode the sign. In recent years, several authors have begun to use context modeling for sign coding [3][4][5].

In [5], A. Deever and S. Hemami examines sign coding in detail in the context of an embedded wavelet image coder. The paper shows that a Peak Signal to Noise Ratio (PSNR) improvement up to 0.7 dB is possible when sign entropy

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coding and a new extrapolation technique based on the mutual information that biorthogonal basis vectors provide to improve the estimation of insignificant coefficients are combined. However, the contribution of sign coding by itself to the PSNR improvement is only up to 0.4 dB.

In [4] the Embedded Block Coding with Optimized Truncation of the embedded bit-streams (EBCOT), core coding tool of the JPEG 2000 standard, encodes the sign of wavelet coefficients using context information from the sign of horizontal and vertical neighbor coefficients (North, South, East, West directions). Five context are used to model the sign coding stage.

In [3], X. Wu presents a high order context modeling encoder. In this coder, the sign and the textures share the same context modeling. This model is based on a different neighborhood for the HL, LH and HH wavelet subbands. For the HL subband, the information of North, North-West, North-East, North-North and South sign is used to predict the current coefficient sign. The neighbors sign information used for the LH subband are North, North-West, North-East, West-West and East. Finally, for the HH subband, an inter-band prediction is used besides the intra-band prediction used by the HL and LH subbands.

Genetic algorithms were first introduced by Holland in [6] and they are nowadays well known techniques for finding nearly optimal solutions of very large problems and also, they have been used in image processing [7][8].

In a genetic algorithm, the evolution usually starts from a population of randomly generated individuals and happens in generations. In each generation, the fitness of every individual in the population is evaluated by means of a cost function that determines the optimal degree we are looking for (i.e compression rate). Multiple individuals are stochastically selected from the current population (based on their fitness), and modified (recombined and possibly randomly mutated) to form a new population. The new population is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population.

In this paper, we will explore the convenience of employing genetic algorithms to efficiently predict the wavelet coefficient signs. If we find a genetic algorithm that help us to define a good wavelet sign prediction, then, instead of coding the sign, we will encode the result of the prediction (i.e success or failure). If the sign prediction is really good, a binary entropy encoder will be able to get significant compression rates. So, our goal is to define a genetic algorithm that finds out the paremeters of our sign predictor that achieve the best prediction performance. As studied in the literature, the parameters to be found by our genetic algorithm will be a) the neighbor set that defines the prediction context, and b) the sign values (sign patterns) of wavelet coefficient neighbor set with the correspondent sign prediction for current wavelet coefficient.

After running the genetic algorithm and configured the sign predictor, we will evaluate the impact of the sign coding module in the overall performance of an image wavelet encoder. In particular, we will use the LTW wavelet encoder [9] to determine the bit-rate savings for several test images.

The remainder of the paper is organized as follows: Section 2 describes our sign coding approximation. In Section 3, we show the results of the global encoder system (with sign coding stage) and compare it with SPIHT and JPEG 2000. Finally, in Section 4 some conclusions are drawn.

2 Wavelet Sign Prediction

Most wavelet image codecs do not consider the use of sign coding tools since the wavelet coefficients located at the high frequency subbands form a zero-mean process, and therefore equally likely positive as negative.

Schwartz, Zandi and Boliek were the first authors to consider sign coding, using one neighboring pixel in their context modeling algorithm [10]. The main idea behind this approach is to find correlations along and across edges.

The HL subbands of a multi-scale 2-D wavelet decomposition are formed from low-pass vertical filtering and high-pass horizontal filtering. The high-pass filtering detects vertical edges, thus the HL subbands contain mainly vertical edge information. Oppositely defined are the LH subbands that contain primarily horizontal edge information.

As Deever explained in [5], given a vertical edge in an HL subband, it is reasonable to expect that neighboring coefficients along the edge have the same sign as the coefficient being coded. This is because vertical correlation often remains very high along vertical edges in images. When a low-pass filter is applied along the image columns, it results in a series of similar rows, as elements in a row tend to be very similar to elements directly above or below due to the high vertical correlation. Subsequent high-pass filtering along similar rows is expected to yield vertically correlated transform coefficients.

It is also important to consider correlation across edges, being the nature of the correlation directly affected by the structure of the high pass filter. For Daubechies' 9/7 filters, wavelet coefficient signs are strongly negatively correlated across edges because this filter is very similar to a second derivative of a Gaussian, so, it is expected that wavelet coefficients will change sign as the edge is crossed. Although the discrete wavelet transform involves sub sampling, the sub sampled coefficients remain strongly negatively correlated across edges. In this manner, when a wavelet coefficient is optimally predicted as a function of its across-edge neighbors (e.g. left and right neighbors in HL subbands), the optimal prediction coefficients are negative, indicating an expected sign change. This conclusion is general for any wavelet with a shape similar to a second derivative of a Gaussian.

To estimate sign correlation in a practical way, we have applied a 6-level Dyadic Wavelet Transform decomposition of the source image and then a low quantization level to the resulting wavelet coefficients. As a first approach and taking into account that the sign neighborhood correlation depends on the subband type (HL,LH,HH) as Deever assesses in [5], we have used three different neighbors depending on the subband type. So, for HL subband, the neighbors used are N, NN and W. Taking into account symmetry, for the LH subband,

those neighbors are W, WW, and N. For the HH subband they are N, W, and NW, exploiting the correlation along and across the diagonal edges. This lead us to a maximum of 3^3 Neighbor Sign Patterns (NSP) for each subband type.

Table 1. Probability distribution of neighbor sign patterns (NSPs) of HL_6 subband ($8x8$ coefficients) in Lena image

C	N	NN	W	Occurrences	%Probability
+	+	+	+	13	20.31
+	+	+	-	8	12.50
-	-	-	+	8	12.50
-	+	+	+	6	9.38
-	-	+	+	6	9.38
Others				23	35.93

In Table 1 we show the NSP probability distribution for HL_6 subband (from the sixth decomposition level) of Lena test image. As shown, the probability that the current coefficient (C) is positive when its N, NN and W neighbors are also positive is around 20%. Besides, if the N and NN neighbors have the same sign and the W neighbor has the opposite sign, the current coefficient (C) has the opposite sign of its W neighbor with a probability of 25% as shown in rows two and three in Table 1. The visible sign neighborhood correlation suggest that the sign bits of wavelet coefficients are compressible. Using the previously mentioned neighborhood for each subband type, we have developed a genetic algorithm (GA) in order to find an accurate sign estimation.

2.1 Genetic Algorithm for Wavelet Sign Prediction

The goal of the desired genetic algorithm would be to find a table where for each Sign Neigborhood Pattern (V_k) we have a sign prediction ($S_{i,j}$) for coefficient $C_{i,j}$. There is no an univocal relationship between a neighbor sign combination, i.e not always for a same V_k pattern, $S_{i,j}$ is always positive or negative. However, it is possible that for a V_k pattern, $S_{i,j}$ is more probably to be positive or negative. But, the problem is still more complex, because a sign prediction for a neighbor sign pattern could fit well for an image and not for others. Therefore, the idea is to find suboptimal neighbor sign pattern predictions that better fit for a representative set of images.

The use of genetic algorithms to compress the sign of wavelet coefficients is twofold. First, when the number of neighbors used to analyze the sign correlation grows or when there is a great number of images to be used in the analysis, the search space is excessively wide. Second, it is not intuitive to find a way of combining the predictions obtained for several images.

In Fig. 1 we show the genetic algorithm pseudocode for sign prediction. First of all we define each individual, containing a sign prediction for each 3^3 NSP, then

each NSP sign prediction of each individual of the universe is randomly initialized as a positive or negative sign. Then, during evolution, sequences mate and mutate to generate new sequences in the population and best sequences are selected for survival on the basis of their fitness function. The mating of sequences is performed through crossover operator, where parents are randomly selected and its gens (NSPs) are mixed. The best two individuals, the ones that exhibit best prediction performance, are selected for survival. Individuals can also undergo mutation, where a sequence prediction is randomly modified. Finally, after performing the maximum iterations, the algorithm finishes, obtaining an optimal/suboptimal sign prediction for each NSP. We have performed the fitness evaluation over Lena and Barbara test images, because these images are representative for both low and high textured images respectively. Several parameters should be taken into account when training a genetic algorithm: The population size, the individuals initialization, the number of iterations performed, the mutation probability, the crossover point, the crossover method, the selection criteria of the best sequences to be selected for survival, etc. We have performed lots of tests varying these parameters to tune the genetic algorithm. The parameters used to obtain the sign prediction are: population size (100), individuals initialization (ramdomly), number of iterations (1000), mutation probability (0.001), crossover point (ramdomly) and crossover method (best two fitness individuals over four randomly selected parents).

```
Individual Structure{
   sign[NSP];//Prediction array for each neighbor sign pattern combination
   fitness; //indicates the goodness of the individual
  }Individual universe[NUM-POPULATION]; //Individual array

function SignPrediction (SubbandType, ImageFiles, mutation Probability)
  //Initialization phase: sign[NSPs]= random(POSITIVE/NEGATIVE)
  Initialize(universe, NUM-POPULATION, NSP);
  //we evaluate each individual of the universe. For each image in ImageFiles
  EvaluateFitness(SubbandType, ImageFiles, universe);
  for i=0 to NUM-ITERATIONS
  //Select the best two individuals from universe for survival.
       best = SelectBestIndividuals(2);
       //Crossover
       crossPoint=random(NSP);
       //randomly selects a father and a mother to mix its gens
       SelectFatherAndMother(random(NUM-POLUTATION));
       universe = MergeFatherAndMother(crossPoint);
       Mutation(universe, mutation Probability);
       universe = universe + best;
       EvaluateFitness(SubbandType, ImageFiles, universe);
  end
  //Finally get the best individual.
  best = SelectBestIndividuals(1);
end of function
```

Fig. 1. Genetic algorithm for sign prediction

After running the genetic algorithm for each subband type, we obtain an individual containing the prediction of the current coefficient sign ($\hat{SC}_{i,j}[k]$), for each NSP (k) of each subband type. So, what we are going to encode is the correctness of this prediction, i.e., a binary valued symbol from $\hat{SC}_{i,j}[k] \cdot SC_{i,j}$ (see Table 2). In order to compress this binary valued symbol, we use two contexts in the arithmetic encoder for each subband type, distributing all sign coding predictions from NSPs between them so as to minimize the zero order entropy of both contexts. The selection criterion is to isolate in one context those NSPs with the highest correctness prediction probability and highest number of occurrences derived from the probability distribution found in the previous analysis. The rest of them are grouped into the other context. However, there are certain NSPs with low correctness probability but with a great amount of occurrences, so we have to heuristically determine the convenience of including them in the first context or not.

Table 2. Sign prediction for HL subband in Lena image for some NSPs

NSP(k)	N NN W	Prediction ($\hat{SC}_{i,j}[k]$)
0	* * *	-
	...	
13	+ + +	+
14	+ + -	+
	...	
26	- - -	+

3 Performance Evaluation

In this section we analyze the behavior of the sign coding when implemented on LTW image encoder [9]. This new encoder implementation is called S-LTW. We will also compare the S-LTW encoder versus JPEG2000 (Jasper 1.701.0) and SPIHT (Spiht 8.01) in terms of R/D and coding delay. All encoders have been tested on an Intel PentiumM Dual Core 3.0 GHz with 2 Gbyte RAM memory.

In Table 3 we show the relative compression gain with respect to the original LTW due only to the sign coding capability for several test images. As we can see, the maximum sign compression gain is 17.35%. Furthermore, we show an estimation of the bit savings for SPIHT encoder.

In Figure 2 we show the R/D improvement when comparing original LTW versus JPEG2000/SPIHT and S-LTW versus JPEG2000/SPIHT. As shown, there is an increase in the PSNR difference between SPIHT and the new S-LTW encoder, and regarding JPEG2000, we can see than now S-LTW has a minor loss in PSNR than original LTW. Regarding coding delay, the use of a higher context modeling in the arithmetic encoder implies a higher computational cost. In order to compensate the coding speed loss, we have changed the arithmetic encoder stage by a fast arithmetic encoder [11]. As it can be seen in Table 4, S-LTW

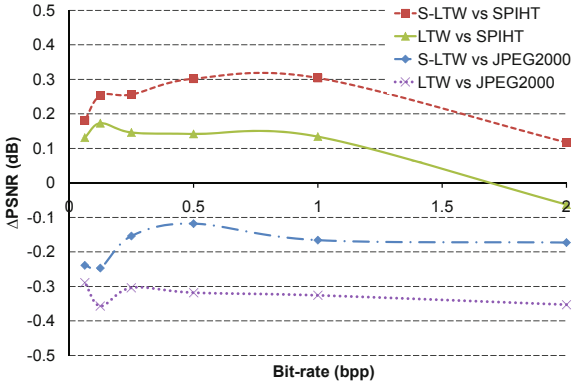

Fig. 2. PSNR-Gain for Bike image

Table 3. Sign compression performance at different bit-rates

Bit-rate (bpp)	S-LTW #Significant Coefficients	S-LTW #Bits Saved	SPIHT #Significant Coefficients	SPIHT #Bits Saved	%Gain
Barbara (512x512)					
1	45740	7936	54657	9482	**17.35**
0.5	22331	3648	27535	4499	16.34
0.25	10484	1520	13460	1951	14.50
0.125	4343	304	6016	421	7.00
Bike (2048x2560)					
1	855266	115200	1371280	184711	13.47
0.5	412212	64424	798202	124758	15.63
0.25	198943	30472	366927	56213	15.32
0.125	91767	11992	162990	21302	13.07

Table 4. Coding delay (seconds)

Bit-rate (bpp)	JPEG 2000	SPIHT	LTW Orig.	S-LTW
CODING Barbara (512x512)				
1	0.080	0.042	**0.037**	0.023
0.5	0.076	0.026	**0.022**	0.014
0.25	0.074	0.018	**0.013**	0.009
0.125	0.073	0.014	**0.010**	0.006
CODING Bike (2048x2560)				
1	2.623	0.920	**0.647**	0.430
0.5	2.543	0.521	**0.381**	0.259
0.25	2.507	0.323	**0.224**	0.162
0.125	2.518	0.221	**0.158**	0.117

encoder is 49% faster on average in the coding process than SPIHT encoder and 86% faster on average than JPEG2000. Furthermore, S-LTW encoder is even faster than the original LTW version which does not include the sign coding stage (1.5 times faster on average in the coding process).

4 Conclusions

We have presented a genetic algorithm that is able to find a good sign predictor of wavelet coefficient sign. So, by encoding the sign prediction result (success or failure) with an arithmetic encoder, the sign information will be highly compacted in the final bitstream. To prove our proposal we have implemented it over the LTW encoder. The new S-LTW proposed encoder has slightly better R/D performance(up to 0.25 dB), or in terms of bitstream, it is able to reduce it up to 17% for the same quality level. Regarding coding delay, the new image encoder is on average 2 times as fast as SPIHT in the coding process and 1.5 times as fast as original LTW.

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