

Particle Swarm Optimization Algorithm vs. Genetic Algorithm for Image Watermarking Based Discrete Wavelet Transform

Omaima N. Ahmad AL-Allaf

Abstract—Over communication networks, images can be easily copied and distributed in an illegal way. The copyright protection for authors and owners is necessary. Therefore, the digital watermarking techniques play an important role as a valid solution for authority problems. Digital image watermarking techniques are used to hide watermarks into images to achieve copyright protection and prevent its illegal copy. Watermarks need to be robust to attacks and maintain data quality. Therefore, we discussed in this paper two approaches for image watermarking, first is based on Particle Swarm Optimization (PSO) and the second approach is based on Genetic Algorithm (GA). Discrete wavelet transformation (DWT) is used with the two approaches separately for embedding process to cover image transformation. Each of PSO and GA is based on co-relation coefficient to detect the high energy coefficient watermark bit in the original image and then hide the watermark in original image. Many experiments were conducted for the two approaches with different values of PSO and GA parameters. From experiments, PSO approach got better results with PSNR equal 53, MSE equal 0.0039. Whereas GA approach got PSNR equal 50.5 and MSE equal 0.0048 when using population size equal to 100, number of iterations equal to 150 and 3×3 block. According to the results, we can note that small block size can affect the quality of image watermarking based PSO/GA because small block size can increase the search area of the watermarking image. Better PSO results were obtained when using swarm size equal to 100.

Keywords—Image watermarking, genetic algorithm, particle swarm optimization, discrete wavelet transform.

I. INTRODUCTION

DIGITAL image watermarking can be regarded as an important research field and has attracted the attention of several researchers in the last decades. Digital watermarking can be used to achieve information security, hiding, authentication and copyright protection of digital images. There is a need for protection algorithms that protect digital content to ensure the ownership of that digital content [1], [2]. According to the domain used for embedding watermark, watermarking methods are classified into spatial domain and frequency domain.

Spatial domain watermarking approaches modify pixels of one or two randomly selected subsets of images and loads raw data into image pixels. The disadvantages of spatial domain watermarking approaches against image processing: noise,

distortion and filtering. Frequency domain watermarking approaches alter values of certain frequencies from their original to another form. They embed a watermark into the selected portion of frequency domain by modifying the coefficients. Frequency domain is mostly used in recent watermarking methods because it is more robust technique than the spatial domain watermarking [1].

Many techniques were used for image watermarking such as Discrete Cosine Transform, Discrete Fourier Transform, DWT and Singular Valued Decomposition [1]-[5]. DWT can be regarded as the most popular technique used in image watermarking according to its ability to decompose the original images into sub bands. The watermarks can be embedded selectively in these sub bands [2].

Recently, Biometric identification systems have gained considerable attention from the research community, because these systems have been used in various commercial applications such as surveillance and access control [3]. Therefore, many algorithms such as PSO, differential evolution (DE), ant colony optimization (ACO), bee algorithm (BA), cat swarm optimization (CSO), and firefly algorithm (FA) have been developed for solving optimization problems [1]-[4].

PSO is a heuristic search algorithm that is based on swarm intelligence to solve optimization problems in different applications. It comes from the research on bird flocks and fish schools movement behavior. PSO algorithms have been widely used and many literature studies focused on enhancing PSO [6]-[13]. At the same time, GAs have been applied by researchers for many years to solve practical problems [14]. GA is the most popular algorithm in computation researches [15]. Many literature researchers for the digital image watermarking based on DWT domain conducted GA to search for good values of parameters [16]-[28] for optimizing image watermarking. The GA's aim is to search for the best locations in the original image to embed the watermark in a way that improves the robustness to attacks, watermark security and the quality of the watermarked image. Meanwhile, other literature researches suggested to use PSO with DWT for optimizing the performance of image watermarking [29]-[36]. Each of literature researches has its strengths and limitations in performance. Therefore, this paper presents two approaches: the first is PSO with DWT, and the second is GA with DWT. PSO and GA are used to optimize the values of fidelity of watermarked image to find suitable locations for watermark insertion within original image to provide optimization of

Omaima N. Ahmad AL-Allaf is an Associate Professor with the Computer Information System department – Faculty of Sciences and Information Technology at Al Zaytoonah University of Jordan- Amman-Jordan, P.O. Box 130, Amman (11733), Jordan (phone: 00962777966787, e-mail: omaimaalallaf@zuj.edu.jo).

image watermarking. The variation of fitness function, population size, mutation and crossover probability has been compared and discussed for both approaches. Many experiments were conducted in this work for each approach, each with different values of algorithm parameters. This is done to find the best parameters that result in improving the performance of image watermarking system. The rest of this paper includes: Section II explains related literature. Section III explains PSO, Section IV describes GA and Section V explains DWT. In Section VI, the research methodology is discussed. Section VII discusses the experiments to demonstrate the performance of each approach, and finally, Section VIII concludes this work.

II. RELATED STUDIES FOR IMAGE WATERMARKING

Digital watermarking is the process of hiding a message related to a digital image within the image itself. This concept is related to steganography that hide a message inside a digital signal. The difference in using steganography that, the digital signal has no relation to a message and it is used as a cover to hide its existence. Digital image watermarking was developed during the last 20 years. Many literature studies [16]-[25], [27], [28] have been used GA for optimizing image watermarking with DWT. Jin and Shi-Hui [16] discussed an approach based on GA for image watermarking. And Dahlia et al. [17] discussed the use of GA with DWT for image watermarking. They applied their approach on several gray scale images. Their results achieved PSNR equal to 76dB in case of the Lena image whereas, Sachinl et al. [18] proposed GA to optimize the robustness of watermarking by searching for appropriate locations in cover images to insert watermark. Surekha and Sumathi [19] proposed an optimization method GA for digital images in DWT domain. They conducted many experiments. Their results got MSE equal to 3.3476, PSNR equal to 42.88 and time equal to 13.5 when using Lena image with number of generation GA equal to 20.

Abduljabbar et al. [20] and Abduljabbar and Azizah [23] studied the effect of embedding domain on the robustness in GA watermarking. Many experiments were conducted in their study based on peak signal-to-noise ratio (PSNR) and numerical correlation (NC) to evaluate the performance of their approach. The DWT results showed more robustness than DCT in watermarking based on GA. The maximum obtained value of PSNR is equal to 45.0dB. At the same time, Ramanjaneyulu and Rajarajeswari [21] presented image watermarking scheme based on DWT for copyright protection. In order to optimize the parameters to get good values of PSNR, they used GA. Experimental results showed PSNR equal to 39.7081 using 20 generations for GA, PSNR equal to 39.2417 using 120 generation for GA. Cauvery [22] presented a secure algorithm for watermarking images. They considered Robustness and Fidelity during watermarking. Robustness of watermark means the strength of the watermark against image processing attacks. Fidelity is the factor which determines the quality of image after embedding the watermark. They used GA to identify the position for marking. Ziabari et al. [24] optimized image watermarking using GA; they improved the

security of watermarking with preprocessing operations. They tried to remove the mentioned implicit error and decreased the time consuming of GA by simplifying the previous algorithms. They used a Cameraman image of size 256×256 for the cover image and a Flower image of size 32×32 stands for the watermark image. They used GA parameters as follows: Crossover rate equal to 0.7, mutation rate equal to 0.001, Initial population equal 20, Iteration equal to 3, and Crossover is two point crossover. Their results showed PSNR equal to 49.7. Jiansheng et al. [25] introduced an algorithm of digital watermarking based on DCT and DWT. Their simulation results showed PSNR equal 35.5801 and NC equal 0.9132 for Lena image. Anumol and Karthigaikumar [27] proposed robust watermarking technique based DWT. They embed a watermark containing key information such as authentication or copyright codes. Finally, Kaushik [28] developed watermarking schemes for digital images stored in spatial and transformed domain using DCT and DWT. They proposed to increase the robustness against some attacks by preprocessing the images. They presented a correlation between the performance of the watermarking scheme against some attacks and the original image characteristics.

At the same time, different literature researches suggested to use PSO with DWT for optimizing the image watermarking [29]-[36]. Surekha and Sumathi [29] proposed a digital image watermarking scheme based GA and PSO. They applied many pre-watermarking stages (image segmentation, feature extraction, orientation assignment, and image normalization) to input host images to obtain image invariance properties when subject to attacks. They embedded the watermark image into the host image using DWT. They applied GA and PSO during the extraction process to improve the robustness and fidelity of the watermarked image by evaluating the fitness function. They evaluated the performance of proposed scheme with 50 images taken from online resources of Tampere University of Technology, Finland and used the MATLAB R2008b to simulate the algorithm. And, Soliman [30] presented a secure patient medical images and authentication scheme using watermarking by invoking PSO in conjunction with DWT and DCT. This is to enhance the security, confidentiality and integrity of medical images transmitted through the Internet. Their experimental results showed that the proposed algorithm yields a watermark which is invisible to human eyes and robust against a variety of common attacks and got PSNR equal to 52.24dB. Nair and Aruna [31] extracted multimodal biometric images such as fingerprint, palmprint, and iris are and individually and fused together using Average, Minimum and Maximum fusion mechanism. PSO watermarking system used to watermark this fused template. The image quality is measured by PSNR, Normalized Absolute Error (NAE) and Normalized Cross Correlation (NCC). They used CASIA database for the biometric images with 8 bit gray level JPEG image with the resolution of 320×280 . Their results showed PSNR equal to 36.45dB. Hammouri et al. [32] proposed watermarking scheme for digital images based on PSO in DWT. They inserted the watermark into the DWT subbands which have

the most important coefficients. They empowered robustness by applying PSO. Their results showed PSNR equal 43.00. Kumar et al. [33] proposed a secure optimized watermarking scheme for digital images based on PSO based on co-relation coefficient are used to detect the high energy coefficient watermark bit in the cover image and then hide the watermark to the cover image. They used DWT for embedding process for the cover image transformation. Their results showed PSNR equal 60.65. Saleh and Abdou [34] introduced a modified watermarking method in Wavelet domain to get better performance using PSO to find the best DWT coefficients in HL subband for embedding the watermark sequence. They formed the PSO fitness function from watermarked image with the best possible quality and proved execution time. Their results showed highest PSNR equal to 58.0864. Manikanda et al. [35] adopted a novel steganography method based on PSO algorithm for hiding secret information with high security and high robustness. Their experimental results demonstrated that the proposed algorithm has high security and good invisibility. Their results showed PSNR equal 60.8476 and MSE equal 0.0909.

Finally, Gayathri and Venkatesan [36] presented DWT with PSO approach for image watermarking. They evaluated their approach using PSNR and Cross Correlation value that is Normalized (NCC). Their GA results showed PSNR equal 42.88347 and MSE equal 3.3476 with 10 number of iterations, while for their PSO results, PSNR equal 31.0891, MSE equal 2.3475 for 20 iterations. Different techniques based on spatial and frequency domain, GA and PSO have several limitations due to unsatisfactory values of fidelity by various researchers [16]-[25], [27]-[36]; therefore, this paper deals with the development of two watermarking approaches for digital images in Wavelet domain to get better performance. PSO and GA are used separately to find the best DWT coefficients in the HL subband for embedding the watermark sequence.

III. PARTICLE SWARM OPTIMIZATION

PSO is an optimization algorithm that is generally based on behavior of birds flocking. It uses swarm of particles as individuals in a population for searching through solution space. A particle represents a point of N dimension solution space and has N dimension speed with fitness function. Each particle adjusts its position, evaluate it and move closer to optimal point and compare itself to its neighbors. Further information about PSO was described in [6]-[13], [37]-[39]. In order to compute the new velocity of each particle, (1) will be used [6]-[13], [37]-[39]:

$$V_i(t+1) = W \times V_i(t) + C1 \times rand \times (Pbest(t) - X_i(t)) + C2 \times rand \times (Gbest(t) - X_i(t)) \quad (1)$$

where V is a particle velocity, Xi is the ith particle, W is a weight, C1 and C2 are speeding factors each with a value equal 2, Pbest is the best value of particle i, and finally, Gbest is best value that a particle reach it.

A fitness value of particle is computed using (2) and the particle can change its value according to new velocity.

$$X_i(t+1) = X_i(t) + V_i(t+1) \quad (2)$$

IV. GENETIC ALGORITHMS

GA is regarded as an optimization algorithm for searching an optimal solution. GA is generally based on natural genetics mechanics and includes many steps [14], [15], [40]-[42]:

1. Initialization: to generate first population of chromosomes that represents problem solutions. Each chromosome is represented as string with zeros and ones.
2. Design Fitness function and determine the values of number of generations; crossover and mutation.
3. Calculating the fitness function for each chromosome.
4. Selection: Each chromosome is evaluated according to its fitness value. And select each pairs of chromosomes for reproduction.
5. Crossover (pc): combine each two selected chromosomes to form new two chromosomes.
6. Mutation (pm): flip a single bit (1 to 0 or 0 to 1) in each selected chromosome.
7. Repeat selection, crossover and mutation until getting chromosome with minimum fitness function [14], [15]. More details about GA were described in details in [14], [15], [40]-[42].

V. DISCRETE WAVELET TRANSFORM

DWT is a time domain localized analysis method with fixed window's size. DWT can be summarized as follows:

1. Transformed spatial domain pixels of original image into wavelet domain frequency bands to embed a watermark.
2. Decompose image into four sub-images: three high-frequency districts (LH, HL, HH) horizontal, vertical, diagonal, and one low frequency district (LL) of different spatial domain and independent frequency district. The frequency parts of LH, HL and HH, respectively, represents the level detail, the upright detail and diagonal detail of original image.
3. The information of low frequency part (sub-image) is an image close to original image and contains most of image energy. Watermark cannot be embedded in this part as it would distort appearance of image by damaging its details.
4. The remaining three parts (detail sub-images) in one of which the watermark can be embedded. These bands are high frequency and contain lesser information about image like edge and texture.
5. The sub-level frequency district information will be obtained if information of low-frequency part is DWT transformed. Fig. 1 shows a two dimension image after decomposed it three times (HL1, LH1, HH1) using DWT. Where, L can represent low-pass filter and H represents high-pass filter. The low-frequency part of the image is decomposed further into sub-level frequency district information (LL2, HL2, LH2 and HH2) [25].

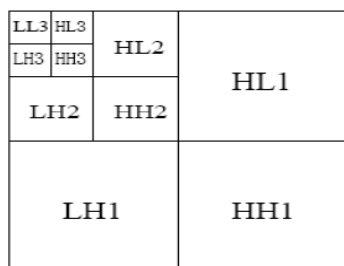


Fig. 1 DWT diagram

VI. RESEARCH METHODOLOGY

In this paper, we suggested to use two digital image watermarking approaches: one based on PSO and the other approach is based on GA. The watermark image is embedded into the original image using DWT on behalf of using PSO and GA separately. The goal of applying optimization in watermarking is to resolve the conflicting requirements of different parameters and properties of digital images. Fig. 2 shows the diagram of image watermarking based on DWT and PSO/GA. The performance of proposed approaches was evaluated with many colored images. The algorithm was implemented using MATLAB R2008b.

A. PSO and GA Parameters

At the beginning, PSO parameters must be initialized as follows: Swarm size (N) equal to 100, each of C1 and C2 value is equal to 2, weight equal to 0.5, Number of Iterations equal to 150, and finally, fitness function is as (3). Meanwhile, GA parameters are determined as follows: Population size equal to 100, Number of Iterations equal to 150, Cross over equal to 0.001, and also fitness function as (3).

B. Watermarking Algorithm

1. Read the 512×512 image (I(h,v)=I(512×512))
2. Extract features from the image (convert I(h,v) to I=IDWT(h,w))
3. Calculate number of blocks in image (I). The image represents the search range. Find the best block to store one bit in this best block, the block dimension is 3×3. The block size is 9. $K=(h \times v)/9 \rightarrow K=(512 \times 512)/9 \rightarrow K=262144/9 \rightarrow K=29127$. According to the above, the search range is equal to 29127.
4. Calculate coefficient of all blocks of that image as follows: for i=1 to 29127 Cof(min(b(i), max(b(i), avg(b(i))). Three parameters to be extracted from the original image (after converting this image to DWT). These parameters are: minimum value, maximum value and average value in each block in image I. These parameter will be stored in matrix: Cof(29127,3).
5. Read watermarking image W(n, m)=W(64×64).
6. Convert this watermarking image (W(n,m)) to binary image Wp(n,m).
7. Execute the PSO algorithm or GA.

C. PSO for Optimization

1. Calculate fitness function using (3):

$$NC = \frac{\sum_{i=1}^N \sum_{j=1}^M w(i,j)w_e(i,j)}{\sqrt{\sum_{i=1}^N \sum_{j=1}^M w(i,j)^2} \sqrt{\sum_{i=1}^N \sum_{j=1}^M w_e(i,j)^2}} \quad (3)$$

2. Extract features ((gbest)) for b() from cof(29127,3)
3. Determine Population size= 100, C1=2,C2=2, weight=0.5, and Iteration =150.
4. Select random velocity (v= P_velocity =random())
5. Calculate present = P_position=random(); for 12_bit
6. Set counter j to 1.
7. Execute the following loop:
 If gbest(j) then Save Wp in Iw(b)
 Else Update parameter using (1) and (2).
8. Increment j with 1. Repeat steps 7 and 8 until j > 4096 then end execution of loop. Otherwise execute PSO again. After end we obtain Iw(512,512).
9. Extract watermarking image from IW(512,512) use PSO and (4) as follows:

$$W_{ep} = \begin{cases} 1 & \text{if } S_w > S_0 \\ 0 & \text{if } S_w \leq S_0 \end{cases} \quad (4)$$

D. GA for Optimization

GA has been successfully applied to obtain good solutions in several applications. The process of robustness and fidelity optimization using GA consists of:

1. Read original image (512×512) and a watermark Lena image (64×64).
2. Determine initial population that represents the initial set of random locations in original image to insert watermark image inside selected positions of original image.
3. Determine fitness function based on optimize robustness and fidelity as (3).
4. Calculate fitness value of each individual population (random embedding positions) by: inserting watermark bits in selected locations in original image; and find correlation between original and watermarked images (fitness value).
5. Select best fitness value and the corresponding best fit individual. Also, the second fit individual with corresponding fitness value is selected.
6. Crossover of the two individuals.
7. Mutation process.
8. Repeat the above steps until producing a population with fitness more than or equal to a threshold value determined at the beginning of algorithm.

VII. EXPERIMENTAL RESULTS

The experimental results of this approach prove to be secure and robust to attacks and additive noise. PSNR, MSE, and computational time are evaluated for a set of colored images using the MATLAB R2008b software. In the first experiment we execute PSO and GA algorithms separately each with 3×3 block dimension. Table I shows the PSO results when select swarm size is equal to 100, number of iterations equal to 150 and 3×3 block. Table II shows the GA results when use population size equal to 100, number of iterations equal to 150

and 3×3 block.

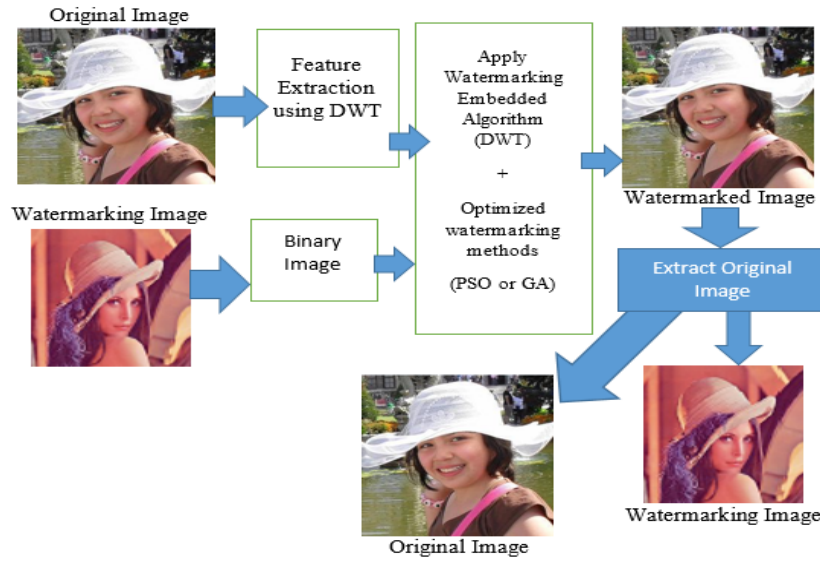


Fig. 2 Watermarking Optimization using GA



Fig. 3 (a) Original images with their associated (b) watermarked images and (c) reconstructed images after removing watermarking image

TABLE I
 PSO RESULTS (SWARM SIZE=100, ITERATIONS=150)

Block(3×3)	Reco.rate	MSE	PSNR
Image1	94%	0.0039	53
Image2	93%	0.0052	51.5
Image3	94%	0.0045	51.7
Image4	94%	0.0047	51.6

From Tables I and II, we can see that results of PSO algorithm are better than results of GA for all images. In the

second experiment, we implement PSO and GA algorithms separately using block with dimension 5×5. Table III shows the results of the PSO algorithm when determining swarm size equal to 100, number of iterations is equal to 150 and block with 5×5 dimension. Table IV shows the GA results when using population size equal to 100, number of iterations equal to 150 and 5×5 dimension.

From Tables I and III, we can note that the block size can affect the quality of PSO results. The results obtained from

executing the PSO with small block size are better than the results when using big block size. Also from Tables II and IV, we can note that the block size can affect the quality of GA results. The results obtained from executing GA with small block size are better than the results when using big block size. Fig. 3 shows many Original images that used for image watermarking system, with their associated watermarked images after adding a watermarking Lena image (64×64) and shows also reconstructed images after removing watermarking image. The third experiment is executed when using different swarm size with constant block size 3×3. Table V shows PSO results when using different swarm size with 3×3 block dimension.

TABLE II

GA RESULTS (POPULATION SIZE=100, ITERATIONS=150)			
Block (3×3)	Reco.rate	MSE	PSNR
Image1	93%	0.0048	50.5
Image2	92%	0.0055	50.2
Image3	92%	0.0049	50.3
Image4	92.4%	0.0046	50.6

TABLE III

PSO RESULTS (SWARM SIZE=100, ITERATIONS=150)			
Block(5×5)	Reco.rate	MSE	PSNR
Image1	93%	0.0041	50
Image2	92%	0.0050	50.1
Image3	93%	0.0047	50.2
Image4	93.3%	0.0045	50.4

TABLE IV

GA RESULTS (POPULATION=100, ITERATIONS=150)			
Block (5×5)	Reco.rate	MSE	PSNR
Image1	92.1%	0.0050	49.5
Image2	92.3%	0.0057	49.3
Image3	92.5%	0.0053	49.2
Image4	92.2%	0.0052	49.1

TABLE V

PSO RESULTS (PSNR) WHEN USING DIFFERENT SWARM SIZE				
3×3 Block	Swarm (50)	PSNR		
		swarm (80)	swarm (100)	swarm (150)
Image1	45.5	46	52.5	49.7
Image2	45.3	47.1	51.5	49.5
Image3	45.2	46	51.7	49.2
Image4	45.7	47.5	51.6	48

TABLE VI

PSO RESULTS WHEN USING DIFFERENT BLOCK SIZE				
	PSNR			
	Block (3×3)	Block (5×5)	Block (7×7)	Block (8×8)
Image1	52	50.6	45.3	43.5
Image2	51.5	50.1	45.2	43
Image3	51.7	50.2	46	44.2
Image4	51.6	50.4	46.2	44.3

From Table V, better results were obtained when using swarm size equal to 100. In the fourth experiment, we implement the PSO algorithm with swarm size equal to 100 and different block sizes. Table VI shows the PSO results

when using swarm size equal to 100 and different block sizes; from this, we can note that better PSO results were obtained when using block size equal 3×3. This is because when using small block size this will increase the search area of the watermarking image.

VIII. CONCLUSION

In this paper, we proposed to use two digital image watermarking approaches: one based on PSO and the other approach based on GA. The watermark image is embedded into the original image using DWT. GA and PSO can be applied separately to improve the robustness of the watermarked image. This is done by evaluating the fitness function. The robustness of watermarked and extracted images are evaluated using PSNR and MSE. From the experimental results, the performance of PSO is better than GA. The performance of the two proposed approaches was evaluated with many colored images. The algorithm was implemented using MATLAB R2008b.

By determining the population size equal 100, number of iterations equal 150 and 3×3 block for the both approaches. PSO approach got better results (PSNR equal 53, MSE equal 0.0039 and Recognition rate equal 94%) than GA approach (PSNR=50.5, MSE=0.0048 and rec rate equal 93%). Also, from experiments, we can note that the block size can affect the quality of PSO/GA results. The results obtained from executing the PSO/GA with small block size are better than the results when using big block size because using small block size this will increase the search area of the watermarking image. At the same time, better PSO results were obtained when using swarm size equal to 100.

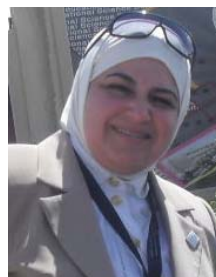
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Omaima N. A. Al-Allaf is an Associate Professor at Computer Information Systems department, Faculty of Sciences and IT, AL-Zaytoonah University of Jordan, Amman, Jordan (from 15 Feb. 2009- to present). She received her B.Sc. in Computer Science from Dept. of CS, Faculty of Sciences, University of Mosul, Mosul, Iraq (1990-1994), and received her M.Sc. from Dept. of CS, Faculty of Computer & Mathematical Sciences, University of Mosul, Mosul, Iraq (1997-1999). She worked as Teacher B in Applied Science University (Private), Amman, Jordan from 2000 to 2004. She received her PhD in CIS from the Department of CIS, AABFS-Amman, Jordan (2004-2008). During 2004-2008, she worked as a part time lecturer in the AABFS. Her research interests are in the fields of: artificial intelligence, artificial neural networks, image processing, web engineering, software process models.