Image compression using Modified Fuzzy Adaptive Resonance Theory

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ABSTRACT

This research developed a software which can be used for image compression. This research proposes two methods: the first uses Joint Photographic Experts Group (JPEG), while the second uses artificial neural network (Modified Fuzzy Adaptive Resonance Theory (MFART)) algorithm. This software is applied on two types of images (jpeg and tiff). Several parameters in compression methods are tested, the results reveal that the MFART is better than the JPEG metod. The Root Mean Square Error (ERMS) for MFART method on jpeg image is equal 3.7 but it is equal to 26.09 when JPEG method implement on to the same image. MATLAB has been used in the implementation of this software.

Keywords: Image compression, Modified Fuzzy Adaptive Resonance Theory.

كبس الصورة باستخدام نظرية الشبكات العصبية (MFART) المعدلة

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الملخص

هذا البحث يتضمن تطوير برنامج لكبس الصور. حيث تم اعتماد طريقتين لذلك, الاولى تطبيق JPEG بينما استخدمت الثانية الشبكات العصبية (MFART), وتم تطبيق الطريقتين على نوعيتين من الصور هما jpg و tif. النتائج قورنت باعتماد عدد من المقاييس وتبين ان طريقة MFART هي الافضل حيث كان ERMS عند تطبيق طريقة MFART على صورة من نوع jpeg مساوية (3.7) بينما عندما طبقت طريقة JPEG على نفس الصورة كانت (26.09) . استخدمت MATLAB في تنفيذ برامجيات هذا البحث.

الكلمات المفتاحية: كبس الصور، الشبكات العصبية (MFART).

1- Introduction

Data compression is the technique to reduce the redundancies in data representation in order to decrease data storage requirements and hence communication costs.

The large amount of time and storage required to transmit pictorial data brings about the need of image compression. Neural network algorithms have high convergence times. Even one of the fastest neural network algorithms is the Fuzzy ARTMAP (FAM) algorithm, tends to lag in convergence time as the size of the network grows [1].

The application of ART1 to image compression was studied, and showed that ART1 network can be a promising alternative [2].

The fuzzy ART network has several advantages over ART1 networks, these advantages are: first the ability to handle the grayscale image, second less implementation cost and processing time, and third the ability to handle both binary and analog vector.

In this work we used a Modified Fuzzy ART (MFART) network which is the hybrid of ART1 and Fuzzy ART networks, as well as a second method which is the JPEG method.

The rest of this research is organized as follows; it describes the architecture and the learning algorithms of Fuzzy ART networks , defines the image compression, the used methods, the used measure criteria, and the simulation results.

2- The learning algorithm of MFART network

The MFART network counts the grayscale difference between the input and category and picks up the category that has minimum difference instead of using fuzzy min operator as in Fuzzy ART.

2-1 The Learning Algorithm MFART [3]

Step 1: Initialize the vigilance parameter (equ.1) and weight vector (equ.2) of each uncommitted node *j*, before presenting it to feature representation field (F) (in fig 1.) :

$$0 \le p \le 1 \qquad \ldots(1)$$

$$w_j = [1\ 1\ 1\ 1\ 1\ .....] \qquad \ldots(2)$$

where w_j and p are the *2N*-dimensional weight vector and vigilance parameter respectively, and *N* is the dimension of input vector before transformation.

Step 2: Transform the *N*-dimensional input vector *I*, whose components are in the interval [0,1], to *2N*-dimensional vector I' as follow .

$$I' = I_1, I_2, ..., I_N, I_{N+1}, I_{N+2}, ..., I_{2N} \qquad ....(3)$$

$$I_{2N}, 1 - I_i \qquad for \quad i = 1,2,..N \qquad \ldots(4)$$

The winning node (or category),(say *j*) is the node with the weight vector (w_j) most similar to input *I* in terms of the minimum difference of grayscale value between the input I' and category *j*, that is, $\left(\sum_{i=1}^{2N} \left| I' - w_{ij} \right|\right)$, in category representation field (layer C) where *2N* is the dimension of $I^{'}$. In case of tie, one of them is to be selected arbitrarily.

Step 3: The selected category *j* is said to meet the vigilance criterion if the following inequality stand.

$$\left(\sum_{i=1}^{2N}\left|I^{'} - w_{ij}\right|\right) \leq N \times (1 - P) \qquad ...(5)$$

Step 4: If resonance, go to Step 5; otherwise, the reset occurs and a new category (node) is added to layer *C* unless there is no new node available. In that case, the operation terminates.

Step 5: Update only the weight vectors associated with the selected category *J* (either the winner *j* or new added category) as follows.

$$W_{ij}^{new} = W_{ij}^{old} \wedge I_i^{'} \qquad for \quad i = 1,2,\ldots,2N \qquad ... (6)$$

where $\wedge$ is the fuzzy min operator.

Step 6: If no new input vector, terminate the process; otherwise, get the next input vector and go back to Step 2.

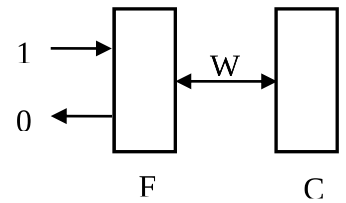


Fig 1. the architecture of MFART

3- Image compression

Reducing the storage requirement is equivalent to increasing the capacity of the storage medium and hence communication bandwidth. Thus the development of efficient compression techniques will continue to be a design challenge for future communication systems and advanced multimedia applications [4].

A digital image I is described by a function $f : Z \times Z \rightarrow \{0,1,..2^k - 1\}$ where Z is the set of natural numbers, and k is the maximum number of bits to be used to represent the gray level of each pixel. In other words, f is a mapping from discrete spatial coordinates (x,y) to gray level values. Thus, $M \times N \times k$ bits are required to store an $M \times N$ digital image. The aim of digital image compression is to develop a scheme to encode the original image I into the fewest number of bits such that the image I' reconstructed from this reduced representation through the decoding process is as similar to the original image as possible: i.e. the problem is to design a COMPRESS and a

DECOMPRESS block so that $I \approx I'$ and $|I_c| << |I|$ where |.| denotes the size in bits (Fig 2) [5].

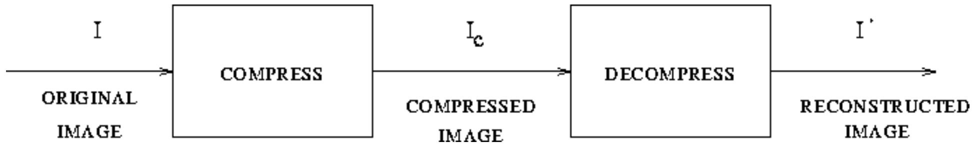


Fig 2 . Image Compression Block Diagram

3-1- Lossy compression methods

In order to achieve high compression ratios with complex image, lossy compression methods are required . lossy compression provides tradeoffs between image quality and degree of compression, which allows the compression algorithm to be customized to the application [6].

3-1-1- JPEG method

JPEG is the first international image compression standard for continuous both grayscale and color images.

JPEG defines four modes of operations:

1. Sequential lossless mode: Compress the image in a single scan and the decoded image is an exact replica of the original image.
2. Sequential DCT-based mode: Compress the image in a single scan using DCT-based lossy compression technique. As a result, the decoded image is not an exact replica, but an approximation of the original image.
3. Progressive DCT-based mode: Compress the image in multiple scans and also decompress the image in multiple scans with each successive scan producing a better-quality image.
4. Hierarchical mode: Compress the image at multiple resolutions for display on different devices [6].

The baseline JPEG algorithm follows the principles of block-based transform coding. Block diagram of the baseline JPEG algorithm for a grayscale image with a single component is shown in Fig 3.

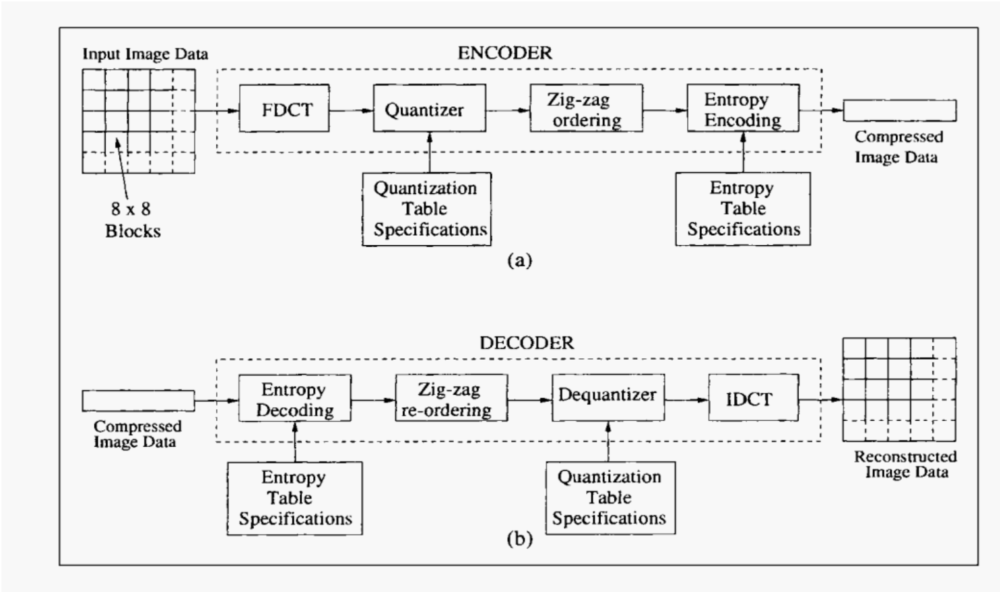


Fig 3. Baseline JPEG: (a)compression, (b) decompression

The image component is first divided into non-overlapping 8 x 8 blocks in the raster scan order left-to-right and top-to-bottom as shown in Fig 3(a). Each block is then encoded separately by the ENCODER shown in the broken box in Fig 3(a). The first step is to level shift each pixel in the block to convert into a signed integer by subtracting 128 from each pixel. Each level-shifted pixel in the 8 x 8 block is then transformed into frequency domain via forward discrete cosine transform (FDCT). The FDCT of an 8 x 8 block of pixels f(x,y) for (x,y = 0,1,. . . ,7) is defined by:

$$F(u,v) = \frac{1}{4}C(u)C(v)\sum_{x=0}^{7}\sum_{y=0}^{7} f(x,y)\cos\left[\frac{\pi(2x+1)u}{16}\right]\cos\left[\frac{\pi(2y+1)u}{16}\right] \quad \ldots(7)$$

for $u = 0, 1, \ldots, 7$ and $v = 0, 1, \ldots, 7$, where

$$C(k) = \begin{cases} \frac{1}{\sqrt{2}} & \text{for } k = 0 \\ 1 & \text{otherwise.} \end{cases}$$

3-1-2 MFART method

This work uses gray image in compression so that the image must check at the beginning if it is gray or not, if the image is colored it is convert to gray, then the gray image compressed and decompressed using MFART algorithm as shown below in Fig 4.

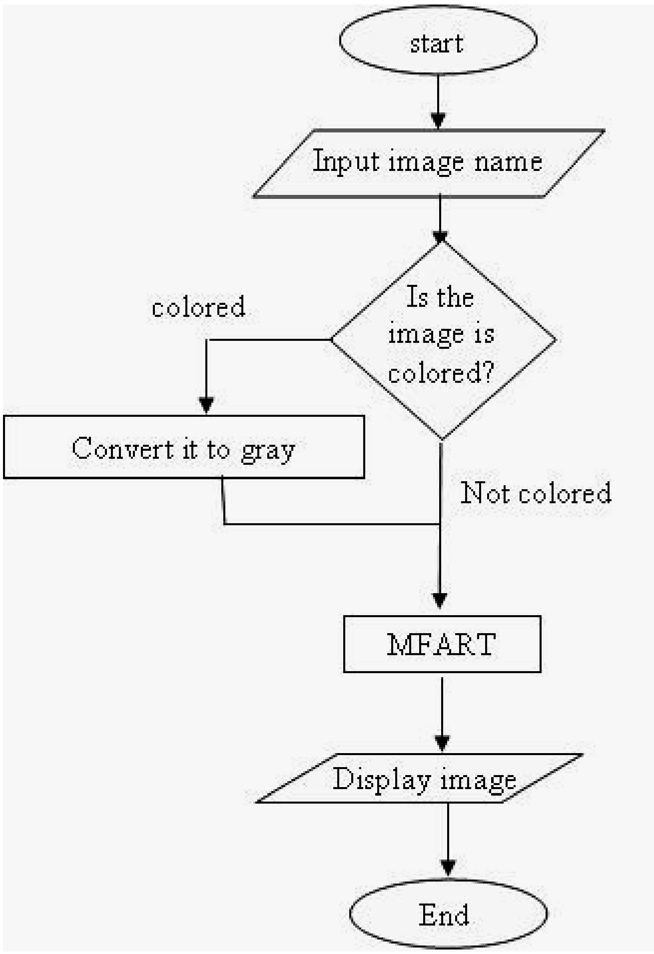


Fig 4.MFART method flowchart

4- The measure criteria

4-1-Compression ration:

The ratio of the original image file size and the compressed file size is referred to as the compression ration. The compression ratio is denote by[6]:

$$compression\ \ ratio = \frac{original\ \ file\ \ size}{compressed\ \ file\ \ size} \qquad \ldots(8)$$

4-2- Root mean square error :

Root mean square (rms) error is the error between an input and output images, let $f(x,y)$ represent an input image and let $f'(x,y)$ denote an estimate or approximation of $f(x,y)$ that results by compressing and subsequently decompressing the input for any value of x and y, the error $e(x,y)$ between $f(x,y)$ and $f'(x,y)$ can be defined by equ. 9 :

$$e(x,y) = f'(x,y) - f(x,y) \qquad \ldots(9)$$

The root mean square error (e_{rms}) between $f(x,y)$ and $f'(x,y)$ can be calculated as follows (equ. 10): [7]

$$e_{rms} = \left[\frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \left[f'(x,y) - f(x,y) \right]^2 \right]^{1/2} \qquad \ldots(10)$$

Where the images size are $M \times N$.

4-3- Entropy:

An important concept here is the idea of measuring the average information in an image which is referred to as the entropy. The entropy for an $N \times N$ image can be calculated by equ. 11 :

$$entropy = -\sum_{i=0}^{L-1} p_i \log_2(p_i) \qquad \ldots(11)$$

Where p_i =the probability of the ith gray level= $\frac{n_k}{N^2}$

n_k = the total number of pixels with gray value k

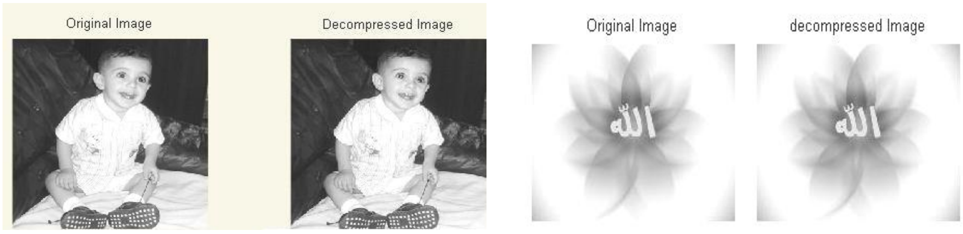
L=the total number of gray levels (e.g 256 for 8 bits) [6]

5- Results

Experiment was performed by two types of images jpeg and tiff using MFART and JPEG method. The original, compressed, and decompressed images for the methods are shown below:

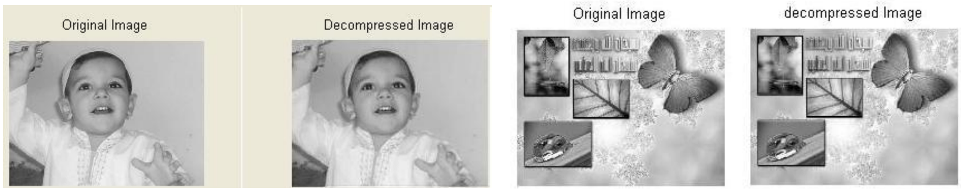
(a) (b)

Fig 5. original and decompressed using MFART on jpeg image



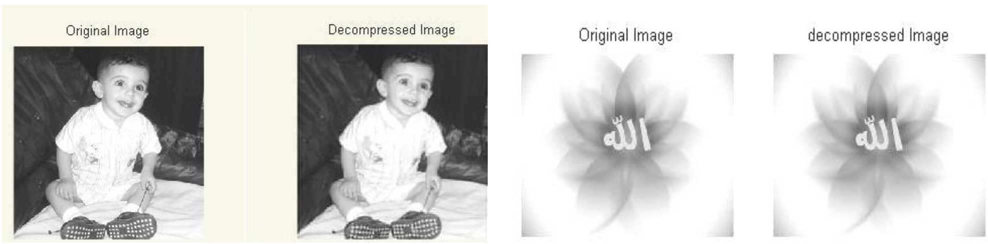
(a) (b)

Fig 6. original and decompressed using MFART on tiff image



(a) (b)

Fig 7. original and decompressed using JPEG method on jpeg image



(a) (b)

Fig 8. original and decompressed using JPEG method on tiff image

So, the Fig 5 and Fig 6 shows original, and decompressed images using MFART on jpeg and tiff images respectively .Fig 7 and Fig 8 shows the images after applying JPEG method on the same images.

The results of measuring criteria which was used to compare between the used methods are shown in the table below

Table. 1 results of measuring criteria

	MFART				JPEG			
	Jpeg image		Tiff image		Jpeg image		Tiff image	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
Compression ratio	0.110	0.105	0.100	0.100	0.468	0.312	0.842	0.342
e_{rms}	1.0681	12.576	0.0465	0.0005	1.9296	77.7348	5.355	0.972
Entropy of original image	0.01135	0.0072	0.0087	0.0244	0.01135	0.0072	0.0087	0.0244
Entropy of compressed image	0.01128	0.0071	0.0088	0.0237	0.20906	0.1896	0.3084	0.5996
Entropy of decompressed image	0.01135	0.0072	0.0087	0.0244	0.01135	0.0073	0.0085	0.0244

The table above found that the compression ratio in MFART is more than that in JPEG, the entropy of compressed image, and e_{rms} in MFART are smaller than JPEG, so that the MFART is better than JPEG method.

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