Fast encoding algorithm based on Weber's law and Triangular Inequality Theorem

Nihad A. Karam[1*], Maha A. Hameed[1] and Suhad A. Hamdan[2]
[1] Dept. of Astronomy, College of Science, University of Baghdad, Baghdad, Iraq.
[2] Dept. of Physics , College of Science, University of Baghdad, Baghdad, Iraq.

Abstract:
In the present work, an image compression method have been modified by combining The Absolute Moment Block Truncation Coding algorithm (AMBTC) with a VQ-based image coding. At the beginning, the AMBTC algorithm based on Weber's law condition have been used to distinguish low and high detail blocks in the original image. The coder will transmit only mean of low detailed block (i.e. uniform blocks like background) on the channel instate of transmit the two reconstruction mean values and bit map for this block. While the high detail block is coded by the proposed fast encoding algorithm for vector quantized method based on the Triangular Inequality Theorem (TIE), then the coder will transmit the two reconstruction mean values (i.e. H&L) with an index of codeword instead of bit map (binary block) after designation binary codebook. In other word, the proposed method enables a sensible decrease of the bit rate with fast in codebook searching, little deterioration of performance, edge preservation, good decoded image quality with greatly decreasing the matching searching time, consequently simplify the computational complexity.

Keyword: Absolute Moment Block Truncation Coding algorithm**,** Vector Quantized method, Weber's law condition, the Triangular Inequality Theorem (TIE).

خوارزمية تشفير سريعة بالاستناد على قانون ويبر ونظرية عدم المساواة المثلثيةِ

نهاد علي كرم*[1]، مها احمد حميد[1]، وسهاد عبد الكريم حمدان[2]
[1] قسم الفلك، كلية العلوم، جامعة بغداد، بغداد، العراق.
[2]قسم الفيزياء، كلية العلوم، جامعة بغداد، بغداد، العراق.

الخّلاصة:
تم في هذا البحث، تطُوير طريقة ضغط الصور وذلك من خلال دمج خوارزمية التشفيرِ(ِ AMBTC) مع طريقة VQ . في بادئ الأمر، أُستخدمت خوارزمية AMBTC بالاستناد على شرط قانون ويبر للتمييز بين البلوكات ذات التفاصيل المنخفضة والعالية في الصورة الأصلية. يقوم المشفر بإرسال المعدل الواطئ فقط للبلوكات قليلة التفاصيل (اي البلوكات المنتظمة مثل الخلفية) بدلا من إرسال قيمتي المعدل العالي والواطئ مع البلوك الثنائي للبلوك الاصلي. بينما البلوكات التي لها تفاصيل عالية تُشفَّر باستخدام الخوارزمية السريعة المُقتَرَحة بالاستناد على نظرية عدم المساواة المثلثية. ثمّ يقوم المشفر بإرسال قِيَمَ (H & L) مع الدليلِ index بدلاً مِنْ إرسال البلوك الثنائي بعد تصميم كتاب التشفير الثنائي. بعبارة أخرى، الطريقة المُقتَرَحة تمكّنت من انقاص نسبة البت مع سرعة في عملية البحث في كتاب التشفير وقلة في تدهور الأداء وحفظ الحافة وجودة في نوعية الصورة مع تبسيط التعقيد الحسابي.

*Email: mahaahmed69@yahoo.com

Introduction:

The Block Truncation Coding (BTC) algorithm developed by Delp and Mitchell is a two-level quantizer. Lema and Mitchell[1] applied the Absolute Moment BTC technique. The compression ratio is always 4. To increase the compression efficiency, so an adaptation is required to improve the compressibility of the Absolute Moment Block Truncation Coding (AMBTC) by utilizing the Vector-Quantization method VQ to represent the binary form of the coded image.

Vector Quantization (VQ) is a widely used technique in many data compression applications [1]. This is because the computational intensive of full search is very high procedure, therefore, there are many methods have been proposed to compress computational complexity of the distortion computations in code vector matching [2,3].

In 1846 Weber showed experimentally the Weber's law, this law stats on " The change in the intensity $\delta\lambda$ to the background intensity λ on human's sensitivity stays constant"; where $\delta\lambda/\lambda$ is a constant [4], depending on this ratio, the low and the high feature areas (blocks) in the image have been separated. When the ratio of the change in the intensity (in this work, it is founded from the difference between the two reconstructed values) to the background intensity (the low mean L value of block) is smaller than the threshold constant, human being would recognize the block as a background (low feature area) and the coder is compressed it by sending only the mean of block, otherwise the coder is compressed the block (i.e high feature area) by adaptive fast VQ method, where it is firstly compressed using the AMBTC method to find the bit map of block then compressed this bit map using the proposed fast encoding algorithm for vector quantized method which based on the Triangular Inequality Theorem (TIE) theorem [4]. Then the coder send the two reconstruction (high and low mean values of block H&L) values with an index of the matched codeword.

Absolute Moment Block Truncation coding (AMBTC):

The Absolute Moment Block Truncation coding algorithm subdivides an image into uniform blocks, typically (*m*n*) pixels in size. For each block, the mean (*M*) and a bit map is created [1]. The mean, high and low mean of block (the two reconstruction levels H&L) can be calculate as [4,5];

$$M = \frac{1}{m*n}\sum x_i \;......(1)$$

$$H = \frac{1}{q}\sum x_i\,, \quad x_i \geq M \;.....(2)$$

$$L = \frac{1}{k-q}\sum x_i\,, \quad x_i < M \;.....(3)$$

Where *k* is (*m*n*) and *q* is the number of pixels whose values are greater than or equal threshold value.

The bit map results from a two- level quantization of the block, where pixels with values greater than or equal to the block mean are represented by 1 and pixels with values less than the block mean are represented by 0. Computing two reconstruction values for each block, based on the encoded moments of same block eq. 2&3, where one value (low mean L) is assigned to the 0-valued pixels in the bit map, the orders (high mean H) is assigned to the 1- valued pixels [5,6].

In the proposed work, the existing AMBTC algorithm has been modified using Human Visual perception based on Weber's law condition to distinguish low and high detail blocks in the original image and improve coding efficiency even further.

Weber's law:

Weber's law is one of the experimental physical laws, it is applicable for different sensory system [4], it states, " The ratio between the change in the intensity ($\delta\lambda = \lambda - \lambda_o$) and the original intensity (λ_o) is remains constant ", in other word, $\delta\lambda / \lambda_o$ = constant= β, the ratio $\delta\lambda / \lambda_o$ is called Weber's ratio and β is Weber's fraction, where β for light intensity takes equal to .01….02.

According to this law, which is more sensitive to texture information, and by depending on the changes of the intensity $\delta\lambda$, for each block, if the ratio between $\delta\lambda$ (this is founded from the difference between the two reconstructed mean values) and λ_o (the low mean value L) is equal to or smaller than

a threshold value β, then the block is classified as a low feature block.
$(\delta\lambda / \lambda_o) \leq \beta$, where β = .02. Otherwise, the block is a high feature block [4].

The Vector Quantization technique (VQ):

Vector quantization (VQ) is a popular technique in image compression. This method can be processes in three steps. There are codebook design, vector encoding, and vector decoding. In other word, the VQ method can be defined as a mapping of k -dimensional Euclidean space (R^k) into a finite subset C of R^k [2,3]. Where $\mathbf{C_i = \{ C_i, i = 1, 2, ….. , N\}}$, $\mathbf{C_i}$ is called a code word which is connected with an index **i** and **N** is the number of the code words in the codebook. The given input vector is encoded by searching codeword with minimal distortion that is done by calculate the Squared Euclidean Distance between the given input vector and each code word in the codebook and assign this square difference [6].

Triangle Inequality Theorem (TIE):

Triangle Inequality Theorem states that "the addition of the lengths of any two sides of a triangle is always greater than the length of the third side", see figure -1,[5].

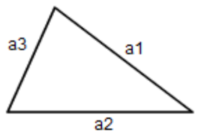


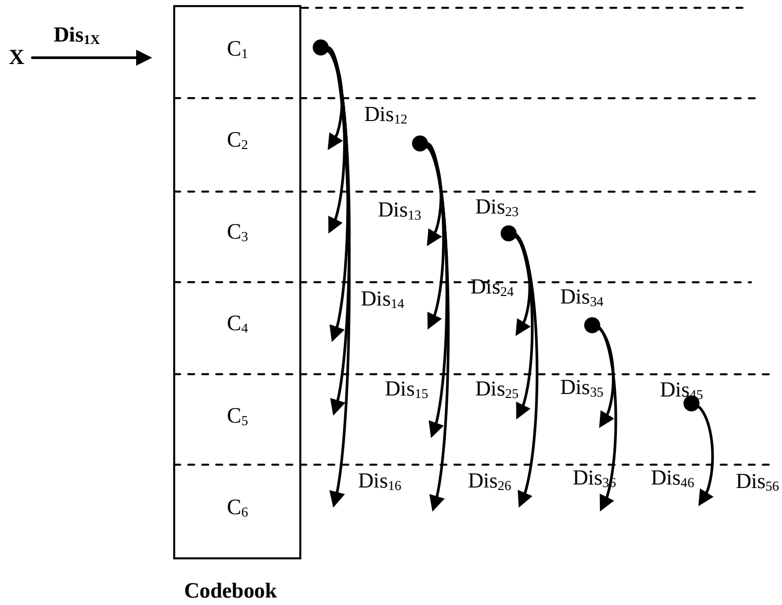
Figure 1- Illustration of the Triangle Inequality Theorem, a1+a2 > a3, a1+a3 > a2, a2+a3 > a1.

In this paper, the elimination rule based on Triangular Inequality criteria very efficient, it can described as follows;
Let $Dis_{(x,ci)}$ be squared error distortion between the input vector x and the code vector c_i, if the $Dis_{(c1,c2)}> 4Dis_{(x,c1)}$, (where $Dis_{(c1,c2)}$ represents the distortion of matching the code word C_1 with C_2 but $Dis_{(x,c1)}$ represents the distortion of matching the encoding vector x with the code word C_1), then eliminate the computation of the distortion of matching the encoding vector x with the code word C_2 (i.e. $Dis_{(x,c2)}$), this process leads to greatly decreasing the matching searching time, consequently simplify the computational complexity with fast in codebook searching.

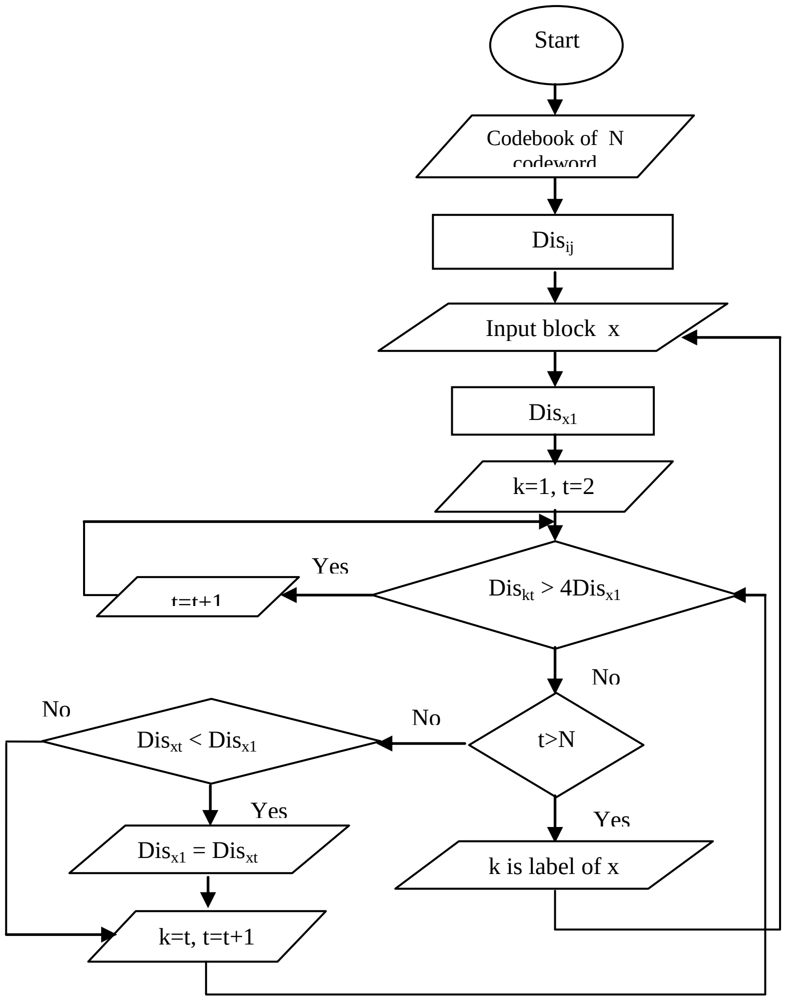
Proposed Fast VQ algorithm:

A fast VQ algorithm can be obtained using the Triangle Inequality Theorem that is an elimination rule. The procedure is as follows.

Step1. Initialization, calculate the distortion Dis_{ij} of matching the code word C_i with C_j, where (i=1, N-1, j=i+1….N), N is code-book size (the number of the code word in the code book), see figure -2.
Step2. Calculating the distortion of matching the input vector x with the first code word in the code book C_1, let $Dis_{(x,c1)}$ or Dis_{x1} is the distortion between the encoding vector x and the code word C_1, set k=1 and t=2.
Step3. If $Dis_{kt} >4Dis_{x1}$, then eliminate the computation of Dis_{xt}, (t) should be incremented by one (i.e. t=t+1), and repeat the process. Otherwise, go to next step.
Step4. If t>N then give the input vector x a label (k), taking the next input vector x and go to step 2.
Step5. Calculating the distortion of matching the x with the (t) code word (i.e Dis_{xt}). If $Dis_{xt}<Dis_{x1}$ then $Dis_{x1}=Dis_{xt}$. k=t, t=t+1, and go to steep 3.
Step6. Taking the next input vector x to code it, and going to step 2.
This method will be very efficient if we can initially find a code word which has small distortion to the encoding vector. The reason many distortion computations can therefore be eliminated.



(a)



(b)

Figure 2- (a) Proposed Fast Vector Quantization method, when codebook size = 6 code word. (b) Flowchart of proposed Fast VQ algorithm.

Proposed algorithm:

For each block in the original image, the full steps of the proposed method are illustrate as follows;

Step1. Taking the threshold condition value (β). Division an image into 4 x 4 sub images. Generation the binary code book containing 256 code words from these vectors of the bit map of image using the well- known LBG algorithm[6].

Step2. Finding the mean then low and high mean values for block.

Step3. Depending on Weber's law condition, the low and high feature areas (blocks) in the image have been separated, when the ratio of the change in the intensity (in this work, it is founded from the difference between the low and high mean values) to the background intensity (the low mean L value of block) is smaller than the threshold constant, human being would recognize the block as low details (i.e. uniform block like background), otherwise the block is high details.

Step4. If the block is low details, the coder will transmit only the mean value of low details block on the channel, then taking the next block and go to step 2. Otherwise, go to next step.

Step5. If the block is high detail, bit map of this block is coding using the proposed fast encoding algorithm for vector quantized method based on the (TIE) theorem, then the coder will transmit the low and high mean values with an index of codeword instead of bit map (binary block), then take next input block and go to step 2.

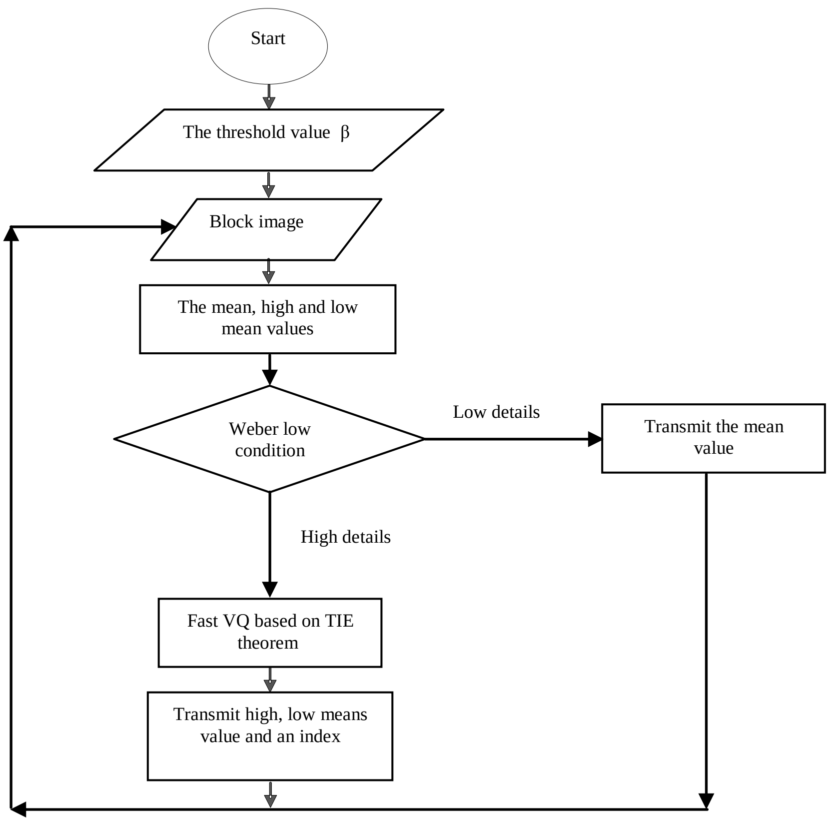


Figure 3- Flowchart of the proposed algorithm.

The proposed method enables a sensible decrease of the bit rate with fast in codebook searching, little deterioration of performance, edge preservation, good decoded image quality with greatly decreasing the matching searching time, consequently simplify the computational complexity.

The performance measure:

The performance measure like *Peak Signal to Noise Ratio* (*PSNR*) is, most often, used to evaluate the performance of image coding methods [6]. For image of size *N*N*, the *PSNR* can be computed as follows:

$$PSNR = 10\log_{10}\left[\frac{(2^n - 1)^2}{MSE}\right] \quad ....(4)$$

Where n is the number of bits per pixel (For an example, if we want to find the *PSNR* between two 256 gray level images, then we set n = 8 bits) and *MSE* is the Mean Square Error between the reconstructed $\hat{x}$ and the original image x . It can be computed as follows:

$$MSE = \frac{1}{M}\sum_{i=1}^{M}(\hat{x}_i - x_i)^2 \quad ....(5)$$

Where M is the number of elements in the image (i.e. $N*N$).

Result and Conclusion:

The main advantage of the present method is to improve the compression ratio by decreasing the bit rate with fast codebook search using AMBTC algorithm based on Weber's law condition to distinguish low and high detail blocks in the original image. Where the coder will transmit only mean of low detailed block (the uniform blocks like backgrounds) on the channel instate of transmitting the two reconstruction values and bit map for this block. For more compression and faster, the bit map (binary block) for high detail block is coded by the proposed fast encoding algorithm for vector quantized method then the coder will transmit the low and high mean values (i.e. H&L) with an index of codeword instead of the bit map (binary block) after designation binary codebook. This idea leads to decrease in the bit rate, increase in compression ratio, with greatly decreasing the matching searching time and decrease in number of computation, with good reconstructed image quality. The efficiency of the proposed fast encoding algorithm for vector quantized method in image compression is examined by computer simulation.

After applying the new proposed method the results that shown in figure -4. It is clear that the introduce algorithm produced a good decoded image quality such us that obtained by the full search technique, but greatly decreasing of the matching searching time and consequently simplify the computational complexity. Using the AMBTC with Weber's condition lead to improve coding efficiency even further.

From the experimental results, using Weber-Fechner condition in AMBTC and fast VQ depending on the TIE, the bit rate and computational complexity are much lower than using the AMBTC or AMBTC+VQ methods with the same image quality.

a. b. c. d.

Figure 4- a. Original image. b. Decoding image using the AMBTC. c. Decoding image using the AMBTC+ full search VQ. d. Decoding image using Weber-Fechner condition in AMBTC and fast VQ method depending on the (TIE) theorem, with β = .02 and 4 x 4 block size for " Natural picture" image.

Table 1- Results obtained using AMBTC, AMBTC+VQ methods, and the proposed algorithm.

Block size	**AMBTC**		**AMBTC+VQ**		**Proposed Algorithm**	
	B.r	**PSNR /dB**	**B.r**	**PSNR /dB**	**B.r**	**PSNR /dB**
4x4	2	31.380	1.27	30.379	0.56	29.064
8x8	1.25	29.119	.84	27.919	0.39	27.119

The Elimination effectiveness of using the Weber's condition and the TIE in the fast encoding algorithm is tested using binary codebook which was generated later. It can be seen from table -2 that 56.163% codeword matching are eliminated by this process.

Table 2- Elimination efficiencies for encoding " Natural picture" image.

Block size	**Elimination efficiencies**
4x4	56.163 %
8x8	31.206%

The Triangle Inequality Theorem rule will be very efficient if we can initially find a code word which has small distortion to the encoding vector. This is because many distortion computations can therefore be eliminated.

References:

1. Sindhu, M. and Rajkamal, R.**2009**. Images and Its Compression Techniques– A Review. *International J. Recent Trends in Engineering*, 2(4), pp: 71-75.
2. Hang, S. H. and Chen, S.H.**1990**. Fast encoding algorithm for VQ based image coding. *Electronics letters*, 26(19), pp: 1618-1619.
3. Chen S.H and Hsieh W.M.**1991**. Fast algorithm for VQ codebook design. *IEEE proc. I*,.138(5)**.**
4. Kang, J., Jianhua, W., Anteo, S. and Jianfeng F.**2010**. Weber’s law implies neural discharge more regular than a Poisson process. *European J. Neuroscience*,31, PP. 1006–1018.
5. Hameed ,M. A.**2005**. Fast encoding algorithm for vector quantization-based on block truncation coding technique. Iraqi Journal of Science, 46(1), pp: 296-298.
6. Hameed, M. A.**1999**. Adaptive block truncation compression technique. MS.C. thesis, College of Science, Dept. of Astronomy, University of Baghdad.