EncodingImageswithFractalGeneticAlgorithm

Olena Osharovska, Mikola Patlayenko
Television and Radiobroadcasting Department
O.S. Popov's ONAT
Odessa, Ukraine
osharovskaya@gmail.com, nick_msa@ukr.net

Кодування Зображень Фрактальним Генетичним Алгоритмом

Олена Ошаровська, Микола Патлаєнко
кафедра телебачення та радіомовлення,
ОНАЗ ім.О.С.Попова
Одеса, Україна
osharovskaya@gmail.com, nick_msa@ukr.net

Abstract—**This article presents the results of applying a fractal modified genetic algorithm for encoding high-definition images. Dependences of the compression ratio on the sizes of rank blocks and the signal-to-noise ratio are obtained depending on the mean square deviation of the average brightness of the compared blocks. A structure for constructing the code and the bit depth of individual fields is proposed. The time spent on encoding and decoding the image has been calculated.**

Keywords—Image, fractal, genetic algorithm, rank block, domain block, compression ratio

Анотація—**Уданій статті наведені результати застосування фрактального модифікованого генетичного алгоритму для кодування зображень високої чіткості. Отримано залежності коефіцієнта стиснення від розмірів рангових блоків і відносини сигналу до шуму в залежності від середньоквадратичного відхилення середньої яскравості порівнюваних блоків. Запропоновано структуру побудови коду і розрядності окремих полів. Розраховані часові витрати на кодування і декодування зображення.**

Ключові слова—Зображення, фрактал, генетичний алгоритм, ранговий блок, доменний блок, коефіцієнт стиснення

I. INTRODUCTION

Fractal compression of images is based on splitting the image into blocks and searching for similar blocks. True fractals have self-similarity properties when scaling and affine transformations. The image is divided into large enough square areas, called domain blocks. Further, the first domain block is divided into smaller rank blocks. The size of the rank blocks during the encoding process can vary depending on the specified quality. The maximum size of a rank block corresponds to a domain block, and the minimum size measuredas two by two image elements. Next, a rank block is compared from the first domain block to other ranking blocks in both its domain and other domains. The desired accuracy of the similarity of blocks is set in the above parameters, K. In addition, rank blocks can undergo affine transformations of the type of rotation, reflection.

At this stage, there are high costs, both computing power, and temporary. In the proposed algorithm, the search for such rank blocks is performed in parallel in all domain blocks. Rank blocks taking similar characteristics can be called "heirs", and the block with which the comparison is made is called "parent". Therefore,thenameofsuchalgorithmsisgenetic[1,2].

II. A VECTOR OF RANK BLOCK PARAMETERS

Define the parameters of image blocks, which will compare the similarity of rank blocks[3,4, 5]. First of all, the average luminance value (chroma) ($P_{X,Y}$) within the block of rankI_1; the standard deviation of brightness (d) within each block.

Standard deviation in rank block (1):

$$d = \sqrt{\frac{\sum_I (P_{X,Y} - m)^2}{N_I}}, \qquad (1)$$

Asymmetry (a) in rank block (2)

$$a = \frac{\sum_I (P_{X,Y} - m)^3}{N_I \cdot d^3} \qquad (2)$$

Inter-pixel contrast difference (c)within rank block (3):

$$c = \frac{\sum_{I} \left|P_{X,Y} - P_{X-d,Y}\right| + \left|P_{X,Y} - P_{X,Y-d}\right|}{N_I} \qquad (3)$$

The following conventions are used in the formulas:

- I - segment of the image;
- N_I– number of pixels in the segment I;
- $P_{X,\,Y}$– pixel brightness value at the point (x, y);
- m– average pixel value in the segment I;
- I_h , I_v–horizontal and vertical coordinates of a rank block in a domain block.

The above parameters, as well as others, on which you can compare and colorimetric proximity, are combined into a vector.Therefore,when comparing rank blocks, the desired accuracy of the matching of the parameters is specified. The higher the accuracy, the higher the number of rank blocks you have to split the image, and the more time it takes for fractal coding. In our models, we limited ourselves to an accuracy of 5% for the average brightness of the rank block [5, 6].

III. Structure Code Under the Genetic Algorithm

The HD 1080 format has a resolution of 1920 × 1080 pixels [7, 8, 9]. The row number and the column number specify the address of each pixel, each of these numbers can be represented by an eleven-bit binary code, which corresponds to the common 22-bit code. The number of pixels in the image is 2073600, because of the progressive scan,if represent all the image elements as a one-dimensional array, then the number of each element can be specified by a 21-bit code.

As test images were selected as artificially created images, and natural (Fig. 1).

Fig. 1. Examples of test images

The construction of the code for the fractal genetic algorithm begins with the number and size of the domain block. In the conducted experiments, the number of domain blocks varied from 200 to 5000. Then, the address and size of the parent-ranking block and its parameter vector are recorded, followed by the addresses of the ranked child blocks. The number of the domain block is necessary, since ranked heirs from the first domain will cover not all areas. The parameter vector does not have a constant length, for example, in the experiments carried out; affine transformations are not used to shorten the coding time. Another feature of the code generation is the permutation of the samples in the rank block in the z-scan type. For each next rank block, the addresses are repeated, that makes it possible to use efficiently statistical coding in the next step, for example, the Huffman code or the arithmetic code.We give the structure of the code and the approximate bit depth of each field (Table I).

TABLE I. The Construction of the Code for the Fractal Genetic Algorithm.

Parameter	Bit Depth
Domain block address	22
The size of the domain block	13
Address of rank block	11
The size of the rank block	5
Vector of the rank block parameters	32
Address of the first heir of the ranking block	33
Addresses of the following heirs	33

If a non-compressed high-definition image for storing the luminance component with a 10-bit code spends 20971529 bits, then for fractal compression with the size of rank blocks 4×4, the number of rank blocks 1228 will require 40673 bits, which theoretically makes it possible to obtain a compression ratio of 515. However, the encoding time will be of the order of 50 seconds, with existing personal computers for mass use.

Developing code structure takes into account the fact that the domain blocks as the rank, in the proposed algorithm selects only a square shape, and in relation to said circumstance is enough to indicate the coordinates of one "corner". The presence of fields indicating the size of the blocks allows you to calculate quickly other addresses.

The coding process develops recursively, from a smaller number of rank blocks with the largest sizes to a larger number of rank blocks with smaller sizes. The larger the rank, the more difficult to find the like, and accordingly, when restoring the image will be more "rough".It is in this case that more similarity properties are considered, including affine block transformations.One can calculate the root-mean-square difference between the original and the restored image.Based on the RMS, it is possibleto calculate image quality indicators consistent with human perception, for example, the structural similarity index SSIM [10, 11, 12, 13, 14].In the case of not satisfactory quality, it is necessary to reduce the sizes of rank blocks by splitting them. Unfortunately, we have to recalculate all the components of the parameter vector and re-search for the heirs.For an extremely small size of the rank block 2×2, the parameter vector can consist of only one value of the average brightness of the block, but the code will increase the number of addresses of the heirs. Of course, in this case, the reproducible sharpness of the image is reduced.The decoding time, on the contrary, decreases in comparison with the large sizes of rank blocks.

IV. RESULTS OF FRACTAL COMPRESSION MODELING

A model of genetic fractal image coding was implemented in MatLab on a personal computer. During the simulation, the number of domain and rank blocks was changed, the compression ratio, the peak signal-to-noise ratio, the average pixel reconstruction error, the time spent on the encoding and decoding process were calculated. Simulation was carried out for all the above images.

Let us present the results of calculating the compression ratio depending on the number of rank and domain blocks for the image "girl in a T-shirt".The subjective quality of the reconstructed image deteriorates as the size of the rank block increases (Fig. 2). When the size of the rank block is 20 pixels, the blocking of the image becomes clearly visible.

Sizeofrankblock = 2

Sizeofrankblock = 8

Sizeofrankblock = 12

Sizeofrankblock = 20

Fig. 2. The image quality at a different size of the rank block

The results of the computational experiment for the image of a girl in a T-shirt are summarized in Table II.The sharp increase in the number of domain blocks with decreasing size of rank blocks attracts attention.

TABLE II. DEPENDENCE OF THE PARAMETERS OF THE FRACTAL CODING OF THE IMAGE "GIRL IN A T-SHIRT" ON THE SIZE OF THE RANK.

PARAMETERS	**Rank 20**	**Rank 12**	**Rank 8**	**Rank 4**
Domain blocks	225	841	2977	4562
Rank blocks	1651	1504	1264	1228
Average pixel error, %	3,79	3,92	3,73	3,69
Compression ratio	4,35	4,68	5,38	5,51
Coding time, s	4,58	12,86	30,25	49,39
Decoding time, s	1,91	1,62	1,41	1,25

Analyzing the results presented in Table II, it can be concluded that reducing the size of rank blocks from 20 to 4 increases the encoding time tenfold, and the compression ratio increases by only 20%. The average pixel score decreases by only 3%. The results underscore the fact that objective characteristics do not provide an adequate idea of subjective quality.

Here also are given results depending on the compression ratio of mean-square error, which is selected by the need to continue or stop the division rank of blocks (Fig. 3).

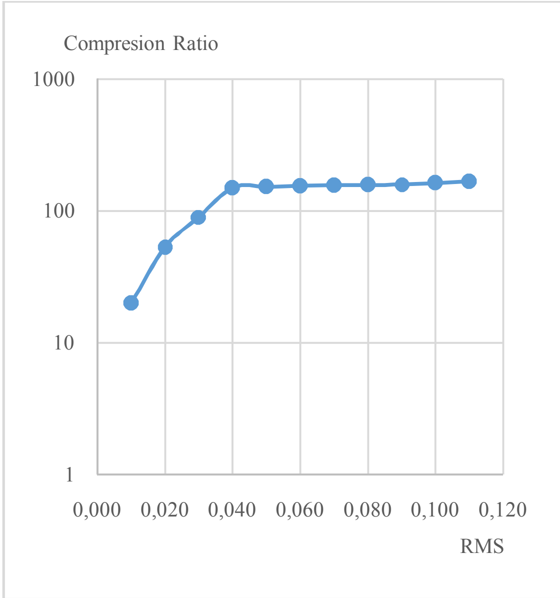

Fig. 3. Dependence of the compression ratio on the mean square deviation

The dependence of the peak signal / noise ratio on the size of the ranks is shown in Fig. 4

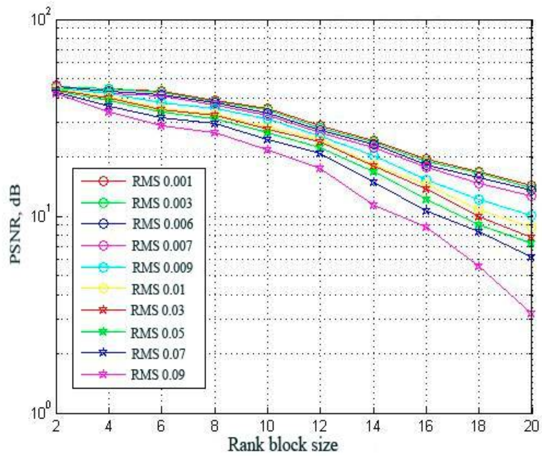

Fig. 4. The dependence of the signal / noise ratio on the size of the ranks

The graphs are plotted for several RMS values, varying from 0.001 to 0.09. With a size of rank blocks greater than 12 × 12 pixels, the difference in signal-to-noise ratio becomes noticeable. Moreover, for RMS = 0.09, the ratio of signal / noise at this block size drops to 20 dB, which confirms the subjective evaluation of the image as not satisfactory.

We also determined the dependence of compression ratio on the size of the rank block (Fig. 5). For this image in particular, an acceptable quality can be obtained with the sizes of rank blocks of no more than 8×8 pixels, which corresponds to a compression ratio of the order of 10. Analyzing the above results, we can conclude that the image of the girl contains many small details, such as hair, the play of shadows on the face and neck, requiring a large number of rank blocks of the smallest size for a qualitative description. On the other hand, an artificially created green background can be described by rank blocks of large size.

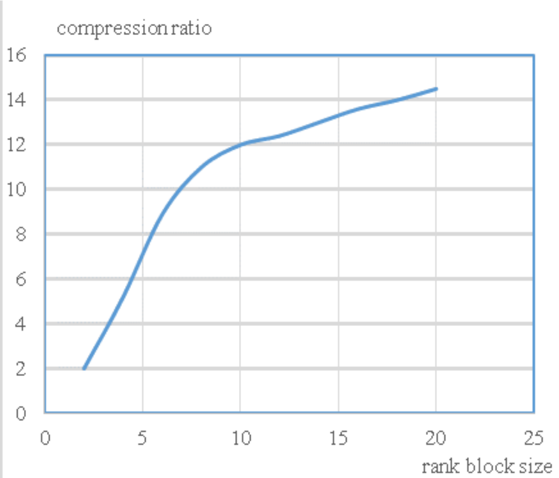

Fig. 5. A plot of the compression ratio of the rank size

V. THE SOME ASPECTS OF ASSESSING THE QUALITY OF FRACTAL CODING MODELS

Subjective image estimation not only takes a long time, but also is very expensive. The procedure is not practical in real-time applications. In addition, there may be individual factors that can affect perceived image quality. Therefore, it is necessary to evaluate the image quality objectively, taking into account the properties of the human visual system (HVS) as the basis for such an assessment. Any objective algorithm for assessing the quality of IQA images must meet the following requirements: it must have a close connection with visual perception; it must work in a wide range of types of distortion; it must be computationally simple and efficient, and it can be embedded in imaging systems or allow real-time evaluation[10, 11, 12].

As a technology for image compression based on structural similarity, fractal image compression was applied not only in image coding, but also in many important image processing algorithms. However, the two main bottlenecks restrain the development and implementation of fractal compression for a long time. First, the coding phase takes a long time. Secondly, the quality of the reconstructed images for some images that have a low structural similarity is usually unacceptable. For example, when the size of the ranking block becomes smaller, the sharpness of image recovery will vary slightly[14].

Ifone ranking block cannot be well approximated, the block will be divided into four smaller blocks, and the coding phase will be continued for these smaller blocks. An error threshold must be set to judge how well the rank block is approximated.

CONCLUSION

The development of the image fractal coding is faced with the tasks of an adequate assessment of the quality of images.Rank blocks are selected as blocks to be encoded, and domain blocks serve as address code words. The process of matching between rank and domain blocks is, in fact, a search strategy in vector quantization. For each ranking block, the search is performed in all blocks of the domain. Then the question arises: if the domain image blocks cannot well approximate the rank blocks, then the quality of the restored image is difficult to satisfy the requirements. The main contribution to the deterioration of image quality is averaging over the rank block, leading to blurring of boundaries, deterioration of visual clarity, color distortion.

Further research is aimed at developing a criterion for assigning images to a particular detail group for fractal coding.

REFERENCESЛІТЕРАТУРА

[1] Y. Fisher, "Fractal image compression – theory and application," N.Y. “Springer," Verlag, 1994, 341 p.

[2] S. Welstead, "Fractal and wavelet image compression techniques," SPIE. 1999, 254 p.

[3] M. Blackledge, "Digital image processing: mathematical and computational methods," Harwood, England, 2005, 783 p.

[4] C.S. Tong, M. Pi., “Fast fractal image encoding based on adaptive search,” in IEEE Transaction on Image Processing. 2001, Vol. 10, № 9, P. 1269 – 1277.

[5] O. Osharovska, M. Patlaenko,"Fractalcodingofvideosequencesbygeneticalgorithm,"inProceedings of the O.S. Popov ONAT,No2, 2017,c. Odessa,Ukraine. 2017, p. 131-138

[6] OlenaOsharovska, MikolaPatlayenko,“FractalCodingofVideoSequencesbyGeneticAlgorithm,”in Fractal Application of Nonlinear Dynamic Systems for Infocommunication:materials VI International Scientific and Practical Conference: Chernivtsi, Ukraine. Chernivtsi "City", 2017, p. 129-130.

[7] Recommendation H.264 (10/16): Advanced video coding for generic audiovisual services.

[8] ISO/IEC, JTC1/SC29/WG11, “Coding of moving pictures and audio - MPEG-4 Visual Standard, ISO / IEC FIS 14446-2, 2000.

[9] A. Murat, Tecalp and all, “Two-dimensional mesh-based visual-object representation for interactive synthetic natural digital video”, in Proceedings of the IEEE, vol 86, No 6, june 1998, pp. 1029 – 1051.

[10] Z.Wang, “Applications of objective image quality assessment methods,” in IEEE Signal Processing Magazine, 28(6), 2011, pp.137-142.

[11] X. Gao, W. Lu, D. Tao and X. Li, “Image quality assessment and human visual system”, in Visual Communications and Image Processing, International Society for Optics and Photonics, July 2010.

[12] C. Rafael, Gonzalez and Richard E. Woods: “Digital Image Processing,” 3rd edition, Pearson Education Inc., 2008.

[13] D.M. Chandler, “Seven challenges in image quality assessment: past, present, and future research”, ISRN Signal Processing, 2013.

[14] J. Wang, Y. Liu, P. Wei, Z. Tian, Y. Li, N. Zheng,“Fractal image coding using SSIM.”Proc ICIP. 2011 Sep; pp. 245–248.