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A. N. ZEMLIACHENKO[1], B. VOZEL[2], V. V. LUKIN[1], A. A. ZELENSKY[1]

[1] ***National Aerospace University named after N. Ye. Zhukovsky «KhAI», Ukraine***
[2] ***University of Rennes 1, France***

PREDICTION OF COMPRESSION RATIO FOR ADCT CODER

One way to predict compression ratio for efficient coder called ADCT is proposed. Prediction is based on determination of a simple parameter before compression that can be easily calculated in 8x8 pixel blocks. Such a procedure allows solving several practically important tasks including saving time and/or energy for compressed data transferring via communication networks. This provides an effect of green communication since CR for ADCT is usually sufficiently larger than for JPEG and JPEG2000 standards (for the same quality) due to using partitioning schemes and adaptation to compressed images.

***Keywords**: compression ratio, lossy compression, prediction, ADCT coder, acceleration.*

Introduction

Images and video are types of information most often transferred via different communication networks [1]. Large size data are also passed downlink from remote sensing (RS) systems installed on-board to on-ground centers of RS image reception, processing and dissemination [2]. All this requires power consumption, signal transmitting, and quite high capacity of communication channels. To meet greenness requirements [3] and to deliver data faster, image compression is applied.

Image compression can be lossless but then reached compression ratio (CR) is usually too small (not satisfactory). Thus, there is an obvious tendency to using lossy image compression. Then, a proper compromise between CR and compressed image quality (introduced losses) has to be provided. Recall here that a larger CR is connected with worse image quality according to both standard criteria as mean square error (MSE) or peak signal-to-noise ratio (PSNR) and visual quality metrics as, e.g. MSSIM [4] or PSNR-HVS-M [5]. However, different coders produce different image quality for a given CR or, in turn, different CR for a given value of a used metric. And, therefore, a better coder is desired.

There are known image compression standards as JPEG and JPEG2000 [6]. Meanwhile, there are also other image compression techniques designed later. One of them is Advanced DCT (ADCT) coder [7] that has a modification intended for providing better visual quality called ADCT-M [8]. For fixed PSNR (or PSNR-HVS-M), ADCT (or ADCT-M) provides CR by about 25…50% higher than for JPEG and JPEG2000 [7, 9]. Certainly, this advantage allows making smaller image transferring time (for fixed transmitted power) or decreasing the transmission (if the time of image transferring via wireless network remains the same).

Meanwhile, ADCT coder has several drawbacks. First, high performance of this coder is reached due to exploiting different (content adapted) sizes of image blocks and partition scheme optimization. This operation requires quite intensive computations [7] and, thus, the coder is considerably slower than JPEG. Second, CR for ADCT is controlled (varied) by quantization step (QS). Dependence of CR on QS is individual for each processed image and, thus, it is difficult to provide a desired CR or used metric value in one iteration [9]. Because of this, several iterations that include image compression, decompression, metric calculation and new QS setting are needed. Although there are approaches to decrease the number of iterations [9], providing of a desired metric value of CR requires considerable time and processor power expenses. Thus, the practical use of ADCT can be expedient if compression is done in one or (maximally) two iterations.

One step towards solving this task can be prediction of CR for ADCT coder before carrying out image compression. Such prediction can be helpful under three conditions. Firstly, prediction is much faster than compression. Secondly, accuracy of prediction is appropriate. Thirdly, these requirements are satisfied for any image to be compressed irrespectively to its structure (complexity), is an image noisy or practically noise-free, what is noise type and parameters, etc.

Note that methods for such a prediction have been recently proposed [10, 11] for the coder AGU [12]. The coder AGU is, similarly to ADCT, based on DCT but block size is fixed and equal to 32x32 pixels. Prediction is based on fast calculation of a simple statistical parameter for an image to be compressed. This parameter serves as argument for predicting (approximating) dependence that is obtained in advance and available be-

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fore carrying out compression. This dependence is obtained by curve fitting into a scatter-plot where input parameter corresponds to X axis and a predicted parameter (CR or bpp) relates to Y axis.

Since this approach works for the DCT-based coder AGU well enough, it is possible to expect that the approach will be able to work well for another DCT-based coder, ADCT one in our case. Thus, the goal of this paper is to check this assumption and to discuss how the approach can be used for the ADCT coder.

1. Prediction dependence obtaining and analysis of its properties

First of all, let us consider requirements to prediction and its background more in detail. The main assumption put into basis of prediction is that there are such output and input parameters for which there is a strict dependence and where the output parameter describes efficiency of image processing (e.g., lossy compression) whilst the input parameter defines some important properties of a processed image [13]. An example of such a dependence taken from the paper [11] is presented for the coder AGU [12] in Fig. 1. Note that the coder AGU has rate-distortion performance slightly better thanJPEG2000.

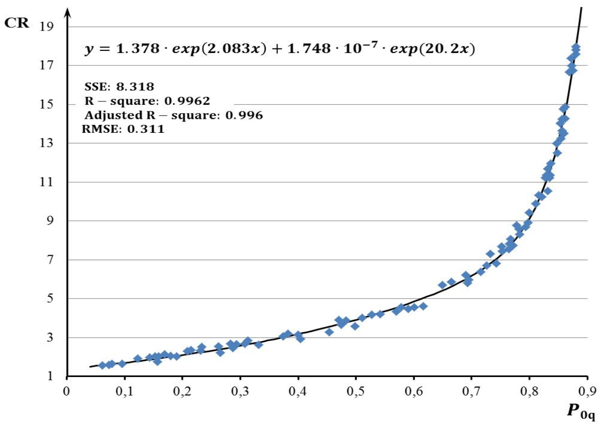

Fig. 1. Scatter-plot of CR vs parameter P_{0q} and the fitted prediction curve for the coder AGU

As it is seen, scatter-plot point positions clearly indicate that there is a rather strict dependence between output (CR for the considered case) and input (P_{0q} in the case in Fig. 1) parameters. This allows fitting a curve describing this dependence and determining parameters that characterize quality of fitting [14]. Fitting is supposed good and a dependence is considered strict if goodness of fit parameter R^2 tends to unity and root mean square error (RMSE) approaches to zero. As it can be seen in Fig 1, fitting is almost perfect. Certainly, fitting depends upon types of functions tried for this purpose and number of free parameters used in them. There can be also restrictions on fitting functions and their values. For example, CR cannot be smaller than unity. Since fitting results presented in Fig. 1 and later are good enough, discussion of fitting details is out of the scope of this paper.

It is worth recalling here how scatter-plots for prediction are obtained. A set that contains a rather large number of test images (more than 30) is used. These images (all grayscale) include natural scenes, textures, a few artificial and remote sensing images to cover possible practical situations and degrees of image complexity. Several levels (variance values) of noise are used to simulate almost noise-free and noisy images. Besides, several values of QS have been used to simulate different degrees of compression (wide range of CR) and almost full range of input parameter P_{0q}.

Now, we have to give more details concerning input parameter. In fact, although methodology of prediction has been already used in image lossy compression and denoising [10, 11, 13], we still do not know the best input parameter. In all cases, calculation of input parameter has been performed in a set of 8x8 blocks where DCT coefficients in these blocks have been processed in one or another manner. In all cases, some mean probabilities have been determined. These were mean probabilities (averaged for all considered blocks) that absolute values of AC DCT coefficients are less or exceed some threshold T linked with standard deviation σ of noise supposed additive, white and Gaussian. In the latest paper [11], a novel statistical parameter, P_{0q}, has been introduced. This is mean probability that AC DCT coefficients become equal to zero after their quantization. An assumption that this parameter can be strongly connected with CR comes from coding theory (e.g., RLE) and results presented in [15].

Therefore, we can expect that similar dependences take place for the coder ADCT and its modifications. Then, it will be easy to predict CR for the ADCT coder and to exploit this in practice in one or another manner.

2. Dependences for ADCT coder

First of all, we have obtained several scatter-plots. Note that, for 8-bit grayscale images, compression efficiency can be characterized by either CR or bpp (bits per pixel) where bpp=8/CR. So, let us first analyze dependence of bpp on P_{0q}. As earlier, for its obtaining, we have studied the aforementioned set of test grayscale images corrupted by additive white Gaussian noise with σ ranging from 1 to 25. These images have been compressed by the ADCT coder with QS=3.5σ (the values recommended for reaching optimal operation point in lossy compression of noisy images [10, 11]) and other values of QS (equal to, e.g. 2σ and 5σ). The values of

P_{0q} and bpp have been saved for each particular case with getting a corresponding point at the scatter-plot presented in Fig. 2.

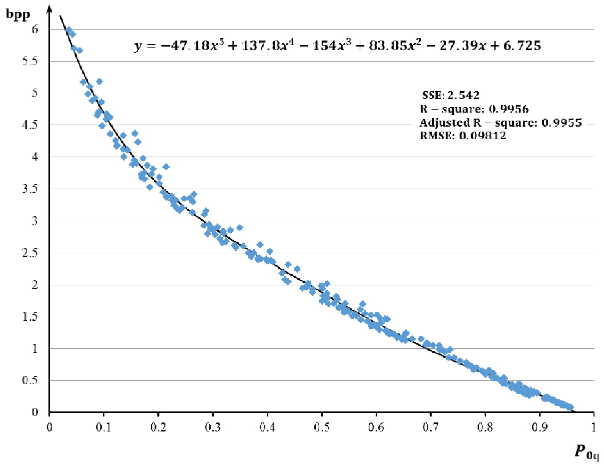

Fig. 2. Scatter-plot of bpp vs parameter P_{0q} and the fitted prediction curve for the coder ADCT

Polynomial function of the fifth order is used for fitting. As it is seen, fitting and, thus, prediction are very accurate – R^2 is larger than 0.995 (very close to unity), RMSE is only about 0.1 and larger deviation of prediction is observed for larger bpp. The fitted curve is monotonous and it tends to 7 (i.e. CR about unity) for very small P_{0q} (i.e. when almost all DCT coefficients are not zeros after quantization) and to very small values (very large CR) for P_{0q} approaching to unity (i.e. when practically all AC coefficients become zeros after quantization). This means that bpp can be predicted well enough (with high accuracy).

Consider now scatter-plots obtained for CR vs P_{0q}. The obtained data can be presented as one (aggregate) scatter-plot but we would like to represent data as three separate scatter-plots that correspond to different intervals of P_{0q} variation. All three scatter-plots with curves fitted in each of them are given in Fig. 3.

As it is seen, the dependence is, in general, monotonous with CR covering a very wide range from almost unity to almost 100. Even the third order polynomials provide good fit with the values R^2 about 0.98. Analysis has shown that the use of higher order polynomials does not provide sufficient improvement of fitting accuracy (increase of R^2 and/or decrease of RMSE). In fact, the use of common fitting function for entire range of P_{0q} variation produces worse accuracy. These were the reasons why we preferred to use three intervals: from 0 to 0.65, from 0.65 to 0.85, and, finally, from 0.85 to unity.

Comparing data in Fig. 1 and 3, it becomes clear that the ADCT coder performs better than AGU. For example, for P_{0q} about 0.7, AGU produces CR about 6 (Fig. 1) whilst CR for the ADCT coder is usually slightly larger than 7 (Fig. 3,b). Similarly, for P_{0q} about 0.8, AGU produces CR about 9 (Fig. 1) whilst CR for the ADCT coder is about 12 (Fig. 3,b). Recall that input parameter used for prediction for both coders is the same (P_{0q}).

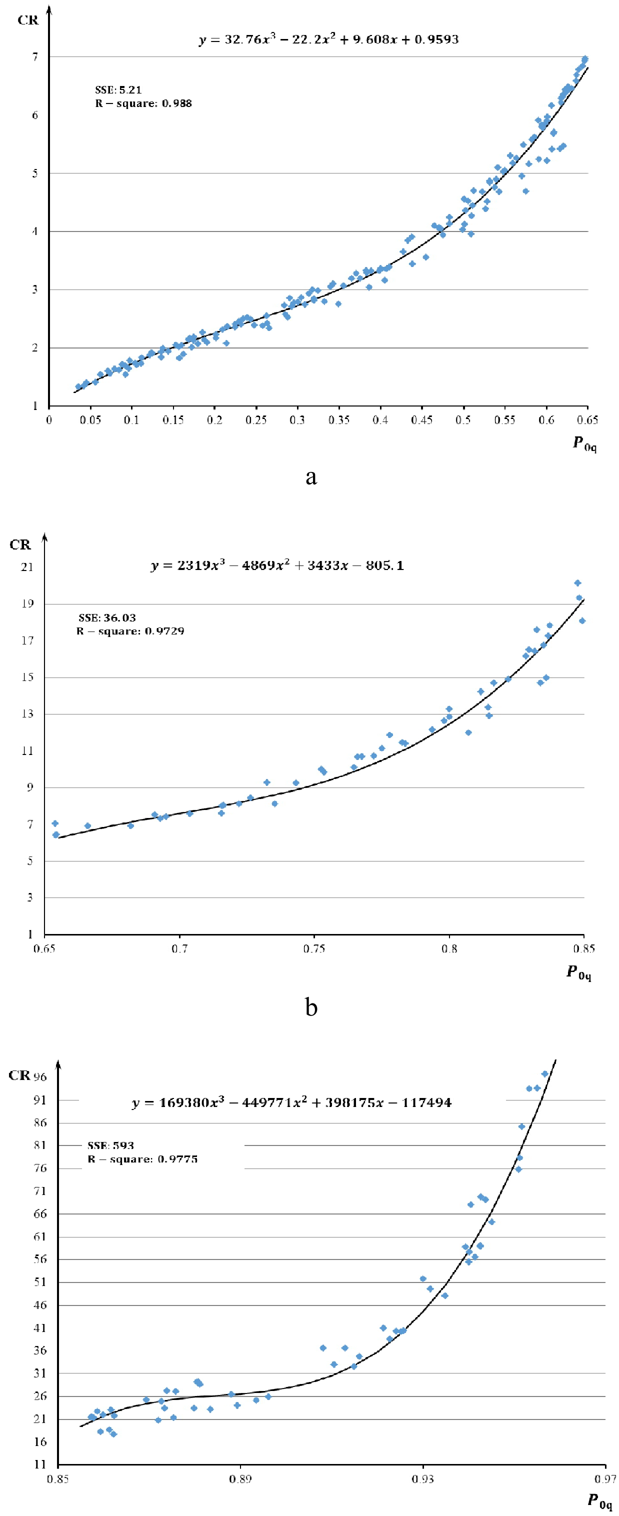

Fig. 3. Scatters-plot of CR vs parameter P_{0q} and the fitted prediction curve for the coder ADCT

Several aspects of practical realization are worth mentioning here. First, discrete cosine transforms for calculation of P_{0q} are performed in 8x8 pixel blocks, i.e. standard means used in JPEG and MPEG can be employed for carrying out this operation quickly. Second, a limited number of blocks is needed for calculating P_{0q} with appropriate accuracy. It us usually enough to have about 500 blocks randomly posed on an image to be compressed or the blocks can be positioned in non-overlapping manner. Therefore, calculation of P_{0q} does not require considerable computations.

One point requires additional explanation. For determining P_{0q} it is needed to set some QS that will determine the threshold of DCT coefficient absolute values to be zeroed. One question is how to set this initial value of QS. Another question is what to do if, e.g., a predicted value of CR occurs to be larger than maximal allowed CR_{ma} (such limitations might happen in practice if there is an image of known size V and it has to be passed via a communication channel of capacity C within time not larger than t_{max}: $CR_{ma} > V/(Ct_{max})$.

We propose the following way out. Initial QS for ADCT coder (applied to 8-bit images) can be set equal to 15 – according to data in [9] such a setting produces visually lossless compression of almost all images, i.e. provides compressed image quality acceptable for most applications. If for this QS the predicted value of CR is smaller than CR_{ma}, then QS should be increased till predicted CR becomes about 10% larger than CR_{ma}. The 10% gap can be useful since there can be prediction error where its relative value is usually smaller than 10% (we have carried out special experiments to come to this conclusion). Roughly, this can be checked from scatter-plots by comparing CR values attained for considered images with prediction (fitted curve value for the same P_{0q}).

Practical algorithms of changing QS can be different (see some analogs in [9]). However, the main difference compared to the approach to providing required parameters of lossy compression in [9] is that no compression/decompression is needed. This greatly reduces time used for compression with desired CR (bpp).

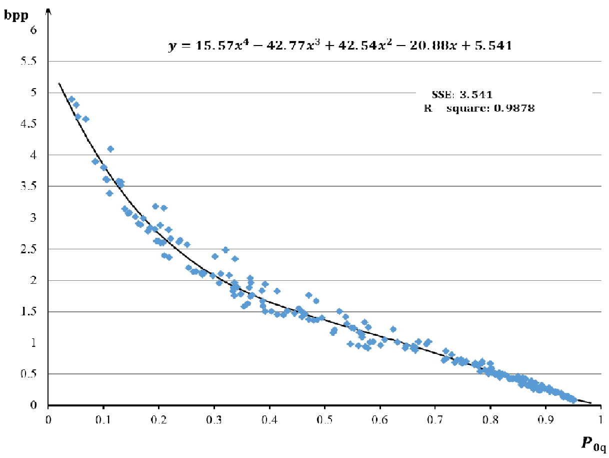

Fig. 4. Scatter-plot of bpp vs parameter P_{0q} and the fitted prediction curve for the coder ADCT-M

One can be interested whether or not CR or bpp prediction is possible for DCT-based coders adapted to produce high visual quality. One of such coders is aforementioned ADCT-M [8, 9]. Since it uses non-uniform quantization of DCT-coefficients, algorithm of calculation of P_{0q} has been slightly modified and it employs frequency dependent thresholds (like in JPEG) proportional to scaling factor. The obtained scatter-plot of bpp vs P_{0q} is presented in Fig. 4. Although no curve is fitted, the scatter-plot appearance analysis shows that fitting can be easily done with expected high accuracy. A more detailed analysis will be provided in the future.

Conclusion

Opportunity to predict compression ratio for the DCT based coder ADCT applied to grayscale images has been considered. It is shown that CR can be quite easily, quickly and accurately predicted. For this purpose, it is enough to calculate statistical parameter P_{0q} (mean probability of zeros of quantization) in DCT domain of about 500 8x8 pixel blocks posed randomly over image area.

The proposed procedure does not only allows predicting CR. In fact, it makes possible to determine QS needed for providing a desired CR. This can be done without any compression/decompression of an image at hand. In turn, this accelerates procedure of compression with desired CR and makes DCT-based compression comparable in this sense with JPEG2000. Meanwhile, the ADCT coder provides considerably larger CR than JPEG and JPEG for the same quality. Then, the proposed approach can be treated as one step to green communications with application of image lossy compression. As it is shown, the approach has to be also applicable to the coder ADCT-M.

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ПРОГНОЗУВАННЯ КОЕФІЦІЄНТА СТИСНЕННЯ ДЛЯ КОДЕРА ADCT

О. М. Земляченко, Б. Возель, В. В. Лукін, О. О. Зеленський

Запропоновано спосіб прогнозування коефіцієнта стиснення для кодера ADCT. Прогнозування базується на визначенні простих параметрів до виконання операції стиснення, які можуть бути розраховані в блоках розміром 8x8 пікселів. Така процедура дозволяє вирішувати ряд важливих практичних задач, у тому числі економії часу і/або енергії, необхідних для передачі стиснутих даних по мережах зв'язку. Це забезпечує ефект зелених мереж, оскільки КС для кодера ADCT, як правило, значно більший, ніж для JPEG і JPEG2000 стандартів (при однаковій якості), що зумовлено використанням схем розбиття та адаптацією до зображення, що стискається.

Ключові слова: коефіцієнт стиснення, стиснення з втратами, передбачення, ADCT, прискорення.

ПРОГНОЗИРОВАНИЕ КОЭФФИЦИЕНТА СЖАТИЯ ДЛЯ КОДЕРА ADCT

А. Н. Земляченко, Б. Возель, В. В. Лукин, А. А. Зеленский

Предложен способ предсказания коэффициента сжатия для кодера ADCT. Прогнозирование основывается на определении простых параметров до выполнения операции сжатия, которые могут быть легко рассчитаны в блоках размером 8x8 пикселов. Такая процедура позволяет решать ряд важных практических задач, в том числе экономии времени и/или энергии, необходимых для передачи сжатых данных по сетям связи. Это обеспечивает эффект зеленых сетей, поскольку КС для кодера ADCT, как правило, значительно больше, чем для JPEG и JPEG2000 стандартов (при одинаковом качестве), что обусловлено использованием схем разбиения и адаптацией к сжимаемому изображению.

Ключевые слова: коэффициент сжатия, сжатие с потерями, предсказание, ADCT кодер, ускорение.

Земляченко Александр Николаевич – канд. техн. наук, ассистент каф. приема, передачи и обработки сигналов, Национальный аэрокосмический университет им. Н. Е. Жуковского «Харьковский авиационный институт», Харьков, Украина, e-mail: hagriel@ukr.net.

Возель Бенуа – профессор, университет Ренн 1, Ланьон, Франция, e-mail: benoit.vozel@univ-rennes1.fr.

Лукин Владимир Васильевич – д-р техн. наук, проф., проф. каф. приема, передачи и обработки сигналов, Национальный аэрокосмический университет им. Н. Е. Жуковского «Харьковский авиационный институт», Харьков, Украина, e-mail: lukin@ai.kharkov.com.

Зеленский Александр Алексеевич – д-р техн. наук, проф., зав. каф. приема, передачи и обработки сигналов, Национальный аэрокосмический университет им. Н. Е. Жуковского «Харьковский авиационный институт», Харьков, Украина, e-mail: zelensky@xai.kharkov.ua.

Zemliachenko Aleksandr Nikolaevich – Candidate of Technical Science, Assistant of Dept. of Transmitters, Receivers and Signal Reception, National Aerospace University named after N. Ye. Zhukovsky «KhAI», Kharkov, Ukraine, e-mail: hagriel@ukr.net.

Benoit Vozel – Associate Professor, Institute of Electronics and Telecommunications of Rennes, UMR CNRS 6164, University of Rennes 1, France, e-mail: benoit.vozel@univ-rennes1.fr.

Lukin Vladimir Vasil'evich – Doctor of Technical Science, Professor, Professor of Dept. of Transmitters, Receivers and Signal Reception, National Aerospace University named after N. Ye. Zhukovsky «KhAI», Kharkov, Ukraine, e-mail: lukin@ai.kharkov.com.

Zelensky Aleksandr Alekseyevich – Doctor of Technical Science, Professor, Head of Dept. of Transmitters, Receivers and Signal Reception, National Aerospace University named after N. Ye. Zhukovsky «KhAI», Kharkov, Ukraine, e-mail: azelens@mail.ru.