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TOPQS measure as a decision making factor in adaptive wavelet image compression

***Streszczenie.** Artykuł omawia adaptacyjną falkową kompresję barwnych obrazów, która ukierunkowana jest na zapewnienie dobrej jakości wynikowego obrazu. W trakcie kompresji dobierana jest najlepsza transformata falkowa dla obrazu lub jego części na podstawie miary TOPQS. Opisane są dwa rodzaje adaptacyjnej kompresji: blokowa oraz kompresja, której dobór parametrów jest dokonywany w trakcie dekompozycji falkowej. (**Miara TOPQS jako czynnik decyzyjny w adaptacyjnej falkowej kompresji obrazu**).*

***Abstract**. The paper presents the wavelet adaptive compression for color images which is targeted to ensure good quality of the resultant picture. In described adaptive compression method the best wavelet transform for an image or a part of it is selected based on perceptual measure TOPQS. Two types of the adaptive compression are described: the block compression and compression on the resolution levels.*

Słowa kluczowe: miara TOPQS, adaptacyjna kompresja falkowa obrazu, blokowa adaptacyjna kompresja falkowa, adaptacyjna kompresja wykonywana na poziomach dekompozycji falkowej.
Keywords: TOPQS measure, adaptive wavelet image compression, block adaptive wavelet compression, adaptive compression on decomposition levels.

Introduction

Image compression is a well-known aspect of image processing. That is why research is done to provide both better compression rate and better quality of the resultant pictures.

This article presents the adaptive wavelet image compression that is designed to provide final pictures of good quality. For this purpose the perceptual measure is implemented. TOPQS (Tuned by Observers Picture Quality Scale) is based on Picture Quality Scale measure. It does not depend, however, on group of observers during compression process. TOPQS measure chooses the most appropriate wavelet transform for considered part of the image. It assesses the visual distortions in the compressed images and in fact, it is a decision making factor for choosing the most appropriate kind of wavelet transform. That is the one which causes the least visual distortions in the compressed image.

In this paper two types of adaptive compression are described. The first type divides the original image into single blocks, which are then compressed separately. For each block the most appropriate wavelet transform is chosen. The second type of adaptive compression is performed on the successive levels of the wavelet decomposition. On each level the best wavelet transform is selected.

Wavelet transform

Wavelet transform is an operation that converts the original image into wavelet coefficients. The conversion is done in such a way that almost all of the image energy is cumulated into a relatively few coefficients. This property of the wavelet transform is used in wavelet compression. The more coefficients approach zero, the more they can be ignored without visible impairment of the image quality. The more coefficients are ignored, the less data there is encoded and saved and the better the compression rate is achieved. Apart from the number of coefficients that are saved, the choice of wavelet transform also influences the quality of the resulting image. Wavelet transform divides the original image into a coarse subimage which contains the averaged image information and three detailed subimages computed [1]. The coarse subimage is then transformed into four next subimages. The process is repeated until the coarse image consists of only one pixel.

The image can be treated as a two-dimensional signal and transformed with Mallat's algorithm [5].

TOPQS Measure

TOPQS is a new measure that was created based on the perceptual Picture Quality Scale [3,4,12]. It was adapted for use with monochromatic [14] and color images [13]. In case of color images the SCIELab color space was used. Incorporation of a neural network [7,11] in the assessment process allows for the use of the TOPQS measure in automatic compression. A group of observers (needed for a PQS measure) is only necessary in order to collect the neural network training data set.

A TOPQS measure computes a single value that represents the level of visual distortions in the compressed image (in comparison to the original). Its value belongs to the interval of [1-5], where 1 stands for the poorest image quality while 5 for lack of visual distortions. Our implementation of Picture Quality Scale, the TOPQS, not only can be used for evaluation of the visual distortions in compressed images (without a group of observers) but also as a tool that affects the compression process.

TOPQS as a decision making factor

The adaptive wavelet compression can be used for both color and monochromatic images. Due to the fact that color images are more common, this case (as more general) will be described. The adaptive compression carries out the compression process using wavelet transforms that are most appropriate for particular parts of the image. Wavelet functions are selected on the basis of the TOPQS value. The compression method features two types of wavelet coefficients coding, both designed for wavelet compression: EZW [2, 6] and SPIHT [5]. It is possible to compress the image using: (1) the block adaptive compression [9, 10] or (2) the adaptive wavelet resolution decomposition [8].

The idea behind choosing the most appropriate wavelet transform in both types of adaptive wavelet compression presented in this paper is similar. The TOPQS measure is the most important factor in our method because is directly influences the final quality of the compressed image. Use of perceptual measure is important because it is able to verify the quality of the image (or part of the image) in a similar manner to the Human Visual System. This means that only these image distortions are taken into consideration that are visible to human observers. The general concept of this process using the TOPQS measure is shown in fig.1.

The whole process involving TOPQS measure in adaptive compression proceeds as follows:
(1) an image or a part of it is compressed using one of the available wavelet transforms, (2) the image/part of the

image is compressed and then immediately uncompressed (3) the TOPQS value is calculated for the uncompressed result, (4) the previous steps are repeated for all of the available wavelet transforms (five types are available), (5) finally, the wavelet transform which causes the least visual distortions is chosen as the most suitable wavelet transform and is used in the final image compression process. A set of wavelet transforms was implemented in our adaptive compression system. This set consists of: Haar, Daubechies 4th, 6th, 8th degree and 5/3 wavelets. This set should ensure good quality in the resultant images. TOPQS measure is independent form the type of the used wavelet transform. For this reason another set of may be created to verify the effectiveness of other wavelet transforms.

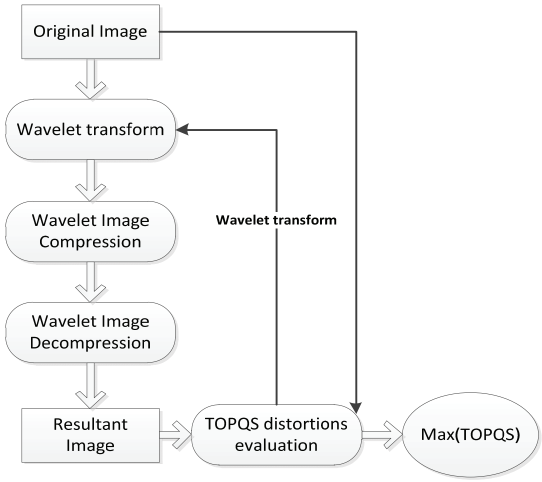

Fig. 1. Selection of the most suitable wavelet transform.

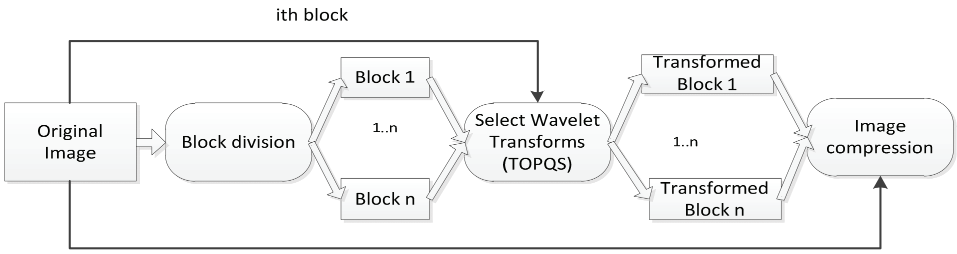

Fig. 2. The scheme of block adaptive wavelet compression of the original image.

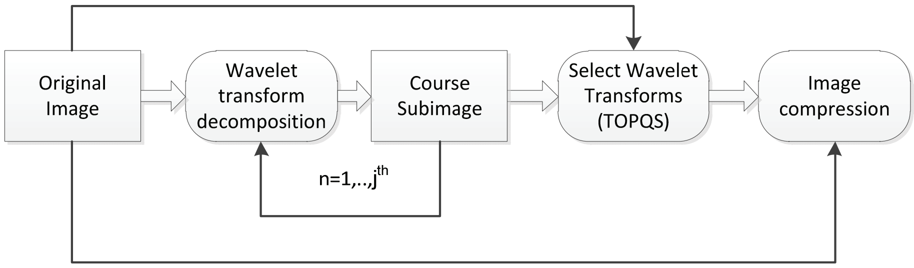

Fig. 3. The scheme of block adaptive wavelet compression performed on the resolution decomposition

Adaptive wavelet color image compression

The adaptive wavelet compression carries out the compression process using wavelet transforms that are the most appropriate at a given compression stage. Wavelet functions are selected on the basis of the TOPQS value. Before the image is compressed, it is converted to the YUV color space. Then the algorithm starts the process of selecting the optimal wavelet transforms. Once the wavelet coefficients are computed they are quantized and coded.

Block adaptive compression

Block wavelet compression is the first type of adaptive compression methods presented in this paper.

During the block wavelet compression, the image is first divided into blocks of a fixed size e.g. 16×16, 32×32 or 64×64 pixels. Then, for each area, the best wavelet transform is chosen by TOPQS measure (as shown in fig. 2). Then wavelet coefficients are computed for each block separately with the selected type of wavelet. Finally the image compression is performed with Embedded Zerotree Wavelet Coding (EZW) [2, 6] or Set Partitioning in Hierarchical Trees (SPIHT) [5]. The difference between traditional and the block adaptive wavelet compression methods is that the separate blocks are transformed using various wavelets.

With this approach additional information, such as the number of blocks and the chosen wavelet transforms, needs to be saved with the compressed image. This information is essential for computing the inverse transform of a particular block. The additional data causes the compression rate to be lower than the compression obtained with only one type of wavelet.

Adaptive wavelet resolution decomposition

Compression using adaptive resolution decomposition is the second type of adaptive compression.

In traditional wavelet decomposition the same transform is used on all levels. However in the adaptive wavelet resolution decomposition the best wavelet transform is chosen at each step. The choice is based on the Tuned by Observers Picture Quality Scale value. Once optimal wavelet transforms are selected and the wavelet coefficients computed for all decomposition levels the image is compressed using Embedded Zerotree Wavelet Transform (EZW) [2, 6] or Set Partitioning in Hierarchical Trees (SPIHT) [5]. The scheme of adaptive compression is shown in Fig. 3.

As the block adaptive compression, the adaptive level approach requires extra information to be saved alongside with the compressed image.

Results

Example results obtained, using the adaptive wavelet image compression for various types of wavelets compression, are presented in figures 4, 5 and 6.

The quality of the image compressed with adaptive decomposition method may be similar to the quality obtained using only one type of wavelet. This is the case for compression ratios that are not very high as in the case of the *Flower* image (TOPQS values - fig. 4, resultant images – figures 6b, 6c and 6f).

However for higher compression ratios the improvement in quality is visible. The chart (diamonds in fig. 5) confirms that the concept of using different wavelet transforms in the adaptive decomposition allows for quality improvement when the compression ratio is fixed.

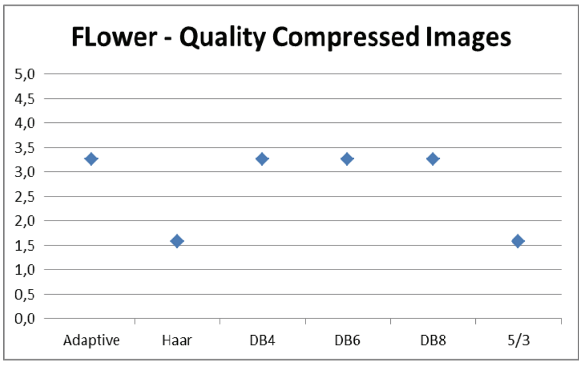

Fig. 4. Quality of the compressed images computed by TOPQS measure. The flower picture was compressed with the use of respectively: adaptive compression performed on the resolution decompositions, Haar, Daubechies 4th, 6th, 8th degree, and 5/3 transforms. All images have a compression rate 1:20.

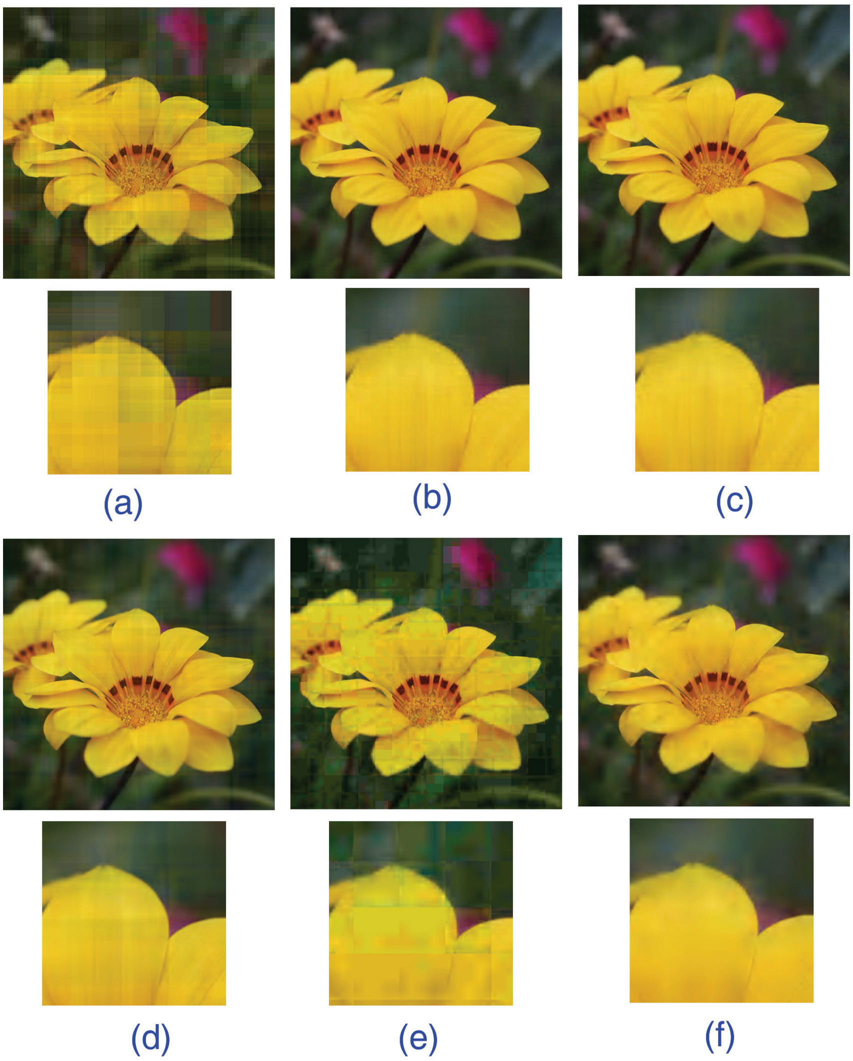

Fig. 6. (a) - (d) Results of the wavelet compression using only one type of wavelet (respectively: Haar, Daubechies 4th degree, Daubechies 6th degree and 5/3), (e) result of adaptive block compression of the *Flower* image with the block size of 32 x 32, (f) the adaptive wavelet decomposition compression of the *Flower* image. The images are presented alongside their respective crops.}

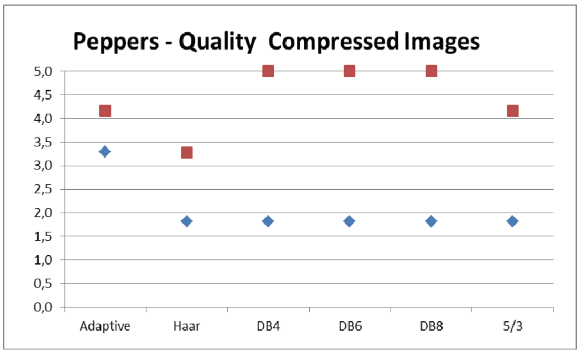

Fig. 5. Quality of the compressed images computed by TOPQS measure. The well known Peppers image was compressed using: adaptive compression (with both resolution decomposition and adaptive block), Haar, Daubechies 4th, 6th, 8th degree, and 5/3 transforms. The diamonds represent the image quality for compression rate 1: 25 (single transforms and on resolution decomposition). The squares represent the image quality for compression rate 1: 7 (single transforms and block adaptive)

The adaptive block compression, produces visible distortions which result from dividing the image. This is clearly visible in fig. 6e. The higher the compression rate and the smaller the block, the more distortions are visible An additional post-processing step such as deblocking filter is needed [10]. TOPQS computed for images compressed using block adaptive approach are usually lower than the ones obtained for images compressed using single wavelet (squares in fig. 5)

During adaptive compression, the various types of wavelet are chosen as the most suitable for the part of the image. The selected wavelet transform for the *Peppers* image for both types of adaptive compression are presented in tables 1 and 2.

Table 1. Wavelet transforms selected during adaptive block compression performed for Peppers image.

BD 4th degree	BD 8th degree	DB 4th degree	5/3
DB 8th degree	5/3	Haar	5/3
DB 8th degree	5/3	DB 8th degree	5/3
DB 8th degree	5/3	5/3	5/3

Table 2. Wavelet transforms selected for consecutive levels of decomposition of the Pepper image (Fig. 5f).

Level	0	1	2	3	4	5	6	7	8
Wavelet	DB 8th degree	5/3	5/3	5/3	5/3	DB 8th degree	5/3	5/3	5/3

Summary

Both types of adaptive wavelet compression methods allow one to compress the image with different types of wavelet transforms. However, they are chosen differently. Block compression divides the image into separate blocks. Each region is then analyzed, and the optimal type of wavelet transform is selected for it. A second type of compression chooses the best wavelet transform for each decomposition level. A disadvantage of adaptive compression is the necessity of writing additional information about the type of chosen wavelet transforms.

Adaptive wavelet compression is an effective way of reducing the size of the original image while maintaining satisfactory image quality. Better results are obtained when the optimal wavelet transform is selected at each stage of wavelet decomposition. In contrast to adaptive block compression, there are no visible distortions resulting from the image division. Results obtained with block adaptive compression need an additional post-processing step in order to reduce these deformities. One possible solution to this problem is the hybrid deblocking filter [10].

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