

Lossy Compression Approach to Transmultiplexed Images

Przemysław Sypka¹, Mariusz Ziółko¹, Bartosz Ziółko²

¹ Department of Electronics,

² Faculty of Electrical Engineering, Automatics, Computer Science and Electronics
AGH University of Science and Technology al. Mickiewicza 30, 30-059 Kraków, Poland

phone: + (48-12) 6173048, fax: + (48-12) 6332398,

E-mail: {sypka, ziolko, bziolko}@agh.edu.pl

Abstract – *The application of image compression methods in transmultiplexer systems is presented. The specific energy distribution in the combined image spectrum makes the standard compression methods, especially these that base on frequency decomposition not efficient. Two cases are described and compared: the compression of combined image and the preliminary compression of input images before transmultiplexing. Wavelet packet decomposition was used to obtain the frequency decomposition of images. Multirate processing involves digital filters that may be used to process images continuously. The results of conducted experiments are presented. The luminance of the transmitted image is calculated using formulae, which include both, upsampling and digital filtering. The combined image can be sent over a single transmission channel.*

Keywords – image transmultiplexer, compression, wavelet packet, JPEG, filter bank

1. INTRODUCTION

Multimedia content is more and more popular in many different types of telecommunications. That is why new and efficient methods of sending several images through a single transmission line are needed. The transmultiplexer is a structure that combines suitably upsampled and filtered signals for the transmission by a single channel. The spectrum of each user's signal is spread over the whole channel bandwidth. It can be only intercepted by a receiver programmed with the same code. Transmultiplexing is easy to apply because it needs only simple digital processing: upsampling, filtering and summing. All operations used in transmultiplexer are linear and time-invariant. It gives important advantages. The z-transform can be used to build the mathematical model and the frequency approach can be applied to analyze or design the considered system. A crucial point for overall performance of such systems is the quality of images delivered to the end user. The separation of images should be perfect and the recovery of each image should be performed without distortion. The main problem in transmultiplexers is preventing image distortion caused by the change of amplitude and phase as well as image leakage from one channel into another. This aim can be achieved by a selection of appropriate filters that ensure a perfect image reconstruction in the receiver [1] [2]. Another advantage is that combined signal may be treated and processed still as an image. Integer-to-integer operations provide an efficient system – images are processed in finite-precision arithmetic and mapped integers to integers. In other words, it is possible to provide all calculations without divisions to omit the

rounding errors. Systems equipped with integer filters can be used not only to transmit images but also for encrypted data, lossless compressed signals, computer software data or other data where a change in even one single bit is inadmissible. In this context there is no reduction of quality due to fulfilling the perfect reconstruction conditions.

In a compression algorithm the number of bits needed to represent the image or its spectrum is minimized. Our fundamental concept of compression is to split up the frequency band of the image and then quantized each subband using a bit rate accurately matched to compromise between the two opposite criteria: minimize distortions and maximize the compression rate.

Over the past several years, the wavelet methods have gained widespread acceptance in signal processing in general, and in the signal compression research in particular. Multirate processing is related to signal transformation using wavelets. Wavelet packets are a way to analyze a signal using base functions which are well localized both in time and in frequency. The properties of wavelet transform make it useful in compression standards. Its frequency character enables us to exploit the knowledge connected with the frequency properties of human vision system. Moreover the local character of wavelet transform does not introduce the block effects and makes it possible to conduct the compression in real time systems. This continuous type of processing is the main advantage in lossy compression which reduces the image spectrum by eliminating redundant information. Lossy compression is generally used where a loss of a certain amount of information will not be detected by most users.

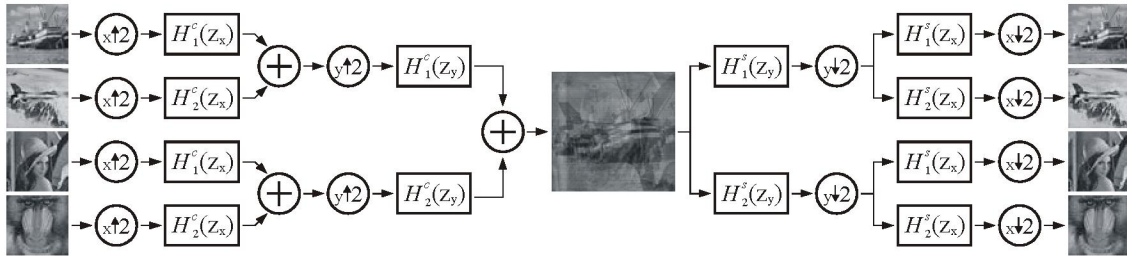


Fig. 1. Scheme of 4-channel image transmultiplexer

2. IMAGE TRANSMULTIPLEXING

Fig. 1 shows the classical structure of the four-channel image transmultiplexer. The input images are upsampled and filtered vertically and summed to obtain two combined images. These combined images are then upsampled and filtered horizontally and summed to obtain the final version of combined image [2]. In presented system the combined image consists of four times more pixels than each input image. At the receiver end, the signal is relayed first to two channels of the detransmultiplexation part, where the signals are filtered and downsampled horizontally. Then these signals are relayed to four channels where images are filtered and downsampled vertically to recover the original images.

3. COMPRESSION

The wavelet transform belongs to the group of frequency transforms, and that is why the proper nonuniform quantization is easy to find. The Wavelet Packet Transform (WPT) gives a tool that can be used to analyze the combined images. The wavelet packet algorithm generates a set of orthogonal subimages that are derived from a single

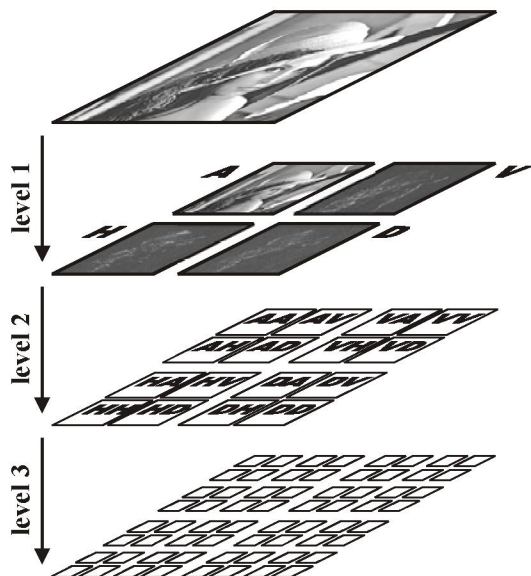


Fig. 2. 2-D WPT structure

combined image. The wavelet spectra are produced by cascading filtering and downsampling operations in a tree-structure. Wavelet packets were introduced for splitting images into its frequency components so that to compress the image by non-uniform quantization.

The 2-D WPT can be viewed as a decomposition system shown in Fig. 2 for three levels. The basis data are the coefficients of wavelet series of the original image. The next level results of one step of the 2-D wavelet discrete transform. Subsequent levels are constructed by recursively applying the 2-D wavelet transform step to the low (A – approximation) and high (D – detail) frequency subbands of the previous wavelet transform step. The higher level component have two times narrower frequency bands when compare with the subsequent lower frequency components. Multirate processing involves the application of filtering and down-sampling. The main subject lies in the design of lowpass and highpass filters which gives useful transformations and allow to recover the transmitted images.

4. EXAMPLE

To verify the frequency properties of transmitted images and the efficiency of compression method, some examples were analyzed. One of them is presented below. Four test images (boats, F-16, Lena and baboon) with 512×512 pixels resolution in 256 grayscale levels were selected for the analysis. The combined image has 1024×1024 pixel resolution. Its luminance values are integer numbers from -1088 to 1884. The combining filters H_i^c and the separation filters H_i^s were designed by algorithm presented in [3]. The obtained coefficient values are presented in Tab. 1. Transmultiplexing does not provide

Table 1. Coefficient of transmultiplexer filters

	H^c		H^s	
1	0	0	0	0
1	-1	0	-1	-1
2	1	1	1	1
-2	1	-1	-2	-2
0	0	-1	-2	-2

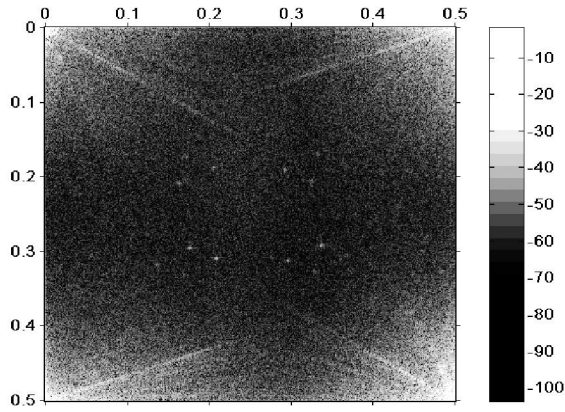


Fig. 3. Amplitude [dB] of spectrum of combined image

distortions because digital filters have integer coefficients which satisfy the requirements of perfect reconstruction.

Linearity of the transmultiplexer system enables to split the combined image into its frequency components. The periodicity of spectrum of the combined image, presented in Fig. 3 especially at corners, results from the periodicity of Fourier spectra of upsampled signals. The sampling densities in the frequency domain for all levels are the same but the amounts of samples are different. The spectrum of the upsampled signal consists of the original spectrum and moreover its components, shifted in frequency, are added. It makes that the image in transmission line has some similarities with the original images (see Fig. 1).

The three level 2-D wavelet packet decomposition was provided by means of discrete Meyer wavelets. The absolute values of coefficients of wavelet packet decomposition nodes are presented in Fig. 4. The main part of energy (96.6%) of the signal is localized in last four subbands of the network AAA (2.5%), HAA (13.3%), VAA (10.4%) and DAA (70.4%). The compression with factor 16 were obtained by omitting information from other bands. The reconstructed output images are presented in Table 2 (second row). Even though the

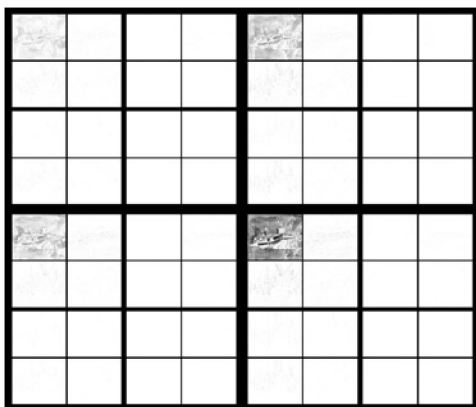


Fig. 4. 2-D WPT coefficients

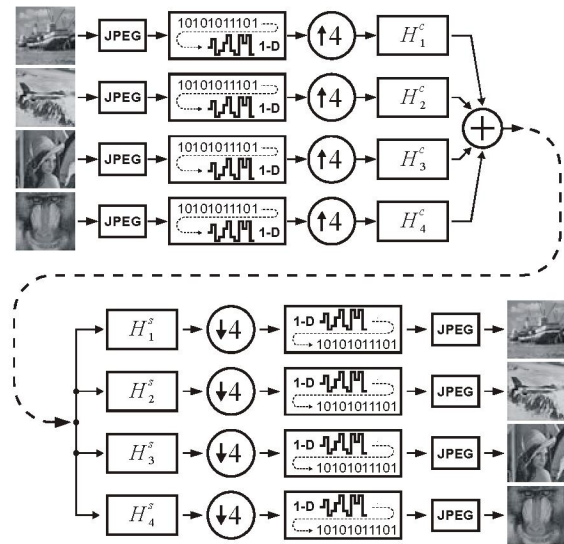


Fig. 5. Alternative structure for lossy compression in transmultiplexer system




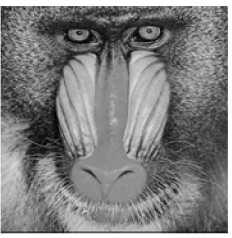



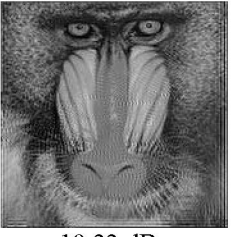



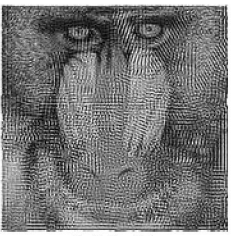



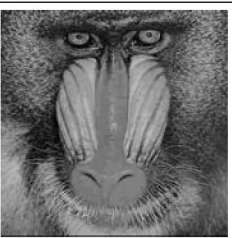
large part of the signal energy was sent and the compression was not very high, some distortions are visible. The obtained PSNR values below 30 dB are unacceptable. The important observation is that the decreasing of compression coefficient degrades the quality of transmultiplexer output images (Table 2, third row). In the presented example data from bands with the energy higher than 0.2% of the whole energy was transmitted. Rejecting other values caused compression with rate equals to 8. The loss of the image quality is connected with proliferation of signal spectra after upsampling. This is why, in contradiction to expectations, transmitting data from only four nodes of WPT network (AAA, HAA, VAA, DAA) gives good results.

Another possible solution is the preliminary compression of the input images, e.g. using JPEG algorithm [4], and applying the 1-D transmultiplexer after converting of the bit streams into integer 1-D signal (Fig. 5). In such a system the rate of compression can be adapted to each of the image separately depending on needs. The compression with factor 16 using the JPEG algorithm on the each of input images allows to gain the better quality of images than in case of the compression of the combined image. However such a method requires careful and precise design of filters. Any change of the signal value on the transmultiplexer output before decompression will cause the total loss of the images. Methods of designing integer filters for 1-D transmultiplexers are presented in [5].

5. CONCLUSION

The important role of high frequencies in the combined image makes impossible the application of standard lossless compression methods. These algorithms, based on reduction of high frequency

Table 2. Comparison of input and output images

Reference images				
WPT, compression ratio 16, preserved energy: 96.6%	 24.27 dB	 23.42 dB	 23.79 dB	 19.33 dB
WPT, compression ratio 8, preserved energy: 98.1%	 19.77 dB	 13.66 dB	 14.70 dB	 9.83 dB
JPEG, compression ratio 16	 30.96 dB	 32.84 dB	 35.59 dB	 23.42 dB

components, cause major errors in output images of the transmultiplexer. The transmultiplexing of already compressed images seems to be more efficient solution. The preliminary compression of the input images applying JPEG 2000 [6] or other method allows to gain the higher compression rate with the better quality of output images. In this case the very precise design of filters is necessary, as they have to fulfill the perfect reconstruction conditions. In the other case any change of the signal in the transmultiplexer system destroys the images completely.

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