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ROBUSTNESS OF TRANSMULTIPLEXED IMAGES

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ABSTRACT: Transmultiplexation changes the parallel transmission into a serial transmission. The paper presents the suitable data preprocessing method of error reduction for images transmitted by transmultiplexer system. The solution is based on blocks of sizes adequate to separation filter orders, used in detransmultiplexation. The proposed method results directly from the detransmultiplexation algorithm. An example of a four-channel transmultiplexer system is presented and analyzed to illustrate the suggested method.

INTRODUCTION

The transmultiplexer is a structure that combines suitably upsampled and filtered signals for the transmission by a single channel. Transmultiplexers have some important applications, in particular in telecommunications, to provide many signals over a single transmission line. The separation of signals should be perfect and the recovery of each signal should be performed without distortion. The main problem in transmultiplexers is the leakage of signals from one channel to another [1] [2].

Most of the modern telecommunications systems send information in packets and frames instead of predefined channels. Such techniques optimize the usage of physical devices and are especially efficient in the case of bursty transmission which is more and more common in the era of Internet. In such systems user data are split into packets which can be sent through different paths of the network. Grouping in frames or containers gives extra flexibility in introducing different services like television, Internet and telephone communication in the same network and co-operating between different kinds of networks. In this sort of a transmitting system some packets can be lost or can be so much delayed that the system treats them as lost packets.

The goal of this paper is to find a serializations algorithm of a combined image which can decreased the error, caused by lost packets. The suitable data preprocessing should be independent on filters coefficients used to image transmultiplexing. The robustness of such services in which loss of the packet does not implicate the error for the whole block due to the coding is considered in this paper. Each packet contains independent information for a very small region of an image, for example 24/M pixels for M – channels transmultiplexer.

IMAGE TRANSMULTIPLEXING

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 seeking. Transmultiplexing is easy to apply because it needs only simple digital processing procedures: upsampling, filtering and summing. It is easy to avoid delays even for slow transmitters and receivers. A crucial point for overall performance of such systems is the quality of images delivered to the end user. In this context there is no reduction of quality due to fulfilling the perfect reconstruction conditions. Another advantage is that combined signal is still an image. Due to this fact it is easy to apply any image compression method.

Usually 1-D instead of 2-D filters are used to filter digital images. Such approach has several advantages, and two of them are the most important. Firstly, the designing methods and sophisticated theory obtained for 1-D signals - can be easily adapted to an image processing. Secondly, each task possible to solve by applying the 2-D filters can be realized in 1-D techniques as well. These advantages encourage us to adapt the ideas developed for 1-D transmultiplexer systems to image transmultiplexers.

Fig. 1 shows the classical structure of the four-channel image transmultiplexer. The input images X_i in the i-th channel 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 C. The luminance of the transmitted image may be calculated using formulae, which include both, upsampling and digital filtering [3] [4]. In presented system the combined image consists of four times more pixels than each input image.

The combined image can be sent over a single transmission channel. 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

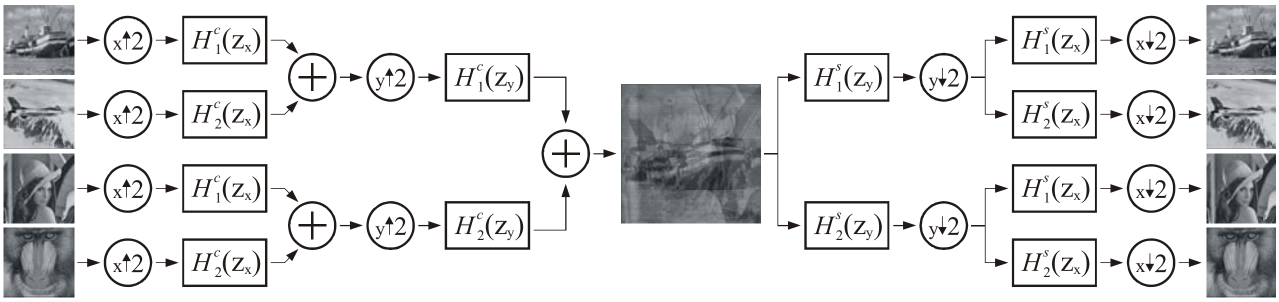

Fig. 1. Scheme of 4-channel image transmultiplexer

relayed to four channels where images are filtered and downsampled vertically to recover the original images. Pixels' luminance of output images Y_i can be computed applying formulas

$$Y_1(n,m)=\sum_{k=0}^{K}\sum_{r=0}^{K}P_{11}^s(k,r)\cdot C(2n-k,2m-r) \qquad (1a)$$

$$Y_2(n,m)=\sum_{k=0}^{K}\sum_{r=0}^{K}P_{21}^s(k,r)\cdot C(2n-k,2m-r) \qquad (1b)$$

$$Y_3(n,m)=\sum_{k=0}^{K}\sum_{r=0}^{K}P_{12}^s(k,r)\cdot C(2n-k,2m-r) \qquad (1c)$$

$$Y_4(n,m)=\sum_{k=0}^{K}\sum_{r=0}^{K}P_{22}^s(k,r)\cdot C(2n-k,2m-r) \qquad (1d)$$

The 2-D separation filters are denoted by P_{nm}^s and they can be calculated in the following way

$$P_{ij}^s(k,r)=h_i^s(k)\cdot h_j^s(r). \qquad (2)$$

Let the order of 1-D separation filters H_i^s be K, and let theirs coefficients be indicated by $h_i^s \in \Re^{K+1}$. The important observation [5] is that the necessary conditions for the perfect reconstruction need the first coefficients of separation filters h_i^s or of composition filters h_i^c be equal to zero. This is why indexes k and r in formula (1) may start from 1. It means that two-dimensional convolution is based only on previous columns and previous rows. The maximal number of non–zero 2-D FIR coefficients is K^2.

PACKET TRANSMISSION

Asynchronous Transfer Mode (ATM) is a worldwide deployed backbone technology. This standards-based transport medium is used within the core, at the access and in the edge of telecommunications systems to send any kind of data at high speeds. ATM has been widely adopted because of its exceptional flexibility in supporting the broadest array of technologies in all over the world, including DSL, IP Ethernet, Frame Relay, SONET/SDH and wireless platforms. Legacy equipment and the new generation of operating systems and platforms co-operate efficiently. ATM freely and easily communicates with both, allowing carriers to maximize their infrastructure investment. Data are sent in the packets with 48 bytes of user's information and 5 bytes of header information for routing and assembling [6], [7]. The same packet standard is in the Distributed Queue Dual Bus – access protocol for MAN networks.

ROBUSTNESS

To verify the properties of a transfer system some examples were analyzed. 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 signal has 1024×1024 pixel resolution. Each packet consists of 48 bytes, which is equivalent to 24 records of 16 bits length, so the combined image was divided into 43 691 packet. 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. I ($K = 4$).

Two cases of packet loss in transmission systems were considered: continues (i.e. temporary) and random. In both cases maximal 256 packets were lost, which is equivalent to the lost of 6 columns of the combining image (almost 0.3% of bit stream). One line (1024 pixels) is equivalent to 42.667 packets. Packets were removed starting from the centre of the combined image. In random case packets were removed from all parts of combined image. The Mean Square Errors (MSE) were calculated for transmitted signals.

The transmultiplexed image can be serialized in many different ways before transmission. The standard method for images is the row or column order. The Zig-Zag order is used in some applications, especially to avoid the boundary effects. In the case of 2-D integer filtering the loss of pixels in the combined image usually causes that the 2-D convolution do not fit into 8-bit resolution. In this case the reconstructed pixels take

TABLE 1. Coefficients of transmultiplexer filters

H^c combining		H^s separation	
1	0	0	0
0	1	0	1
1	1	1	0
-1	-1	-1	1
0	0	-1	1

the extreme values of 0 or 255. It may cause the rapid growth of MSE. This is why the serialization of data before transmission should base on $K \times K$ blocks, directly connected with the separation filter orders. In this case, the loss of packets leads to the lower number of wrongly calculated pixels in output images.

To provide simulations and tests in MATLAB environment, the column serialization was chosen (COL in Fig. 3). Such choice do not influence on the correctness of the analysis. It results from the properties of 2-D convolution. In the considered case the loss of a single packet causes the wrong calculation of 26 pixels in output images. Meanwhile, in case of $K \times K$ block serialization only 12 pixels are lost. This situation is explained in Fig. 2, column serialization on the left and serialization that bases on blocks $K \times K$ on the right. Calculated MSE values are presented in Fig. 3 for the case of the continues loss and in Fig. 4 for the case of the random loss.

The MSE for the column serialization in the case of the continues loss of packets has unusual and interesting properties (Fig. 3). In some cases the increase of the amount of the lost packets during transmission does not increase the MSE. The reason of such anomaly is that the lost of consecutive pixels of the combined image is within the subsection of the two-dimensional convolution used to calculate the same pixel in the output image. In the extreme case, the loss of all pixels in the range of size $K \times K$ does not cause the growth of MSE. This situation is similar to the one presented in Fig. 2 but the pixels of the consecutive column, on the right side of pixels already removed (black), have to be removed also. In the case of serialization based on $K \times K$ blocks such phenomena do not exist.

The reduction of MSE in case of $K \times K$ block serialization is clearly seen in case of random loss of transmitted packets.

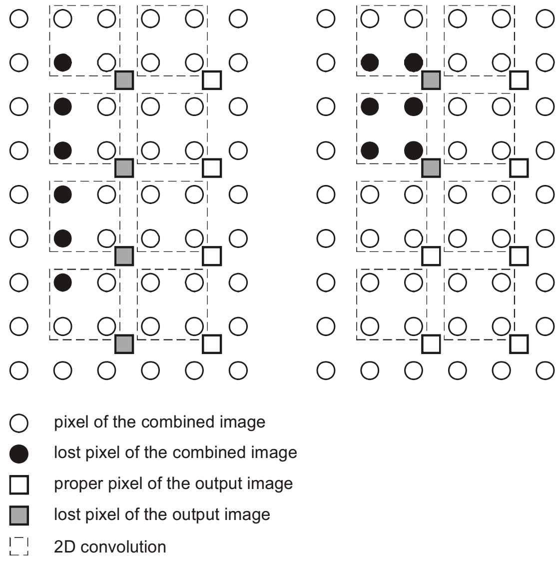

Fig. 2 Scheme of lost pixels, 6 pixels per packet and $K = 2$.

Fig. 5 presents the output images obtained in different channels in the extreme case of 256 packets lost.

CONCLUSIONS

Transmultiplexing does not cause distortions. The main advantage lies in the great variety of realizations which are available by the proper designing of digital filters H_i^c and H_i^c.

The proper order of data can minimize errors under random or temporary fading of the combined image.

The proper data ordering before transmission, causes the reduction of MSE for the case of random packet loss of the composed image. In the next stage it is reasonable to apply the lowpass filters to reduce the disturbances which result on the lost packages.

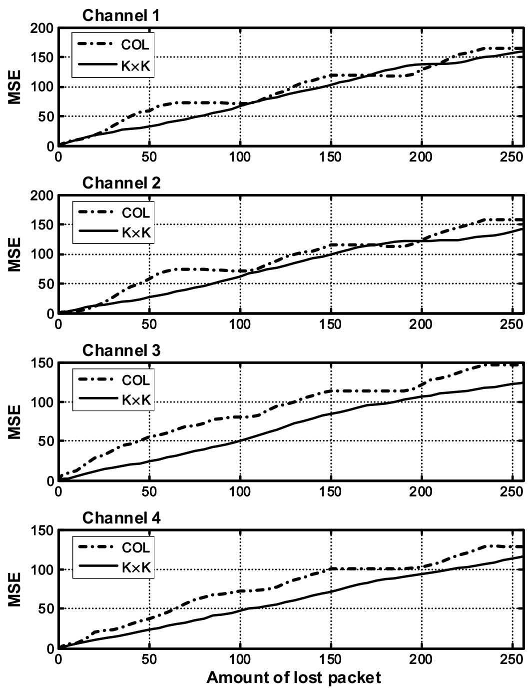

Fig. 3. The relationship between the error and the amount of lost packets, CONTINUOUS case

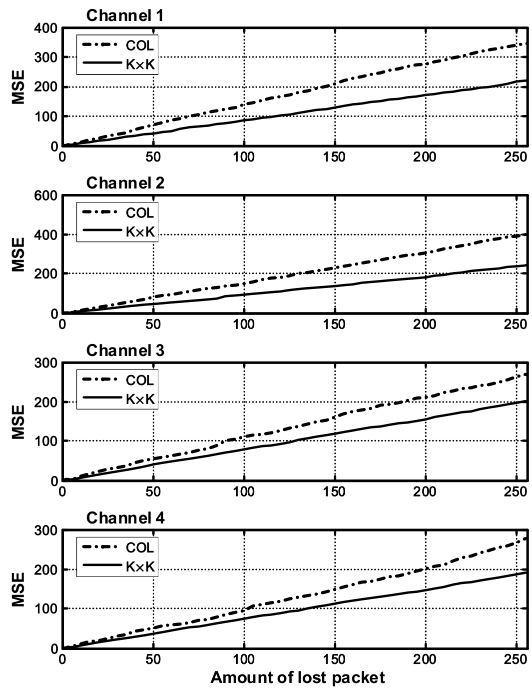

Fig. 4. The relationship between the error and the amount of lost packets, RANDOM case

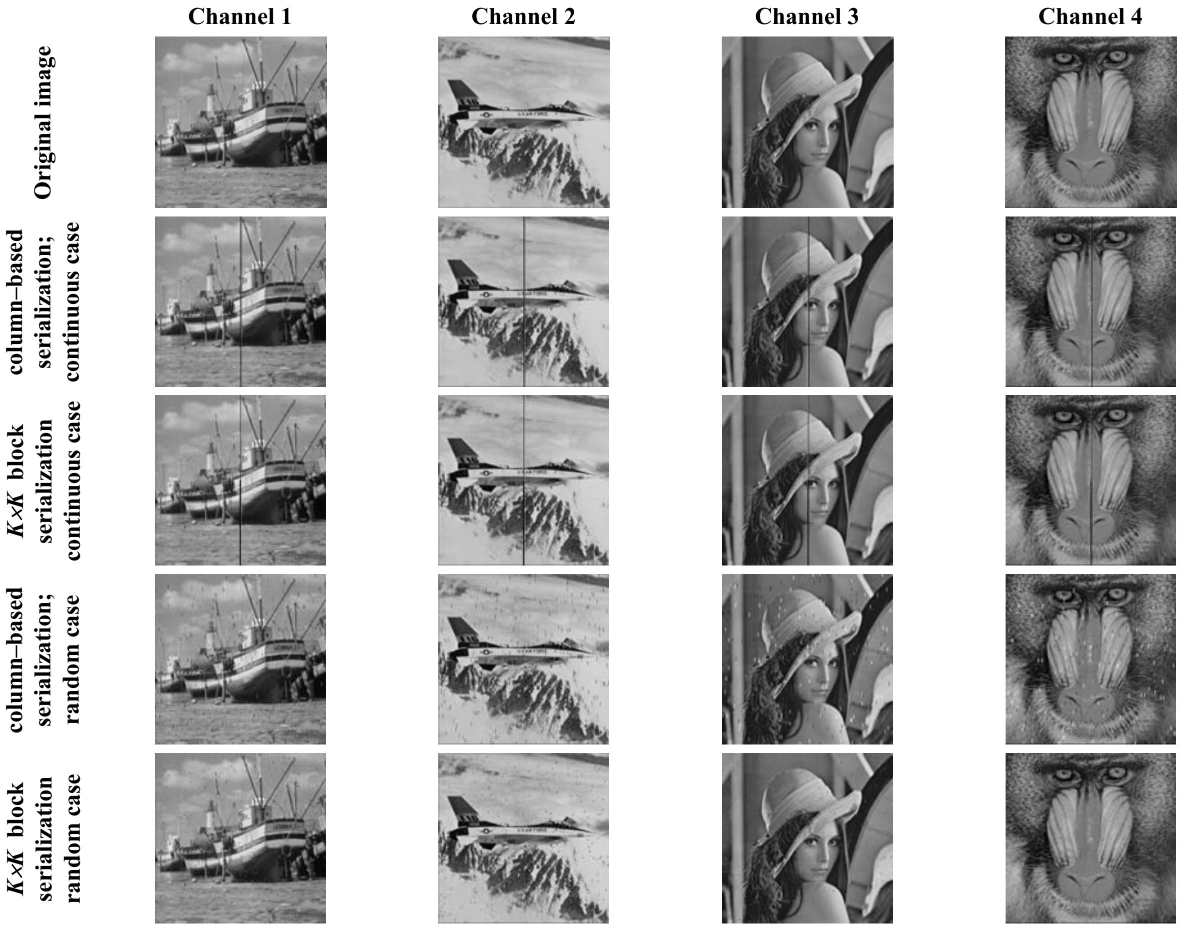

Fig. 5. Comparison of images with 256 lost packet in transmission

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