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Ekaterina A. Kapranova*, Vadim A. Nenashev*, Alexander M. Sergeev*, Dmitry A. Burylev*, Sergey A. Nenashev*

*Saint-Petersburg State University of Aerospace Instrumentation

67, Bolshaya Morskaia str., Saint-Petersburg, 190000, RUSSIA

ABSTRACT

Optical location systems implemented on the basis of high-resolution video cameras are currently used in many areas. These are, for example, medical equipment, traffic control systems, satellite monitoring systems, preventive security systems, object recognition and classification systems, etc. For these systems, the requirements for high-resolution image processing speed of 8K, 16K and more are increasing every year.

Processing of such information becomes even more difficult when providing a high frequency of reading frames from the matrix of the video camera, especially for systems operating in real time and using high-speed networks of exchange, processing and integration of information. This requires to determine a set of types of information processing procedures: masking, compression, noise-protected coding, etc., for which algorithms should be revised in case of multi-user and multi-position application in distributed information processing and aggregation systems.

In this regard, the problems of development and improvement of new ways of representation, compression, storage, masking and error-correcting coding of high-resolution images with a common mathematical basis are relevant.

Most information transformation procedures are based on the use of orthogonal bases, in particular orthogonal and quasi-orthogonal matrices. The paper presents the results of the search and formation of such bases, the methods of synthesis of quasi-orthogonal matrices for image processing problems that meet the formulated requirements.

The methods of guaranteed synthesis of matrices of symmetric, cyclic, block-cyclic and other structures of different orders, assuming economical storage and generation, are proposed. Such matrix bases, which are constantly expanding, provide developers with a wide range of algorithms to choose the most appropriate one from them.

The problem of search and study of extreme quasi-orthogonal matrices has great importance for a wider range of information processing tasks, not just images. The proposed mechanisms for finding new classes of matrices allow creation and development of competitive methods of storage, presentation, compression, noise-resistant coding of data during their transmission in wireless high-speed networks of exchange, processing and aggregation.

The results of the work correspond to the world level of research and have a universal character, as they can be applied in a variety of fields, including orthogonal cryptography, models of crystallography and biology, in the finite models of dynamic processes, etc.

Keywords: masking images, noise-protected coding of high-resolution images, compression images, information processing and aggregation systems, orthogonal bases, quasi-orthogonal matrices, the problem of search and study of extreme quasi-orthogonal matrices, noise-resistant coding of data during their transmission in wireless high-speed networks.

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1. INTRODUCTION

Nowadays there is a significant contradiction, in the field of digital image processing algorithms that use matrix transformations. This applies mainly to symmetric algorithms based on the use of orthogonal matrices: compression / decompression of images, their masking/unmasking and noise-resistant coding / decoding during transmission in wireless communications, etc.

The size of digital images is constantly increasing multiples – this, firstly, because of consumer satisfaction in the desire to have better pictures, and, secondly, the constant progress of technology manufacturers of video matrices and monitors (TVs). Today, high Definition (HD) and Ultra HD have become widely used.

Of particular interest are high-resolution images used in the monitoring of minerals in mountainous areas, agriculture, in agricultural areas, in search and rescue operations carried out with a group of unmanned aerial vehicles (UAVs) [1].

That's why there is an increasing need to develop specialized compression algorithms, their masking and noise-resistant coding in a distributed system of processing and aggregation of information where the subjects of distributed system are UAVs and center of control, processing and aggregation of information.

2. DISTRIBUTED UAV SYSTEM OF INFORMATION PROCESSING AND AGGREGATION

Development of a high-performance wireless network, whose objects are small aircrafts and ground station, which is capable of transmitting, processing and integrating the following types of information: high-resolution radar images, images obtained from optical location systems (video frames), navigation information, radar information, etc. Thus for such systems it is required that this information has been masked, compressed, encoded, etc. during transmission within the considered distributed system.

These procedures of processing and transmission of information are planned to be carried out on the basis of the new theory of quasi-orthogonal matrices. In general, the formation of a new extended basis of quasi-orthogonal matrices, different from those used today, can lead to a significant development, improvement and possibly revision of the theory of signal processing, images and their coding.

To solve the problems of monitoring territories and objects in the civil sphere, in the field of environmental reconnaissance, in search and rescue operations and exploration of hard-to-reach places, UAVs or a group of them are used [1,2]. But their main criteria to guarantee the performance of the task is the implementation of real-time mode, which requires high-speed computing resources and fast processing algorithms, received and transmitted within the information system. In addition, in such systems, it is required to provide a reliable noise-resistant wireless channel for transmitting information between several users in difficult electromagnetic environments.

To implement such distributed systems, first of all we need to determine the type of information collected from radar device on board of UAV: as a rule these are high-resolution images received from optical ranging systems, taken in the visible or infrared range, radar images formed by synthesizing he antenna aperture or stream video, etc. So basically it is an image that is matrix structure.

The distributed UAV system receives images from several sides, which allows for the complex processing of these images of different nature to solve the problems of mapping and classification of objects with the required accuracy [3].

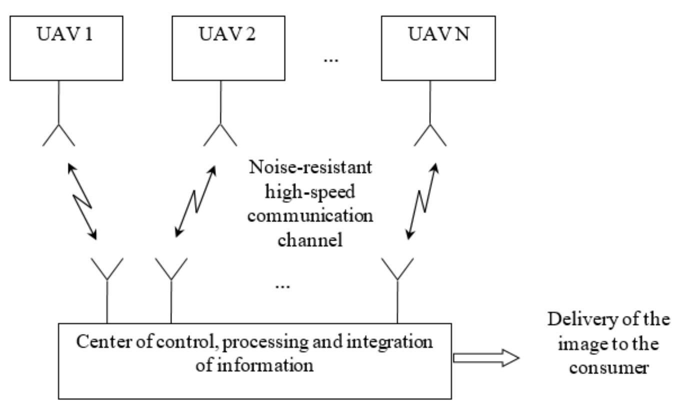


Figure 1. Distributed UAV system and control and processing center

However, it requires the simultaneous implementation of specialized algorithms of compression, masking and noise-resistant image encoding to exchange high-speed distributed system, which is formed by the UAV and the center of control, processing and integration of information (figure 1).

3. IMPLEMENTATION OF COMPRESSION PROCESS

One of the methods to solve the problem of high-quality image processing with high resolution is the creation and use of new compression filters, new algorithms of noise-correcting coding based on the use of orthogonal and quasi-orthogonal matrices of large sizes. At the same time, to meet the requirements for the quality of the transmitted image, firstly, it is required to implement high-speed exchange, and secondly, on board of the UAV, it is required to evaluate the compressed image with quality metrics before transmitting it.

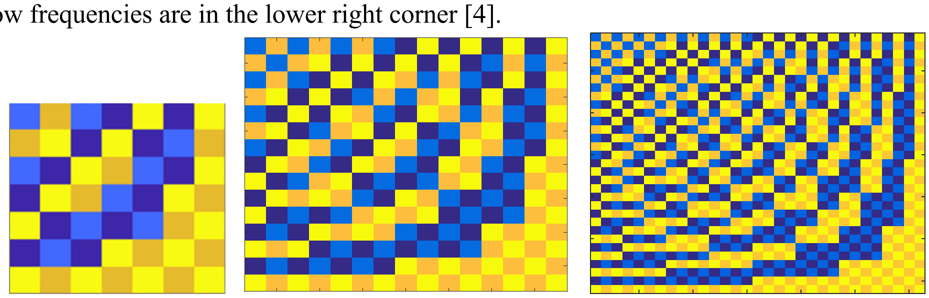
Symmetric constructions of Hadamard-Walsh matrices which are obtained from classical Hadamard matrices by ordering columns by frequency (by the number of sign changes of their elements) are of particular interest for certain image processing problems [3].

It is known that the lossy compression procedure, as the most promising, allows to obtain high compression ratios, compared with lossless compression. At the same time, using lossy compression it is possible to achieve a compromise between the requirements for image quality and the compression ratio, which allows you to develop a compression algorithm for a specific application task.

The paper considers the possibility of replacing the discrete cosine transformation (DCT) in the chain of transformations by an orthogonal transformation with special matrices. However, in contrast to the use of two-level symmetric Mersenne matrices, it is proposed to use four-level matrices, when searching for them, the value $a = 1$ is not fixed for the coefficients using the formulas given in [3].

Such four – level quasi-orthogonal Mersenne matrices sorted by Walsh, namely symmetric four-level Mersen-Walsh matrices [3,4], proved to be better in the experiments carried out in this work.

Figure 2 shows a color portrait of such matrices of order 7, 15 and 31. It is obvious that when it is used in image conversion, in contrast to DCT, low frequencies are in the lower right corner [4].



7×7 15×15 31×31

Figure 2. Portrait of a four-level Mersenne-Walsh matrix

For the equivalence of image compression experiments with DCT and Mersenne-Walsh matrices, the same compression coefficients were given, the value of which is related to the quantization threshold. The test image was formed by the radar optical systems equipment on board the UAV (figure 3).

Figure 3. Test image generated by radar optical systems equipment on Board the UAV

As an example, figure 4 shows the restored image after compression for the transformation cases with DCT (dimensions 8x8, 16x16, 32x32) and with the Mersenne-Walsh matrices shown in figure 2, respectively.

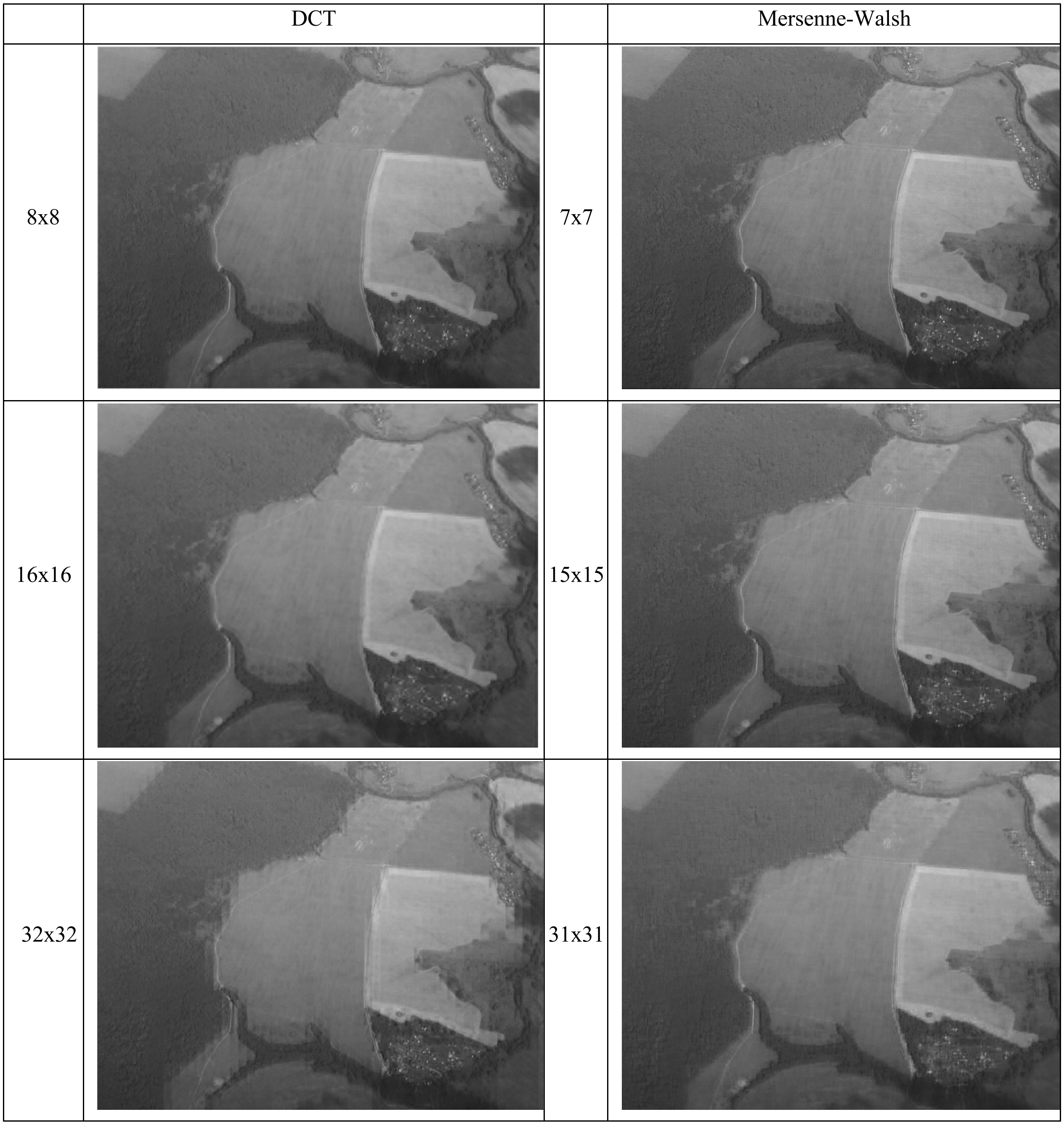


Figure 4. Recovered images for compression ratios of 1.5: left with using DCT, right with a four-level Mersenne-Walsh matrix

Comparison of the original image formed during UAV monitoring process and the image obtained in the simulation of the compression algorithm show that the compression of ratio 1.5, in the case of the Mersen-Walsh matrices, the restored image is more consistent with the quality of the original image.

4. IMPLEMENTING THE MASKING PROCESS

One of the effective methods of protective coding of visual information is the method of double-sided matrix masking. The term "matrix masking" should be understood as a computational procedure for converting digital images using matrix operations, destroying it to a form perceived visually as noise.
The following are the results of the grayscale image conversions. Masking color images is performed separately for each component of the digital representation of the image. The restore is the same process but in reverse order because of the symmetry of the transformation.
An example of the original black-and-white image and the result of its "ideal" masking (data in the communication channel) is schematically shown in figure 5.

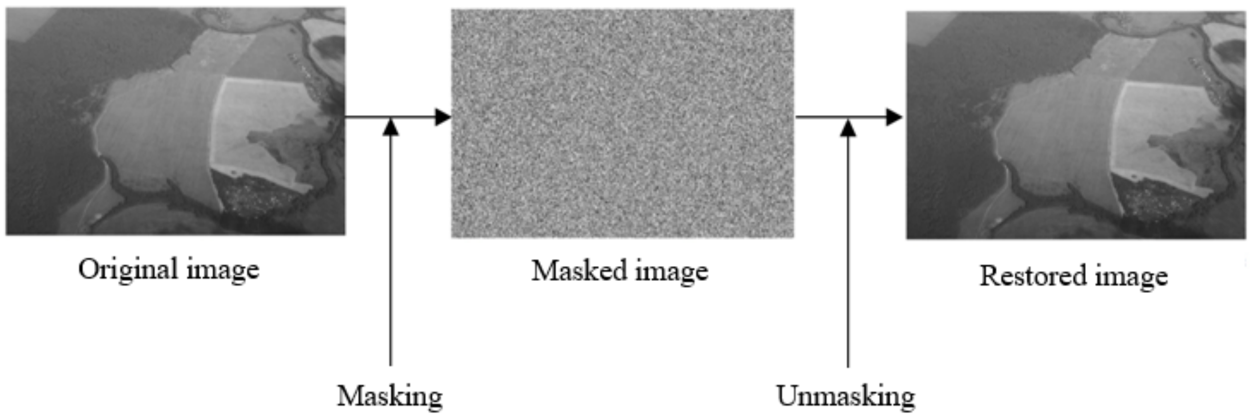


Figure 5. Results of the masking / unmasking procedure

According to this method, on the transmitting side, the image (frame) **P** is masked by an orthogonal matrix in the as $\mathbf{Y}=\mathbf{H}^{T}\mathbf{P}\mathbf{H}$. This transformation provides a visual destruction of the image to a level close to noise, with computational costs significantly lower than the implementation of encryption methods. This allows you to mask images in real time, at the rate of obtaining them from the matrix of the video camera or camera of the location aperture.
Given the fact that the basis of the masking method is strip transformation, masked image becomes resistant to possible distortion and loss of information in communication channels [5].
Presented in figure 5 visualizations of masked images which are transmitted in a distributed system, shows the feasibility of using this method to solve the problem.

5. INFORMATION AGGREGATION

Using the implementation of the compression and masking algorithm described earlier, it is required to implement the combination of information for the transmission system of image frame. That system is in a distributed system of remote data transmission over the radio channel to the recording device for processing and aggregation of information.

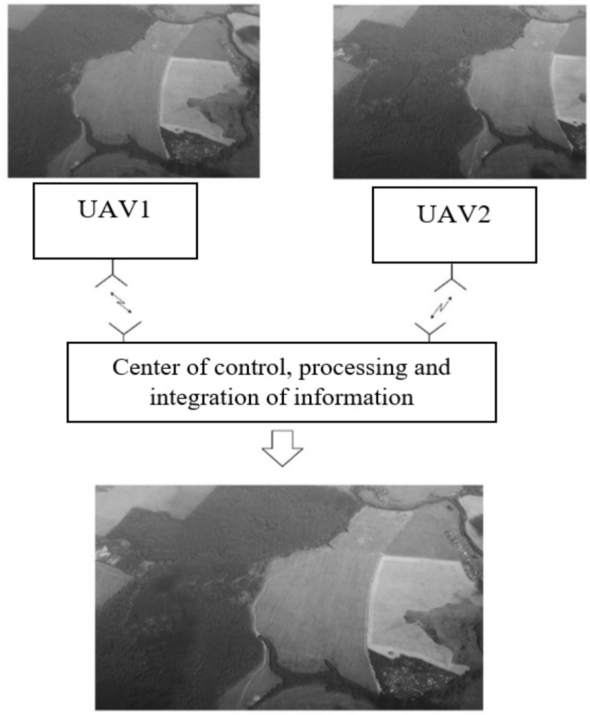


Figure 6. Information aggregation in two-position location optical system

Figure 6, shows two images received over a wireless high - speed channel to the center of processing and aggregation from UAV1 and UAV2. These images are obtained from different angles. As the result of integration, there is the final image ready for further implementation of algorithms for location and classification of objects in order to perform the tasks of environmental monitoring, search and rescue, etc.

6. CONCLUSION

The results of the experiment confirmed the possibility of implementing a high-resolution image compression algorithm for a distributed UAV system.

Based on the results of the experiments, it is possible to formulate recommendations for adjusting the software for processing matrix structures of large volumes in real time. The developed complex of algorithms is applicable for realization of onboard algorithms of high-speed exchange. The results of the work are easily adapted for working out algorithms of compression, masking and coding of the generated images recorded during field tests.

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