THE STATE COMMITTEE FOR COMMUNICATION, INFORMATIZATION AND TELECOMMUNICATION TECHNOLOGIES OF THE REPUBLIC OF UZBEKISTAN

TASHKENT UNIVERSITY OF INFORMATION TECHNOLOGIES

On rights of manuscript

UDC: 621.397

ABDULLAEV DILSHOD ABDIKODIROVICH

Developing an algorithm for assessing the quality of video sequences on the multimedia applications

5A330202 - Informatics and multimedia technologies

Dissertation for academic master's degree

Supervisor: Varlamova L.P. (PHD)

Tashkent-2014

CONTENT

Introduction

Subject topicality. is associated with an increased flow of video, video sequences, broadcast media streams that have to meet high quality demands. Ultimately, the result of analysis of video sequences is the quality of their broadcast. For assessing the quality of video sequences, passing certain stages of transformation requires algorithmic software on the basis of modern computer technology. Every year, there are new technical equipment for recording, storing and transmitting video, and with them the video stream is increased by the requirements for quality of the video or video sequences. Since video signals are delivered to the end user in an increasingly wide range of applications, it is important to have available automatic evaluation methods video (VQA), which could help in the management of the quality of the video delivered to a variety of purposes, from decoding video sequences obtained from satellites, to critically minded audience. Naturally, quality assessment submission video motion plays an important role in perception.

Object and subject of the research. Video sequences. The methods and techniques on creation of algorithm to assess the quality of video sequences.

The purpose and tasks. is to study and analysis of algorithms and compression techniques video sequences, eliminating redundancy and spatial statistical algorithm development for assessing the quality of video sequences multimedia applications, their numerical solution.

Seeks to improve the image quality are important because of the increasing flow of video, video sequences, broadcast media streams that have to meet high quality demands.

Ultimately, the result of analysis of video sequences is the quality of their broadcast. For assessing the quality of video sequences, passing certain stages of transformation requires algorithmic software on the basis of modern computer technology.

To achieve this goal it is necessary to solve the following sequential tasks.

1. Review, analysis and comparison of methods and algorithms for image lossless compression.

2. Utilization of methods of converting color spaces; Metadata video sequences coding techniques, methods of decoding; wavelet methods (wavelet)-transformations.

3. Creation of developed algorithms for software for wavelet compression and quality assessment of the reconstructed images used in the industry.

4. Testing the developed algorithms and software for solving practical problems in the educational process.

General Procedure for the job. To send videos or images from one place to another, we want the quality of videos and images not to decrease in spite of they have been compressed in order to send quickly etc. In this case, this job assists such advantages:

─The algorithm based on Lucas-Canada and built by using wavelet - transformation dependences have indicated the improvement of the quality of the decoded image;

─The time of decoding or deblocking has been reduced by optimizing based on wavelet transforms.

Methods of research. The followings have been utilized in this dissertation. They are numerical methods matrix transformations; Algorithms and methods for compressing video images without loss; methods of converting color spaces; Metadata video sequences coding techniques, methods of decoding; wavelet methods (wavelet)- transformations.

Scientific novelty. of the obtained results in the dissertation is as follows: Based on the MPEG-4 standard has been used for the most efficient compression algorithms,with object selection, developed a hybrid algorithm based on the algorithm of Lucas - Canada and wavelet transforms (DWT).

The theoretical and practical significance of the research results. The results of the work which is theoretical and practical are almost up-to-date. The results can be used in research professionals involved in the study of qualitative transformations video and audio, video sequences transformation followed by translation in multi-media systems.

The main results of the work performed. A package of applications in C# + package MathCAD.

Publication. Main results of the master's thesis published in [10,48], reflecting the main content of the work.

As the rapid development of computer technology has led to the emergence of various multimedia applications and programs that use text, pictures, animations and sound fragments, for processing of the video requires algorithms by which the storage and transmission of video - images possible in high quality format. In communication systems and broadcasting are limited choices available frequency bands, so acute problem of lowering speed digital audio and video streams without reducing the subjective quality playback. In the field of digital audio as well as to improve the sound quality requires increasing the sampling frequency and the number of bits without increasing the size of the support and reduce the recording time [1].

In addition to communications and broadcasting in the development of algorithms quality evaluation system of video sequences are interested in industrial digital video technology - various kinds of digital security systems video surveillance regime's industrial facilities, video monitoring and remote management processes ore mining in the mining industry; storage and transmission of satellite images for the needs of the meteorological, etc. Transmission and storage of such information expended a lot of resources (power, memory and bandwidth) and as a consequence of the cost of transmitting video. Therefore, one of the important tasks of storage, transmission and processing of video compression are the problems of static images. These problems are solved by many researchers for more than 20 years (D. Vatolin A. Ratushnjack, GKWallace, WB Pennebaker, etc.), and despite the relatively good results (algorithms JPEG and JPEG2000), are still remaining relevant [2 - 6]. Transmission and storage of video (static images and video sequences) still remain the most resource consumption part of such digital systems. In practice, this leads to a rather strict requirements, such as transmission bandwidth, and as a consequence, the cost of its rental; computing power and energy equipment which is important for embedded systems in hazardous industries; storage size of video data, such as video surveillance systems, etc. It should specify that the most common class of realistic photo images in the industry. This class includes color and grayscale images with a large range of colors and tones (usually at least 256) and smooth change of brightness, for example, pictures of people with cameras, scanned photos, landscapes, remote sensing data, etc. [6-7].

Nowadays, online broadcasts in real time are widely used on the Internet. Broadcast media streams are especially popular in the educational systems and services. Hardware and software systems, which are organized with the help of the webcast, as a rule, consist of three main components: a video encoder, media server and video player user. Encoder generates a media stream from a camera or other device that captures the signal and sends it to the media server. Further remote clients connect to the media server and receive the requested broadcast through the network protocols. During the transmission of multimedia streams over the Internet, mainly the interaction of the media server with clients, the quality of multimedia streams is affected by various network interference, so the picture and sound quality on the side of client in some cases are not good enough. In turn, the better picture and sound quality on the side of the end user, the more attractive service for the customer. It is therefore important to assess the ability of users in advance to receive one or another media stream at a given time in a certain place, so that if it is necessary, you can fix the problems in advance, causing deterioration in the quality of the multimedia stream.

Structure and scope of the dissertation. The dissertation consists of an introduction, three chapters, conclusion, list of references and application.

Chapter I. Review of existing systems and algorithms

1. Comparative analysis of video sequences with audio sequences

Existing compression algorithms video sequences can be divided into two classes [6].

• lossless compression;

• lossy compression.

Class of algorithms lossless image compression is rarely used for photorealistic image compression, for example derived from an analog video camera security system sensitive sites, as provides a low compression ratio, usually not more than 5. It is worth to note that the solution of practical problems in industry, the most common color (with a color depth of 24 bits per pixel) and grayscale (shades of gray depth of 8 bits per pixel) of the image [6,7]. Basically, these limitations are caused by the characteristics of the applied video equipment. For example, the vast majority of digital video cameras provide video data in these formats.

The most common algorithms for lossy image compression are based on the assumption that the source image contains information that is poorly perceived by the human visual system (ZSCH). When compressing this piece of information is irretrievably lost, which can significantly increase the rate of image compression at "unchanged" from the point of view of human capacity. The loss of this information or the compression ratio will determine the quality of the decompressed image. It is obvious that compression algorithms, such as security systems video surveillance regime objects will place high demands on the aspect ratio (should be stored in the video; for a long time, for example, not less than one year), the quality of the decompressed image (operator or guard should be given the opportunity to recognize people's faces, numbers of vehicles, etc.) and the speed of compression / decompression of images (you need to watch the process of accessing an object in real time, for example, provide 1-3 video frames per second).

Based on the analysis results of domestic and foreign research and application projects on image compression can be formulated on the basic requirements (performance criteria) to the algorithms of lossy image compression used in the industry [7,8]:

1. Small time compression and decompression (40 ms);

2. High compression ratio (up to 150);

3. Reconstituted high quality (uncompressed) image (peak signal / noise ratio of 24-26 dB or more, depending on the application solved the problem).

At the present stage of development of algorithms for image compression algorithm compression JPEG2000, successor JPEG and wavelet-based, are considered the best on the second and third criteria and are accepted by many authors of their own as the standard compression algorithms [7-9]. However, to satisfy the first criterion fails completely, because this algorithm is difficult to implement and sufficiently demanding computing resources [10-12]. Therefore, the problem that is still relevant is not resource-intensive development of algorithms for image compression used in the industry.

Noting that not all of the criteria for evaluating the effectiveness of compression algorithms are easy to numerical measurement. Thus measurement of the speed and the compression ratio are simple tasks; evaluation of the quality of the reconstructed images depends on the human factor (expert opinion), which makes topical issue of assessing the quality of the reconstructed images without human intervention. [10]

There are two classes of methods for image quality evaluation:

• subjective (expert);

• objective (mathematical).

It is known that the most reliable estimates of image quality provide subjective methods, but their practical application requires a large number of trained people and time. Effective solution to this problem is to use objective methods or " mathematical estimates [11].

Historically, objective methods for image quality evaluation are bbased on simple mathematical expressions, such as the mean square error or dispersion (standard deviation, Eng. Mbe name) and the peak signal / noise ratio (POSSH, Eng. R8KE1 name) [7,10,11-12]. This explains the relatively little research of the work of the human visual system (ZSCH). Also, the prevalence of these algorithms due to the simplicity of their software implementation, and high-speed computing. Relatively recently been proposed more complex computationally intensive algorithms - structural similarity index (English title BBGM) and wavelet structural similarity index (English title C \ ¥- 881M), which in some applications show good consistency with peer review (far superior algorithms based on SD [12]) and have the potential for modernization, which aims - to increase reliability of the evaluation results [12-14]. The term accuracy here in after, with reference to the results of the mathematical evaluation of image quality means that the algorithm must evaluate as close as possible to that which was obtained during the expert method. Therefore, the task of developing new and improving existing, such as SSIM and CW-SSIM, image quality evaluation algorithms still relevant.

Visuals compared with audio sequences characterized by a large number of elements. Distinguish static and dynamic video sequences.

Static visuals include graphics (drawings, interiors, surface characters in graphics mode) and photos (photos from scanner image).

Dynamic video series are sequences of static elements ¬ Comrade (frames). We can distinguish three types of groups:

■ regular video (life video) - a sequence of photos (about 24 frames per second);

■ quasyvideo - sparse sequence of images (6-12 frames per second);

■ animation - a sequence of animated images.

The first problem in the implementation of video sequences - screen resolution and number of colors. There are three directions;

■ VGA standard gives resolution of 640 x 480 pixels (dots) on the screen at 16 colors or 320 x 200 pixels with 256 colors;

■ standard SVGA (512 KB video memory, 8 bits / pixel) gives a resolution of 640 x 480 pixels with 256 colors;

■ 24 -bit graphics cards (2 MB video memory, 24 bits / pixel) let you use 16 million colors.

With the advent of digital television, the task of assessing the quality of a new value. When a television signal compression lossy video quality assessment to evaluate the impact of different types of distortion on the quality of the resulting video. For such an assessment is necessary to use subjective quality assessment methods, since the purpose of the experiments is to determine the subjective quality at the same objective degree of distortion of the image.

One method to improve the image quality is the use of methods to improve the quality of video sequences. This is due to the fact that the problem of digitizing documents with high resolution is not completely solved. Despite the large number of high quality technical equipment, the problem of assessing the quality of images on the basis of algorithms is particularly relevant. If we talk about a lossy compression algorithm, it is necessary to conduct a final evaluation of how the discarded information is important or essential to perception. In addition, various file formats, stream velocity difference, network protocols, formatting options, in various combinations can have a significant impact on the quality of the image.

Quality assurance includes primarily quality control (QA) throughout the process of transmitting video sequences from the camera lens to the screen display. And that means that we need a reliable and high- quality technical controls that are based on the hardware and software [6].

Obviously, to build high-quality video sequences requires JavaScript benchmark or reference image. But this method is subjective because it does not always take into account the large number of various input parameters, interference and noise. This means deterioration of the video. The next approach is to use the expert approach. However, this approach requires a large number of people and time, and in the case of a large number of the estimated amount of information costs may increase by several times.

Currently, multimedia technologies are rapidly developing area of information technologies. In this regard, active significant number of large and small firms, technical universities and studios (including IBM, Apple, Motorola, Philips, Sony, Intel, etc.) Areas of application are extremely diverse: interactive learning and information systems, CAD, entertainment and etc.

The main characteristic features of these technologies are: - Information Association multicomponent media (text, sound, graphics, photos, videos) in a uniform digital representation;

- Providing reliable (no distortion) copy and durable storage (shelf life is - for decades) large amounts of information;

- Ease of information processing (from routine to creative operations).

Made technological basis is based on a new standard for optical media DVD (DigitalVersalite / VideoDisk), having a capacitance of the order of units and tens of gigabytes and replaces all previous: CD-ROM, Video-CD, CD-audio. Using a DVD possible to implement the concept of homogeneity of digital information. One device replaces the music player, VCR, CD-ROM, floppy drive, slider, etc. In terms of presentation DVD optical media brings it to the level of virtual reality.

Multicomponent multimedia environment should be divided into three groups: Audio dubbing, visuals, text information.

Audio dubbing may include speech, music, effects (sounds-like noise of thunder, creaking, etc.). The main problem when using this group is multi-media information capacity. To record one minute WAVE- top quality sound requires memory of 10 MB, so the standard amount of CD (640 MB) allows you to record more than an hour WAVE. To solve this problem, there are methods of compression of audio information.

Another trend is the use of multi-media sound MIDI (Musical Instrument Digital Interface). In this case, the sound of musical instruments, sound effects, synthesized software- controlled electronic synthesizers. Correction and digital recording MIDI- sounds by using music editors (software sequencers). The main advantage of MIDI is a small amount of memory required - 1 minute MIDI-sound takes an average of 10 KB.

Visuals compared with audio sequences characterized by a large number of elements. Distinguish static and dynamic video sequences.

Static visuals includes graphics (drawings, interiors, surface characters in graphics mode) and photos (photos and scanned images).

Dynamic video series are sequences of static elements (frames). We can distinguish three types of groups:

- Regular video (life video) - a sequence of photos (about 24 frames per second);
- quazyvideo - sparse sequence of images (6 to 12 frames per second);

Dynamic visuals can be represented in the usual video (24 frames per second) video discharged (6... 12 frames per second) and animation. Use of multimedia technologies in educational process places high demands on the screen resolution. The second problem - increased memory requirements.

Increased productivity and performance of personal computers allow you to create and use in the educational process multimedia software systems and systems that combine text, sound, video, graphics and animation.

Multimedia training systems combine both traditional static visual information (text, graphics) and dynamic information (speech, music, movies, animation), causing the simultaneous effects on visual and auditory senses of students that allows you to create dynamic time - developed images in a variety of representations of information (audio and visual). Organization of the educational process with the use of multimedia technology allows you to transfer large amounts of information, training material expounded illustrate the video, animated videos with audio accompaniment. Provide an opportunity to multimedia learning systems:

• interactivity with the system - provides feedback and helps to organize joint activities in the scheme of "teacher - student PC ";

• visualization of educational information - promotes better memorization and learning educational material;

These and other problems led to the development of audio compression algorithms signals based on various models of auditory perception. Currently, audio encoding used in European digital radio systems DAB (Digital Audio Broadcasting - Digital Audio Broadcasting), DRM (Digital Radio Mondiale - worldwide digital radio), American Dolby AC- 3 (ATSC, Advanced Television System Committee- Committee on advanced television systems), optical disk system DVD-Audio, mini magneto-optical disks, audio disks of MP3, the Internet to transmit high -quality sound.

The most widely used the following algorithms compression of digital audio data are used in the latest systems digital broadcasting and television sound [11-13]:

• MPEG-1 ISO/IEC 11172-3;

• MPEG-2 ISO/IEC 13818-3 and 13818-7 AAC;

• MPEG-4 ISO/IEC 14496-3;

• ATSC Dolby AC-3 (A/52).

Advances digital video industry (primarily broadcast digital video and DVD- video) based on international standart ISO / IEC 13818, commonly known by the acronym MPEG- 2 (so named yeas expert working group on the moving images that developed this standard, - Moving Picture Experts Group). The need to develop better compression has generated further video compression standard known as ISO / IEC 14496 Part 2 (MPEG- 4 Visual) and the recommendations of ITU-E H.264/ISO/IEC 144496 Part 10 (abbreviated as H.264). MPEG-4 Visual and H.264 have a common origin and the many common features. They both have been developed on the basis of the earlier standard compression. However, they develop the old standards in substantially different directions [11-14].

2. Assessment of quality of video sequences

Static visuals include graphics (drawings, interiors, surface characters in graphics mode) and photos (photos and scanned images).

Dynamic video series are sequences of static elements (frames). The rapid development of telecommunication systems for receiving and transmitting video data requires solving a number of problems:

- Improving the quality of video sequences,

- Increase memory capacity and computing power hardware included in the telecommunication systems. The composition of these tools include universal or specialized computers, specialized input - output image, means for storing or archiving video and related software. In general, the complex of such funds should also provide input, output and transmit images of different physical nature.

Under input image is a procedure for transforming a source image to a form suitable for computer systems. Input can be made as a standard peripheral computer devices (OVC scanners), and with respect to non-standard computer devices. The latter includes, for example, television camera and a CCD array.

Under the image output is the operational visualization on the video monitor, with the aim of archiving long time storage and documentation of the information required. Transferring images includes the exchange of images between different units of processing and sharing images via data transmission between the device and not its member.

It should be noted that the various functions can be assigned to the function-oriented workstations based on personal computers connected to a LAN with access to the global network [6, 8].

As a quality control scheme can offer the diagram shown in Figure 1.1 [9].

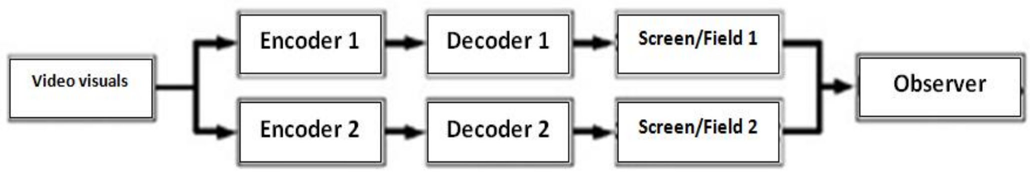


Fig.1.Quality control scheme

In determining the image quality of the video showing the serial recommended with five-digit rating scale. However, the measure of quality - conventional concept, so to assess often the preferred method of comparing two images. This method is useful if there are two different methods of compressed video, where necessary to determine the preferred method. Using Parallel display video in real time allows the conditions close to the real television. When receiving the video image is converted by two pairs of the encoder and decoder, each with different parameters. This scheme is based on a parallel display of the video that passed system: codec screen by giving the observer the possibility of obtaining an undistorted or filtered image [10].

Deblocking filter appears in video compression standards MPEG-4. According performance analysis [9] active filter spends about 20% of processor operations required to perform decoding operations. Particular attention was given to the decoding operation as the first, in most cases, restrictions on the number of operations available to the encoder, higher than at the recovery side of the video image, and secondly by encoding the major share operations, work spent on eliminating filter block artifacts significantly low. Therefore, optimization of deblocking filter can significantly reduce the resource consumption of the decoder. On the other hand, it may affect the quality of the reconstructed image. Deblocking filter is adaptive. Before he shares borders filtration units to those that contain block artifacts and those who are the real image boundaries. In accordance with the results of the evaluation filter defines " border effect ", is the degree to which this boundary should be filtered.

According to the analysis of resource stages of the codec in terms of the number of operations spent on the execution of each of the functions of the decoder, the definition of "border force" requires the most resources, as it requires a large number of test conditions. The task of determining the strength of the boundary can be simplified if we assume that for each face of the block "border force" unchangeable. In this case, the calculation can not make for each and every fourth pixel. This condition is fulfilled in most cases.

3. **Digital representation of the image**

Computer image in its digital representation is set of values of the intensities of the light flux distributed last area. Monochrome images in which the intensity of the emitted light energy per unit area at the point with coordinates(ξ, η) image can be represented by a number of B (ξ, η). A single picture element, characterized by a certain value (ξ, η) - pixel, and the value of z = f (ξ, η) - brightness [4].

From a mathematical point of view, grayscale images can be represented as a real function of two real variables I and Y x. Function I (x, y) image is generally determined in the coal industry directly, but for the convenience of research work all the images defined in the square areas. T.ex $\in$ [0; W], and y $\in$ [0; H], where W - width of the image, Ah - image height and W = H.

Divide all the images can be in two groups: the palette (8, 16 and 256 - color) and without palette. Images have a palette in a pixel (one report image value of the function I (*x*, *y*) for a particular *xi* and *yi*) stored number - index in some dimensional vector flowers, called a palette [8-9].

If the grayscale value of each pixel is defined as the brightness of the point, it is possible to view the image with 2, 16 th and 256 th gray levels. In the case where the image is represented in some color systems, each pixel is in its structure, which describes the color. The most common color system is used in electronic and computer systems, the system is RGB. In this color system defined as a combination of red, green and blue colors. And each of the components account for one byte. There are other types of color systems, such as CMYK, CIE, YUU, YCrCb, Luv, Lab [11,12].

In order to correctly assess the degree of compression of the image, and the applicability of a compression algorithm to this image introduces the concept of class images [8], as a set of images, the use of which, the compression algorithm gives qualitatively the same result. For one class of compression algorithm provides excellent compression ratio, and another class of images on the contrary, increases the volume of the compressed file [8]. There are roughly the following classes of images:

• image with few colors and large areas filled with one color. In the picture there are no smooth color transitions. These classes usually refers business graphics, scientific and technical, engineering or poster graphics;

• images with smooth colors, built on the computer: graphic presentations and virtual model;

• photorealistic images obtained after digital photography, scanning, as well as post-processing of these images.

Summary of Chapter I

— An overview of the types of images

— The analysis of existing video compression standards

Chapter II. Methods of assessment the quality of video images.

1. Methods of video signals compression

All methods of data compression are based on the simple assumption that the data set always contains redundant elements.

Compression is achieved by the search and coding redundant elements [14,15]. The flow of image data is a significant amount of redundant information that may be substantially eliminated without noticeable distortion for the eye. We differentiate between two types of redundancy.

Statistical redundancy is associated with correlation and predictability of data. This redundancy can be removed without loss of information, thus the original data can be fully recovered [16-17]. The most effective methods known character encoding based on the knowledge of each character frequencies present in the message. Knowing these frequencies, build a table of codes, has the following properties:

• Different codes may have a different number of bits;

• character codes with a higher frequency of occurrence, have fewer bits than the character codes from a lower frequency;

• although codes have different bit length, they can be recovered only way that codes are constructed as prefix.

Have these properties Huffman Lucas-Canada, RLE, ZIP [15,17].

Visual (subjective) redundancy, which can be resolved with a partial loss of data, there is little impact on the quality of reproduced images; this information can be removed from the image, the non-offending visually perceived image quality.

Eliminating redundant visual image is the main reserve reduction of transmitted information [16-18]. To optimize the encoding process in order to ensure transmission of the smallest necessary amount of information, on one hand, transmit redundant information, and on the other hand - to prevent excessive loss of image quality. Until now, there was no simple and adequate model of visual perception of images suitable for optimizing their coding [18].

The problem of image compression composed of two main parts: encoding and decoding. If the decoded image always corresponds exactly to the encoded image, such encoding-decoding algorithm called lossless compression algorithm. If the decoded image is different from the encoded, then such an algorithm is called a lossy compression algorithm. The general scheme of the image compression process can be represented as follows: the original image - secondary compression - compressed image - Decoding - decoded image [19-20].

The first step is the transformation of raw data from one presentation to another. In particular, when images are compressed depending on the type of compression algorithm can be transitioned from a source image to the different types of representations.

In the second stage the components are quantized and conversion to the form convenient for entropy encoding, and then encoded. At this stage the seal provides information stream. There are several different approaches to the problem of compression. Some are very complicated theoretical mathematical basis, others are based on the properties of the flow of information and algorithmically simple enough. Any method which implements data compression is to reduce the amount of output data flow aid reversible or irreversible transformation. Therefore, all compression methods can be divided into two categories: reversible and irreversible compression [20]. Digital image compression techniques can be classified according to their main characteristics, such as accuracy of reconstruction, the main symmetry transformation and the type of transformation [17].

Reversible compression (lossless compression). Reversible compression always leads to a decrease in the output stream of information without altering its information content, i.e. without loss of the information structure.

Furthermore, from the output stream, using a reducing algorithm can receive input [19-23].

Irreversible compression (lossy compression). Under irreversible compression implies a transformation of the input data stream, wherein the output stream based on a specific format information is quite similar in external characteristics of the input stream object, but differs from it in volume. The degree of similarity of input and output determined by the degree of conformity of certain properties of objects (ie, compressed and uncompressed data in accordance with some specific data format) that is represented by the flow of information.

2. Methods for assessing the quality of image compression

There are various methods for estimating the parameters of the compression of the video:

• on the basis of the optical flow in the video sequence (i.e., on the basis of the shift vectors for each pixel);

• based on the extraction of characteristic points of the image (ie, through the allocation of the characteristic features of the image and find a match between them in successive video series);

• based on the direct use of brightness of pixels of the input image [24].

Any processing of video sequences with the release of information on the movement consists of two parts: pretreatment, optical flow computation and post-processing the received data stream with an attempt to extract information from them. Studies have shown that even at the stage of computing optical flow may make algorithmic modifications that will help accelerate the process of calculating without significant loss of information. Problem of estimating the parameters of geometric transformation is as follows. For each image of the video sequence is necessary to estimate its geometric transformation relative to the previous (or more previous), while believing that the video image are the same stationary background. Under geometric transformation can involve arbitrary continuously differentiable bijective coordinate transformation.

The most common are the following transformation:

• Affine transformation, which describes well the arbitrary small geometric transformations in video sequences and is ample for the stabilization problem.

• The projective transformation that accurately describes the variation of the video if the scene is a plane. This is important for aviation surveillance tasks when the observed surface of the Earth in many cases can be considered flat. The disadvantage of this transformation is its non-linearity with respect to the transformation parameters, which leads to the need to use non-linear optimization methods to search for it.

• The quadratic transformation, which can be regarded as a linear approximation with respect to the parameters of the projective transformation. Its main drawback is not to preserve the properties of quadratic with repeated application.

Calculate estimates the transformation parameters can offset their impact.

Method Lucas-Canada. One of the most widely used methods for assessing differential optical flow method is the Lucas-Canada, based on partial signal [25-28].

The basic equation of optical flow (2.1) which has two unknown variables, and can not be unambiguously resolved. Algorithm Lucas-Canada bypass is not unique due to the use of the neighbor pixels at each point. The method is based on the assumption that the local neighborhood of each pixel p-value optical flow equally; thus, it is possible to record the basic equation for optical flow and the neighborhood of pixels to solve the resulting system of equations the least squares method.

Lucas-Canada algorithm less sensitive to noise in images than in-line methods, but is purely local and can not determine the direction of the pixels within the homogeneous regions. Assume that the displacement of pixels between two frames is small, hence the algorithm Lucas-Canada optical flow must be the same for all pixels located in the window centered at p. Namely, the optical flow vector (Vx, Vy) at the point p must be a solution of the equations:

$$\begin{aligned}
\mathbf{I}_x(\mathbf{q}_1)\mathbf{V}_x + \mathbf{I}_y(\mathbf{q}_1)\mathbf{V}_y &= -\mathbf{I}_t(\mathbf{q}_1),\\
\mathbf{I}_x(\mathbf{q}_2)\mathbf{V}_x + \mathbf{I}_y(\mathbf{q}_2)\mathbf{V}_y &= -\mathbf{I}_t(\mathbf{q}_2),\\
&\vdots\\
\mathbf{I}_x(\mathbf{q}_n)\mathbf{V}_x + \mathbf{I}_y(\mathbf{q}_n)\mathbf{V}_y &= -\mathbf{I}_t(\mathbf{q}_n),
\end{aligned} \tag{2}$$

wherein **q1, q2,..., qn**-pixels within the window, **Ix (qi), Iy (qi), It (qi)** – partial derivatives of the image coordinates *x*, *y*, and time *t*, computed at point *qi*. This equation can be written in matrix form $Av = b$, where

$$\mathbf{A} = \begin{bmatrix} \mathbf{I}_x(\mathbf{q}_1) & \mathbf{I}_y(\mathbf{q}_1) \\ \mathbf{I}_x(\mathbf{q}_2) & \mathbf{I}_y(\mathbf{q}_2) \\ \vdots & \vdots \\ \mathbf{I}_x(\mathbf{q}_n) & \mathbf{I}_y(\mathbf{q}_n) \end{bmatrix}, \quad \mathbf{v} = \begin{bmatrix} \mathbf{V}_x \\ \mathbf{V}_y \end{bmatrix}, \quad \mathbf{b} = \begin{bmatrix} -\mathbf{I}_t(\mathbf{q}_1) \\ -\mathbf{I}_t(\mathbf{q}_2) \\ \vdots \\ -\mathbf{I}_t(\mathbf{q}_n) \end{bmatrix}. \tag{3}$$

The resulting overdetermined system is solved by the least squares.Thus, a system of equations 2 × 2:

$$\mathbf{A}^T\mathbf{A}\mathbf{v} = \mathbf{A}^T\mathbf{b} \text{ or } \mathbf{v} = (\mathbf{A}^T\mathbf{A})^{-1}\mathbf{A}^T\mathbf{b}, \tag{4}$$

where $\mathbf{A}^T$– the transposed matrix **A.** We obtain:

$$\begin{bmatrix} \mathbf{V}_x \\ \mathbf{V}_y \end{bmatrix} = \begin{bmatrix} \sum_i \mathbf{I}_x(\mathbf{q}_i)^2 & \sum_i \mathbf{I}_x(\mathbf{q}_i)\mathbf{I}_y(\mathbf{q}_i) \\ \sum_i \mathbf{I}_x(\mathbf{q}_i)\mathbf{I}_y(\mathbf{q}_i) & \sum_i \mathbf{I}_y(\mathbf{q}_i)^2 \end{bmatrix}^{-1} \begin{bmatrix} -\sum_i \mathbf{I}_x(\mathbf{q}_i)\mathbf{I}_t(\mathbf{q}_i) \\ -\sum_i \mathbf{I}_y(\mathbf{q}_i)\mathbf{I}_t(\mathbf{q}_i) \end{bmatrix}. \tag{5}$$

Wavelet transform. Currently, one of the modern mathematical apparatus is wavelet analysis [29-30]. For the wavelet analysis of the images are typically computed pyramidal version wavelet spectrum. Wavelets, as functions of time, have their frequency representation. Frequency representation of the wavelets is important in determining the filtering properties of wavelet transforms, and fast wavelet transform based on a pyramidal algorithm Malla and thinning spectrum frequency wavelets. In accordance with the frequency approach to wavelet transform wavelet frequency domain can be divided into two components - the low frequency and high frequency. Low pass filter frequency gives way to approximate (rough approximation) signal and high frequency filter - for its detail.

Let symmetric complex wavelet transform mother wavelet is written as *ω (u) = g (u) ωcu*, where *ωc*-center frequency of the filter, *g (u)* - a slowly varying function is symmetric. Then the family of mother wavelet functions, which is a set of shifted and scaled versions of the mother wavelet can be written as follows [29,30]:

$$\omega_{s,p}(u) = \frac{1}{\sqrt{s}}\omega(\frac{u-p}{s}) = \frac{1}{\sqrt{s}} g(\frac{u-p}{s}) e^{j\omega_c (u-p)/s}, \tag{6}$$

where s ∈ R + - zoom level, p ∈ R-level shift.

Then, for some continuous signals (u) continuous wavelet transform is as follows:

$$X(s,p) = \frac{1}{2\pi} \int_{-\infty}^{\infty} X(\omega)\sqrt{s}G(s\omega - \omega_c)e^{j\omega p} d\omega, \tag{7}$$

function *X (u)* and *G (u)*. Discrete wavelet transformation complex is given in [29].

If you move from temporary sequential presentation video for the frequency obtained by the wavelet transform image's brightness level. Then the computation of optical flow method Lucas-Canada will have the form

$$\begin{bmatrix} V_x \\ V_y \end{bmatrix} = \begin{bmatrix} \sum_i W_x(q_i)^2 & \sum_i W_x(q_i)W_y(q_i) \\ \sum_i W_x(q_i)W_y(q_i) & \sum_i W_y(q_i)^2 \end{bmatrix}^{-1} \begin{bmatrix} -\sum_i W_x(q_i)W_t(q_i) \\ -\sum_i W_y(q_i)W_t(q_i) \end{bmatrix}, \tag{8}$$

Where $\mathbf{W}x(\mathbf{q}i),\mathbf{W}y(\mathbf{q}i),\mathbf{W}t(\mathbf{q}i)$ – partial derivatives of the wavelet spectrum image coortidates *x*, *y*, and time *t*, computed at point *qi*.

Thus, it is known that the analysis in the frequency domain provides advantages in assessing the noisy signals [29,31]. To investigate the accuracy of estimating the parameters of geometric transformation studies were carried out on video sequences with noise. At each iteration, the test image was superimposed additive white Gaussian noise, with the ever increasing standard deviation (SD). As a result of the comparison and the basic implementation of the proposed algorithm using Haar wavelet D4 standard deviation in the basic algorithm, more than 3 times higher than modified.

This algorithm is less sensitive to noise in the video frames and produces good results with low contrast images.

3. Assessment of the quality of the video sequences by using wavelets

Particularly relevant problem of assessing the quality of images in the development of various image processing algorithms, because often before the final testing and comparison with similar solutions need to conduct some research and experiments on the tuning and optimization of the developed algorithm. For example, in the development of lossy compression algorithms of both static and dynamic images you need to determine how the discarded information is essential in the perception of [2.19]. It is known that the surest way to obtain an estimate of the image quality is the use of the expert approach, but its use requires a large number of people and time, especially in the case of a large number of images being evaluated [24]. Effective solution for reducing the complexity and time when quality assessment is the use of objective (mathematical) metrics, giving as close as possible to the expert evaluation approach of image quality. Under the metric (in image processing) we mean a function that determines the distance of the estimated image to the reference or the perfect images in the image space. In modern literature describes a sufficiently large number of objective metrics, which can be divided into three classes [2]:

• Full reference (*full reference, FR*) - suggest the presence of the original image, which is regarded as a reference or a reference image, when compared, since it does not is noisy and has a perfect quality.

• Noreference (*noreference, NR*) - suggest that the process of obtaining a reference image quality assessment or reference image is missing. These metrics are the most difficult to implement and are often focused on a particular kind of distortion.

• Reducedreference (*reducedreference, RR*)- suggest that some of the information about the reference image is present together with a noisy image, the amount of this information is significantly less than the volume of information required for the reference image.

In this section we consider the class benchmark metrics for the following reasons:

• assessments of the quality metrics values given class closest to peer review;

• The most common problem in which they are used - static and dynamic compression of images;

• the largest number of proposed and described in literature metric assigned to this classification.

Today, the most common practice following reference metric:

MSE, PSNR, MSAD, VQM, SSIM, MSSIM, VSNR, CWSSIM [2,24,29]. Of these metrics according to [2,19,31] closest to the expert approach gives results metric CWSSIM.

CWSSIM metric is an expanded version of the metric SSIM using oriented complex wavelet transform [2]. Such transformations are widely used for the analysis of images borders, noise removal, synthesizing textures, motion detection, because they have [32,33]:

•the possibility of expansion in different scales (subbands);

•orientation (direction), excluding correlation oriented subband decomposition.

Application of a complex wavelet transform in the evaluation of image quality can improve the quality evaluation for both structural and geometric distortion type for the shear strain, reduction, enlargement, rotation, and that satisfy the definition of more nonstructural than structural distortion [2].

Consider the complex wavelet transform details [2,31,32 7]. Let symmetric complex wavelet transform is written as a mother wavelet $\omega(u)=g(u)e^{j\omega_c u}$, where $\omega_c c$ – center frequency of the filter, *g (u)* - a slowly varying symmetric function. Then the family of mother wavelet functions, which is a set of shifted and scaled versions of the mother wavelet can be written as follows [2, 33]:

$$\omega_{s,p}(u)=\frac{1}{\sqrt{s}}\omega(\frac{u-p}{s})=\frac{1}{\sqrt{s}}g(\frac{u-p}{s})e^{j\omega_c(u-p)/s}$$

where s ∈ R + - zoom level, p ∈ R-level shift.

Then, for some continuous signal *x (u)* continuous wavelet transform is as follows:

$$X(s,p)=\frac{1}{2\pi}\int_{-\infty}^{\infty}X(\omega)\sqrt{s}G(s\omega-\omega_c)e^{j\omega p}d\omega,$$

where $X(\omega)$ and $G(\omega)$ converted into the Fourier series of *x (u)* and *g (u).*
Discrete wavelet transformation complex is given in [34].

Algorithm to compute metrics CW_SSIM reduced to comparing areas (windows) images (previously subjected to complex wavelet transform) into two components Q and F corresponding subbands oriented original (source) and the estimated images [19, 31]:

• value

$$Q(c_x,c_y)=\frac{2\sum_{i=1}^{N}|c_{x,i}||c_{y,i}|+K}{\sum_{i=1}^{N}|c_{x,i}|^2+\sum_{i=1}^{N}|c_{y,i}|^2+K}; \quad (9)$$

phase shift

$$F(c_x,c_y)=\frac{2\left|\sum_{i=1}^{N}c_{x,i}c_{y,i}^*\right|+K}{2\sum_{i=1}^{N}|c_{x,i}c_{y,i}^*|+K}, \quad (10)$$

where N – number of wavelet coefficients in sliding square window size L × L pixels, $c_{x,i}$ and $c_{y,i}$ – i_-th complex wavelet coefficients of the sliding window of the original image and the estimated ($c^*_{y,I}$ denotes the complex conjugate coefficient $c_{y,i}$), K – coefficient before Abhor division by zero. Meaning CWSSIM window is defined as follows [2, 6]:

$$\mathrm{CW-SSIM}(c_x, c_y) = Q(c_x, c_y) F(c_x, c_y).$$

The final value of the metric CWSSIM lies in the interval [0,1] and is calculated as the average of all indicators CWSSIM areas (windows), the resulting incremental movements of a square window at a given level S complex wavelet transform and the estimated original image:

$$M[\mathrm{CW-SSIM}_S] = \frac{1}{Z}\sum_{i=1}^{Z}\mathrm{CW-SSIM}(c_x, c_y),$$

where Z - number of windows covering image. Agreeing [31] when calculating the value of the metric CWSSIM recommended to use the following parameters:

• window shift step $H = 1$ pixel;

• the size of the sliding window of 7×7 pixels;

• The level of the wavelet decomposition (step wavelet transform) $S = 2$;

number of oriented subbands $K = 16$.

During the implementation and testing metrics CWSSIM noted the following deficiencies:

• inadequacy of (metric value with the value diverges Defect) in the case of the image distortion of the form:

additive white Gaussian noise (AWGN), Gaussian blur and JPEG compression is strong;

• high demands on the amount of RAM in calculating estimates.

The calculation was based on the metrics of package MathCAD with elements of programming in C # (Appendix).

The reason for these short comings are not optimal values of the metric: window shift step *H,* the number of oriented subbands *K* and the number of decomposition levels *S*.

The analysis through the wavelets has been a good alternative in replacement of the classical analyses that utilize the Fourier series, chiefly when treating acoustic signals, interpreting seismic signals and in the solution of numerical method sapplied to electromagnetism and electrostatics [34-36]. In general the wavelets can be defined by:

$$\psi_{a,b}(x) = |a|^{-1/2}\,\psi\left(\frac{x-b}{a}\right) \quad a, b \in R, a \neq 0$$

Some kinds of wavelets are mentioned in the literature, making it possible for new family models to be built from them, which adapt more appropriately to each case. Fig. 2.1 represents the Morlet or Modulated Gaussian wavelet, which is expressed by:

$$\psi(x) = e^{i\omega_0 x} e^{-x^2/2} \quad (11)$$

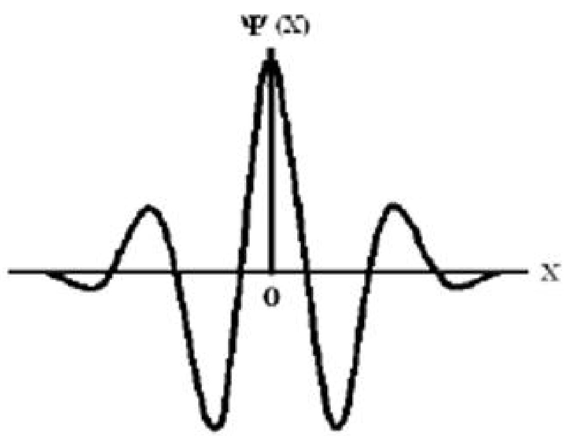


Fig.2. Morlet

It was previously mentioned that many functions can be used as the expansion function: Among them, the pulse function, the truncate cosine function and the wavelets can be mentioned. Thus, after applying the method of the moments, and considering the Haar wavelets, a function f(x,y) can be approximated by:

$$f(x,y)=\sum_{k=-\infty}^{\infty} c_k\phi(x,y)+\sum_{j=-\infty}^{\infty}\sum_{k=-\infty}^{\infty} d_{j,k} f_P(x,y)\psi_{j,k}(x,y)$$

In this equation "j", and "k" are the resolution and the translation levels, respectively. Moreover, once the Haar wavelets, and the so-called mother function and scale function father are applied, the formulation, for two-dimensional applications, will result in a product combination, given by [37]:

$$\phi^{(H)}(x)=\begin{cases}1 & 0\leq x<0.5,\text{ and}\\ 0 & \text{for other intervals}\end{cases}$$

$$\psi_{j,k}^{(H)}(x)=\left[\ \phi(x)\ \psi(x)\psi(2x)\psi(2x\text{-}1)\ldots\psi\left(2^j x-k\right)\right]$$

$$\psi_{j,k}^{(H)}(y)=\left[\ \phi(y)\ \psi(y)\psi(2y)\psi(2y\text{-}1)\ldots\psi\left(2^j y-k\right)\right]$$

$$\left\{\psi_{j,k}^{(H)}(x),(y)\right\}=\phi(x)\phi(y),\phi(x)\psi(y),\ldots,\psi(2x\text{-}1)\psi(2y-1)$$

4. Comparative analysis of compression algorithms

According to [36], if we look at a short list of formats often used for PC, Apple, and UNIX platforms: ADEX, Alpha Micro systems BMP, Auto logic, AVHRR, Binary Information File (BIF), Cal comp CCRF, CALS, Core IDC, Cubicomp Picture Maker, Dr. Halo CUT, Encapsulated Post Script, ERM apper Raster, Erdas LAN / GIS, First Publisher ART, GEMVDI Image File, GIF, GOES, Hitachi Raster Format, PCL, RTL, HP-48sx Graphic Object (GROB), HSIJPEG, HIS Raw, IFF / ILBM, Img Software Set, Jovian VI, JPEG / JFIF, Lumena CEL, Macintosh PICT/PICT2, MacPaint, MTV Ray Tracer Format, OS / 2 Bitmap, PCPAINT / Pictor Page Format, PCX, PDS, Portable Bit Map (PBM), QDV, QRT Raw, RIX, Scodl, Silicon Graphics Image, SPOT Image, Stork, Sun Icon, Sun Raster, Targa, TIFF, Utah Raster Toolkit Format, VITec, Vivid Format, Windows Bitmap, Word Perfect Graphic File, XBM, XPM, XWD, you can see a list of compression algorithms. The only coincidence is JPEG. However, this does not mean that it should be widely used. In the literature, often the word ' format ' and ' compression algorithm ' used interchangeably [37-41]. However, between these two sets of no -one correspondence. Thus, various modifications RLE algorithm implemented in a huge number of graphics formats. Including TIFF, BMP, PCX. And, if in a particular format a file takes up space, it does not mean that the corresponding compression algorithm bad. This means only that the implementation of the algorithm used in this format for the image gives poor results. At the same time many modern recording formats supported by using multiple algorithms or backup without archiving. For example, the TIFF 6.0 format can save images using algorithms RLE-Pack Bits, RLE-CCITT, LZW, Huffman fixed table, JPEG, and can save the image without archiving. Similarly, TGA and BMP formats allow you to save files as using compression algorithm RLE (various versions) and without it.

Thus, for many formats, talking about file size, you must specify whether to use a compression algorithm and, if used, what.

In this paper we apply a compression algorithm based on wavelet transform. A comparative analysis of the existing data compression algorithms, we can conclude that the algorithm is based on wavelet transforms, a high compression ratio shows a good result, namely, the visual quality of the image is slightly lower, but it is not used for post-processing images (quite 'reasonable' smoothing) (Table 1.).

Since for determining the quality of the video in the first step must be to evaluate the level of noise.

transform $w: R^3 \rightarrow R^3$, represented in the form

$$w(\bar{x}) = w\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} a & b & t \\ c & d & u \\ r & s & p \end{pmatrix} \bullet \begin{pmatrix} x \\ y \\ z \end{pmatrix} + \begin{pmatrix} e \\ f \\ q \end{pmatrix}$$

where a, b, c, d, e, f, p, q, r, s, t, u real numbers and $\begin{pmatrix} x & y & z \end{pmatrix} \in R^3$ called three-dimensional affine transformation

original image	Image after using the wavelet transformation
	

Table 2. The difference between the original image and image after using the wavelet transformation.

Definition. Let the $f: X \rightarrow X$ transformation in the space *X*. Point $x_f \in X$ such that $f(x_f) = x_f$ called a fixed point (attractor) conversion.

Definition. transform $f: X \rightarrow X$ in a metric space (X, d) is a contraction if there exists a number s: $0 \leq s < 1$ such that $d(f(x), f(y)) \leq s \cdot d(x, y) \quad \forall x, y \in X$

Note: Technically, we can use any contraction mapping in fractal compression, but really only used three-dimensional affine transformations with sufficiently strong restrictions on the coefficients.

Theorem. (About compressing transformation)

Let the $f: X \to X$ in a complete metric space (X, d). Then there is exactly one fixed point $x_f \in X$ this transformation, and for any point $x \in X$ sequence $\{f^n(x): \quad n = 0,1,2\ldots \quad\}$ converges to x_f A more general formulation of this theorem guarantees us convergence.

Definition. Image is a function S, defined on the unit square and takes values from 0 to 1 or $S(x, y) \in [0\ldots1] \quad \forall x, y \in [0\ldots1]$. Let the three-dimensional affine transformation $w_i: R^3 \to R^3$, written as $w_i(\bar{x}) = w_i\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} a & b & 0 \\ c & d & 0 \\ 0 & 0 & p \end{pmatrix} \bullet \begin{pmatrix} x \\ y \\ z \end{pmatrix} + \begin{pmatrix} e \\ f \\ q \end{pmatrix}$ and defined on a compact subset D_i cartesian square [0..1]x [0..1]. Then it transfers part of the surface S in the region R_i located shift (e, f) and turn specified matrix

$$\begin{pmatrix} a & b & 0 \\ c & d & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

At the same time, if we interpret the value of *S* as the brightness of the corresponding points, it will decrease in time *p* (conversion is bound to be a contraction) and change to shift *q*.

Definition. Finite set *W* of contracting three-dimensional affine transformations w_i, on certain areas D_i such that $w_i(D_i) = R_i$ и $R_i \cap R_j = \phi \quad \forall i \neq j$, called iterated function system (IFS).

Iterated function system is uniquely associated fixed point - the image. Thus, the compression process is to find the coefficients of the system, a decompression process - in an iterative system to stabilize images obtained (fixed point IFS). In practice, it is enough to 7-16 iterations.

As it has become clear from the above, the main objective in the fractal compression algorithm is to find the appropriate affine transformations. In the most general case, we can translate any size and shape of the area of the image, video sequences, but in this case we obtain an astronomical number of searched variants of different fragments that can not be processed at the current time, even on a supercomputer.

Therefore, the use of wavelet transforms (8) reduces the complexity and time of the evaluation of the quality of the video.

Summary of Chapter II

- Compression methods studied video sequences;
- For differentiable bijective coordinate transformation used affine transformation;
- Based on the affine transformation and the method of Lucas - Canada describes the optical flow;
- Partial wavelet spectrum to obtain a system of equations for the optical flow of the video to the coordinates *x*, *y*, and time *t*, computed at point q*i* (*pixel*)
- Above equations show that the analysis in the frequency domain provides advantages in the assessment of noisy signals. To investigate the accuracy of estimating the parameters of geometric transformation studies were carried out on video sequences with noise. At each iteration, the test image was superimposed additive white Gaussian noise, with the ever increasing standard deviation.

Chapter III. Numerical solution of algorithm for video quality assessment

1. Features of video data compression

Digital video from the source (video or recorded video) to the receiver (video display) involves the development of a chain of various components and processes. The key link in this chain is the process of compression (encoding) and decompression (decoding), in which an uncompressed digital video signal is reduced to a size suitable for transmission and storage, and then restored for display on a video monitor.

Sophisticated development of the processes of compression and decompression can give a significant commercial and technical product advantage, providing better video quality, more reliable and flexible adaptability compared to competing solutions.

Thus, there is a lively interest in the development and improvement of methods of compression and decompression of video [19,42-46].

Speed data networks as well as hard drive capacity, flash memory and optical drives are constantly growing. Bearing in mind the price cut transmission and storage of bits of information, it is not immediately obvious why you need video compression and its improvement. Video compression has two important advantages. First, it allows the use of digital video transmission and storage medium of video content, which does not support an uncompressed ("raw") video. For example, today's Internet bandwidth is insufficient to handle the uncompressed video in real -time, even at low frequency and low frame its size. Digital multi-layered DVD video can accommodate only a few seconds of uncompressed video resolution and frame rate, providing a normal broadcast quality, so the use of DVD would be completely impractical without the use of audio and video compression.

Secondly, the video compression makes more efficient use of resources in the transmission and storage of video data. If you see a high-speed link, you seem more attractive solution to transmit the compressed high-definition video instead of uncompressed video low resolution. Despite the steady increase in capacity storage devices and bandwidth data channels, it is very likely that the video compression will remain an essential component of multimedia services for many years. A signal carrying some information can be compressed by removing from it the existing redundancy. Redundancy - this data components, without which you can do to correct the image of the original information. Many types of data comprise a statistical redundancy. Such data can be efficiently compressed using lossless compression. Unfortunately, lossless compression applied to a video and a relatively small gain. Therefore, to achieve high compression efficiency necessary to use lossy compression. For video compression lossy uses several types of redundancy:

• coherence of an image - a small change in color images in the neighboring pixels (the property that all the algorithms exploit lossy image compression);

• redundancy in color planes - use a large importance for the perception of image brightness;

• similarity between frames - use the fact that at 25 frames per second, usually neighboring frames vary slightly.

Using the similarity between frames in the simplest and most frequently used means coding is not the case of the new frame, and its difference from the previous frame. For a video of "talking head" (TV news, videophones) the most of the frame remains unchanged and even such a simple method can significantly reduce the data stream. A more sophisticated method is to find for each block in the least compressible frame differs from a block in a frame, used as a base. Further, the difference between the coded blocks. This method is much more resource-intensive.

Application requirements to the algorithm encoding (compression) [3.6]:

1. Random Access - implies the ability to find and show any frame for a limited time. Provided by the presence in the data stream of so-called entry

points - frames compressed independently (ie, as a normal static image). Acceptable time frame considered arbitrary search 1/2.

2. Fast forward / reverse - means quick display frames unfollow each other in the feed stream that requires additional information in the stream. This feature is widely used by all possible players.

3. Showing frames of a movie in reverse is rarely required in applications. Under severe restrictions on the show the next frame, this requirement can dramatically reduce the compression ratio.

4. Audiovisual synchronization - the most serious requirement. Data necessary to achieve synchronous audio and video tracks, substantially increase the size of the video data. For video, this means that if you do not have time to get the show and at the right time a frame, it is necessary to correctly show the frame next to it.

5. Error resilience - a requirement due to the fact that most of the channels are unreliable. Spoiled hindrance image should recover quickly. The requirement is easy enough to meet the required number of independent frames in the stream. It also decreases the degree of compression, as on the screen with 2-3 (50-75 frames) can be the same image, but we will have to load the stream independent frames.

6. Time coding / decoding. In many systems (eg, video), the total delay for encoding - decoding transmission should not exceed 150 ms. Moreover, in applications where it is necessary to edit, normal line operation is not possible if the response time is longer than 1 second.

7. Editable. Under editable refers to the ability to change all the frames as easily as if they were recorded independently.

8. Scalability - simplicity of the concept of " video in the window." Need to quickly change the height and width of the image in pixels. Zooming is capable to generate unpleasant effects in the algorithms based on the discrete cosine transform. Correctly implement this feature for MPEG is presently possible, perhaps only for a sufficiently complex hardware implementations,

only scaling algorithms will not significantly increase the time of decoding. Interestingly, the scaling quite easily performed in the so-called fractal algorithms. They even exaggeration image several times, it does not break up the squares, i.e. no "grainy." If you want to reduce the image (which only rarely, but sometimes you need to), then the good job would be algorithms based on wavelet- transform.

9. Partly cost hardware implementation. When designing at least about to be assessed and taken into account the final cost. If this cost is high, even if the algorithm is used in international standards manufacturers will offer their own, more capable competitor of algorithms and solutions. In practice, this requirement means that algorithm must be implemented bit chipset.

2. Color spaces and their transformation

RGB. In the RGB color space color image pixels are represented by three numbers that indicate the relative ratio of red (Red), green (Green) and blue (Blue) colors (the three main components of visible light). RGB color space is well suited to capture and display color images. Colored electron beam tubes CRTs (Cathode Ray Tubes) and liquid crystal displays show the RGB image separately illuminating red, green and blue components of each pixel in accordance with frequency. Looking at the screen from a distance of ordinary viewer, the various components are merged into a single "right color". By this, the RGB color space is used in the computer technology, however, this approach is practically no possibility of efficient image compression, because to display properly, all three components must be provided with the same resolution. Next color space offers a way out of this situation.

YCbCr. It is known that the body of a person is less sensitive to color objects than to their brightness (luminance). In the RGB color space, all three colors are considered equally important, and they are usually stored with the same resolution. However, you can display a color image more effectively separating luminance and color information from presented higher resolution than color.

YCbCr color space and its variations (sometimes refer to YUV) are popular methods for efficient representation of color images. The letter Y represents a luminance component, which is calculated as a weighted averaging of the components R, G and B by the following formula

$$y = krR + kgG + kbB, \quad (3.1)$$

where *k* denotes the corresponding weighting factor.

Color information can be presented color difference components, ie Each of these components is a difference between the components *R, G* and *B* and the luminance component *Y.* Thus:

$$Cb = B - Y$$

$$Cr = R - Y \; (3.2)$$

$$Cg = G - Y$$

Thus, the color image is fully described luminance component *Y* and three chromatic components.

A reasonable question - to convert had three components make up the image - was four. However, knowing two of the three chromatic components can be easily cleaned. Fourth, since the sum of *Cb* + *Cr* + *Cg* is constant. Components *Cb* and *Cr* are to describe the image. Advantages of this method is to represent images that can not squeezing component luminosity *Y*, squeeze light components, presenting them with a lower resolution, which is carried out in the JPEG algorithm in the second stage of compression. Before you display a picture on the screen, it is required that to make a down conversion from YCbCr to RGB. Formulas for the direct and inverse transform as follows [19,42]:

$$Y = k_r R + (1 - k_b - k_r)G + k_b B$$

$$C_b = \frac{0.5}{1 - k_b}(B - Y)$$

$$C_r = \frac{0.5}{1-k_r}(R-Y) \tag{3.2}$$

$$R = Y + \frac{1-k_r}{0.5}C_r$$

$$G = Y - \frac{2k_b(1-k_b)}{1-k_b-k_r}C_b - \frac{2k_r(1-k_r)}{1-k_b-k_r}C_r$$

$$B = Y + \frac{1-k_b}{0.5}C_b$$

Recommendation ITU-T c identifier VT.601 offers coefficients k_b= 0.114 and k_r= = 0.229. With these coefficients, the following formulas:

Y_{601} = 0.299R' + 0.587G' + 0.114B'

Cb = –0.172R' – 0.339G' + 0.511B' + 128

Cr = 0.511R' – 0.428G' – 0.083B' + 128

These formulas are used to encode the eight bit RGB signal with a range of possible values from 16 to 235 which means 16 corresponds to a completely white, and 236 - completely black. This is done in order to improve the transmission of images and video sequences on transmission lines (television). For such values of the intervals from 0 to 15 and 237 to 256 contain noise when converting discarded, thereby improving the noise characteristics of the image. When it is used in computing the need for this eliminated, and the range of signal values is complete RBG - from 0 to 256. In this case, use the following conversion formula:

Y_{601} = 0.257R' + 0.504G' + 0.098B' + 16

Cb = –0.148R' – 0.291G' + 0.439B' + 128

Cr = 0.439R' – 0.368G' – 0.071B' + 128

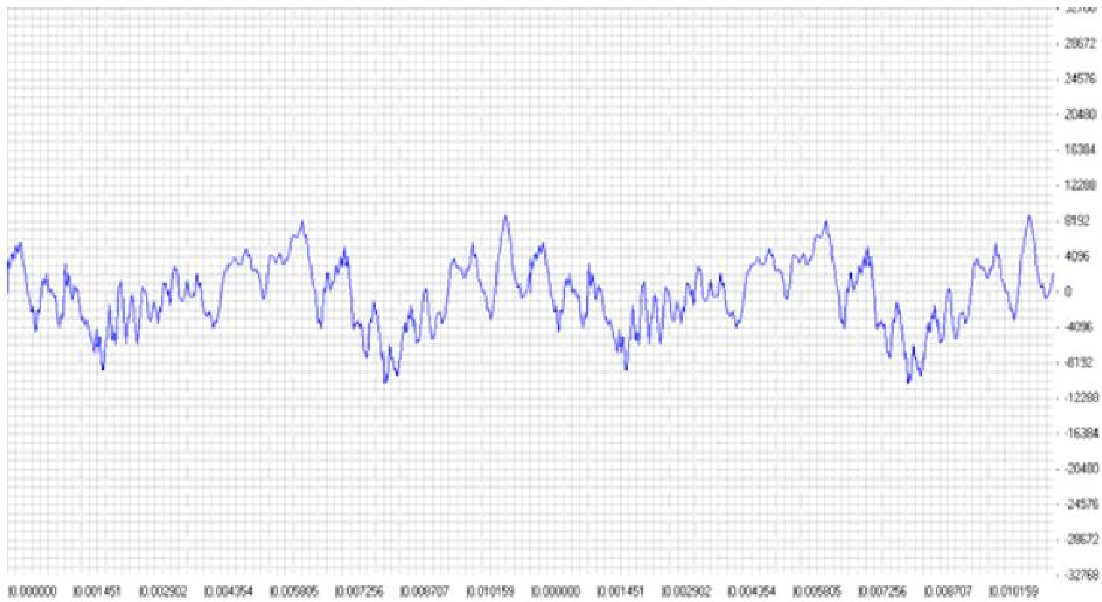


Fig.3. The form of the video sequences in the presence of white noise in the space YUV (using algorithm MPEG)

In this case, all white color - 0, all black - 256.

Examples of using this coding in broadcasting say "Superblack" and "superwhite" colors.

This option is called conversion YCbCr YCbCr: SDTV (Soft Definition Television). There is also another embodiment of the conversion. The recently broadcast standard HDTV (High Definition Television) uses several different formulas for the transition from RGB to YCbCr when RGB range is from 16 to 236:

$$Y_{709} = 0.213R' + 0.715G' + 0.072B'$$

$$Cb = -0.117R' - 0.394G' + 0.511B' + 128$$

$$Cr = 0.511R' - 0.464G' - 0.047B' + 128$$

and when the full range is from 0 to 256

$$Y_{709} = 0.183R' + 0.614G' + 0.062B' + 16$$

$$Cb = -0.101R' - 0.338G' + 0.439B' + 128$$

$$Cr = 0.439R' - 0.399G' - 0.040B' + 128$$

YUV, used standards PAL (Phase Alternation Line), NTSC (National Television System Committee) and SECAM (Sequential Color with Memory). YCbCr color space was developed as part of recommendations ITU-R BT.601 on the basis of this color space. Formulas for the transition from RGB to YUV are as follows:

1. $Y' = 0.299*R' + 0.587*G' + 0.114*B'$
2. $U = -0.147*R' - 0.289*G' + 0.436*B'$
3. $V = 0.615*R' - 0.515*G' - 0.100*B'$

3. Visualization algorithm for determining the quality of video sequences based on wavelet – transformation

In Fig.3. shows the variation in signal to noise ratio depending on the quality factor, which is used for generating a quantization matrix, and which control the degree of loss of control of the quality of the compressed images. In the Fig.4. displayed according to all analyzed in the study of color spaces.

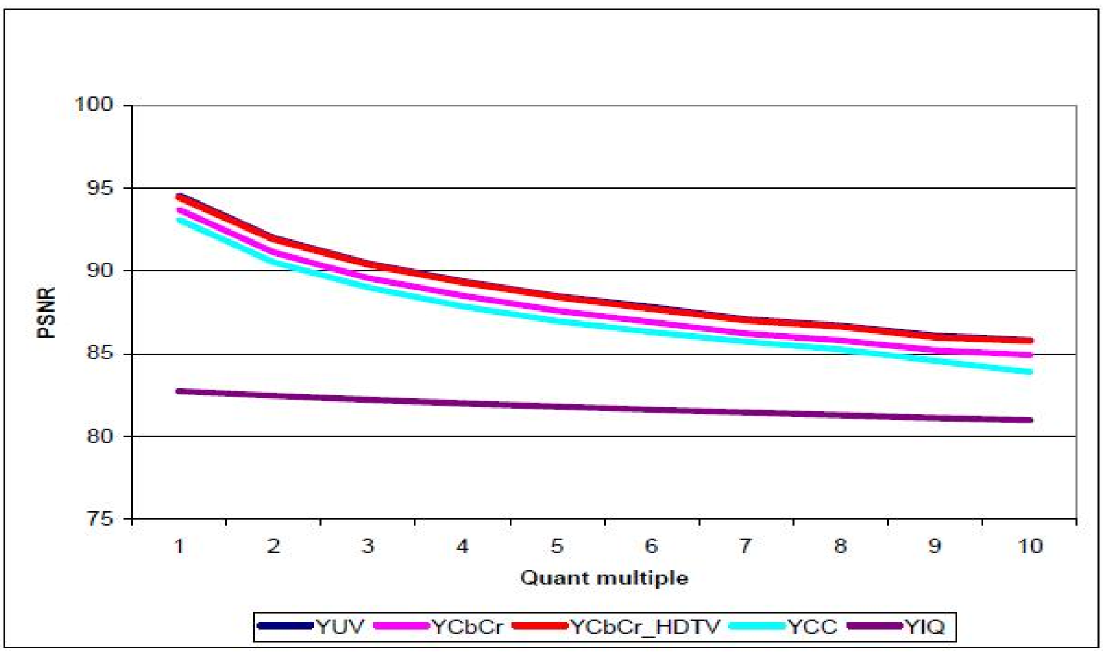


Fig.4. After filtration of the video compression based on wavelet (wavelet) and the method of transformation of Lucas-Canada (in different color spaces).

Using the method of moments, and Haar wavelets on the potential long straight wire can be estimated by the scalar product of these functions. As an illustration, Fig.4. represent the function with respect to a Haar sizes and two levels of resolution [46-48].

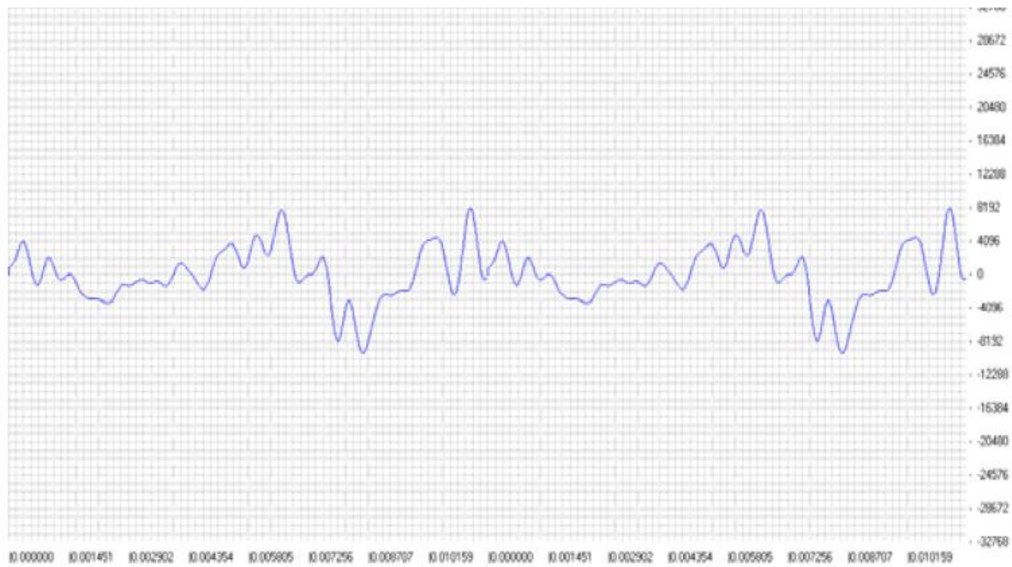


Fig.5. Form of the video sequences after using the algorithm Lucas-Canade.

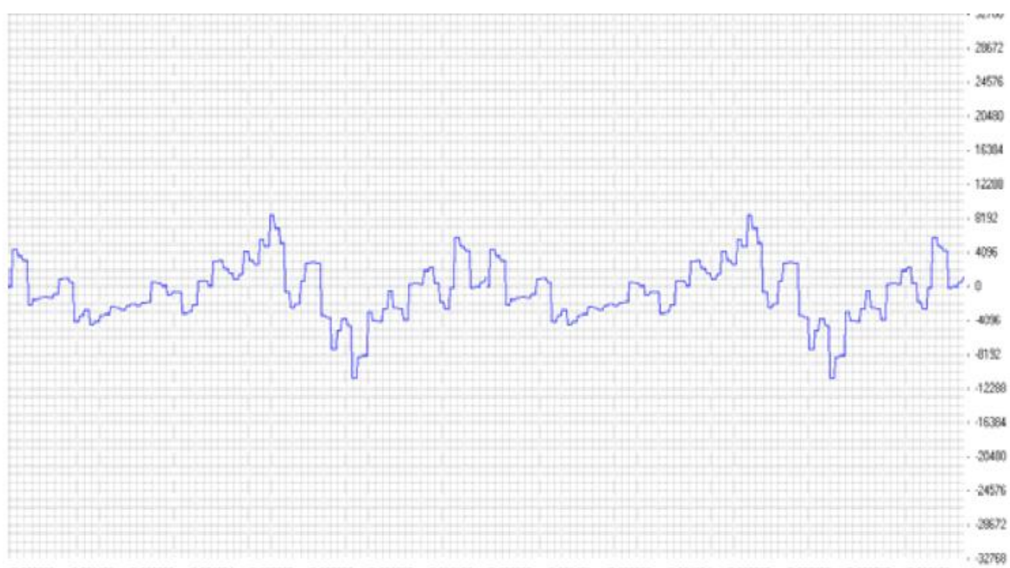


Fig.6. Form after decompression of the video by using the method based on wavelet transforms.

As can be seen from Fig.6. Output signal is more smooth and purified than the white noise. If you see this as a signal of the video, it will look like Fig.7. a) original image, b) used the compression method, and c) the method used on the basis of a wavelet transformation.

a)

b)

c)

Image 1. Image after using different compression methods.

Using Parallel display video in real time allows the conditions being close to the real television. When receiving the video image is converted by two pairs of the encoder and decoder, each with different parameters (Fig.1. Chapter 1).

Used when making comparisons of one or two close to the quality of the monitor (Image 1.). However, for more accurate results prior to the study of subjective evaluation to align video compares the location of the same images, then the results are determined by the normalization of the results of this study.

Only investigated the decoding operation, since, firstly, in most cases, restrictions on the number of operations available to the encoder, higher than at the recovery side of the video image, and secondly by encoding the major share operations, work spent on eliminating filter block artifacts significantly low. Therefore, optimization deblocking filter can significantly reduce the resource consumption of the decoder. On the other hand, it may affect the quality of the reconstructed image.

High-pass filter, built based on the algorithm of Lucas - Canada is an adaptive and more resistant to white noise. Before filtering, it shares borders blocks those that contain block artifacts and those who are the real image boundaries. In accordance with the results of the evaluation filter defines "border effect", ie the degree to which this boundary should be filtered. According to the analysis of resource stages of the codec in terms of the number of operations spent on the execution of each of the functions of the decoder, the definition of "border force" requires the most resources, as it requires a large number of test conditions. The task of determining the strength of the boundary can be simplified if we assume that for each face of the block "border force" unchangeable. In this case, the calculation can be carried out not for everyone, and every fourth pixel. This condition is fulfilled in most cases.

The comparison was performed between the compressed images, using standard and optimized filter (Image 1.).

Application of Haar wavelet showed the following values (Table 3.) and Fig.7.

Point	Haar Wavelet (Level)		
	2	3	4
1	8.835	9.376	9.957
2	8.835	9.376	8.764
3	8.835	8.376	8.411
4	8.835	8.274	8.219
5	7.970	8.274	8.102
….			
12	7.970	8.059	8.102
13	8.835	8.274	8.219
14	8.835	8.274	8.411
15	8.835	9.376	8.764
16	8.835	9.376	9.957

Table 3. Results of Haar wavelet.

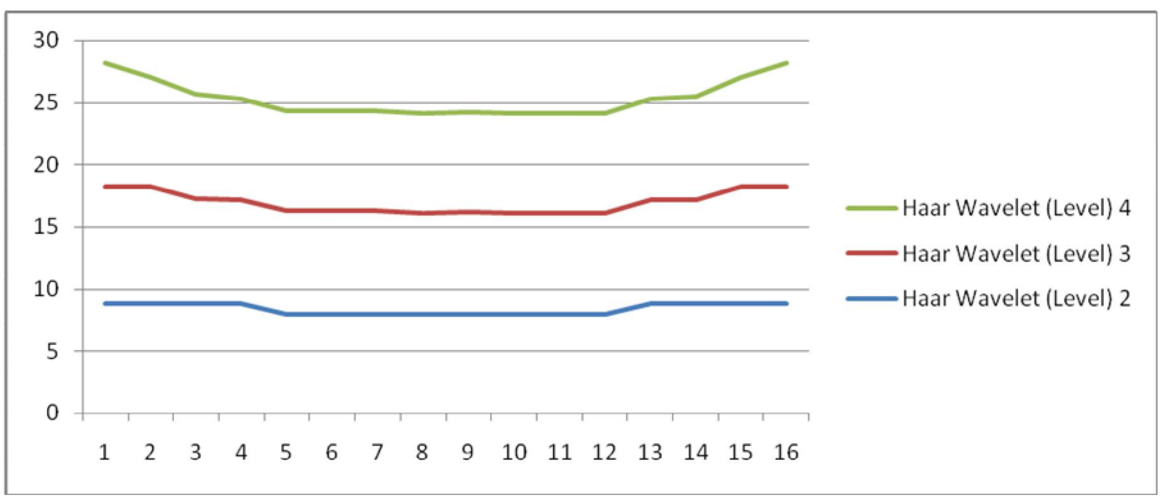


Fig.7. Results of Haar wavelet in different levels.

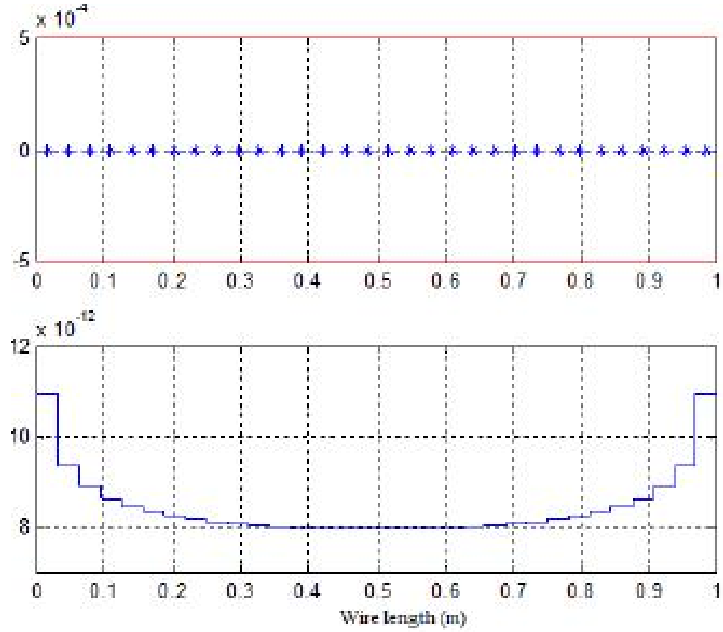
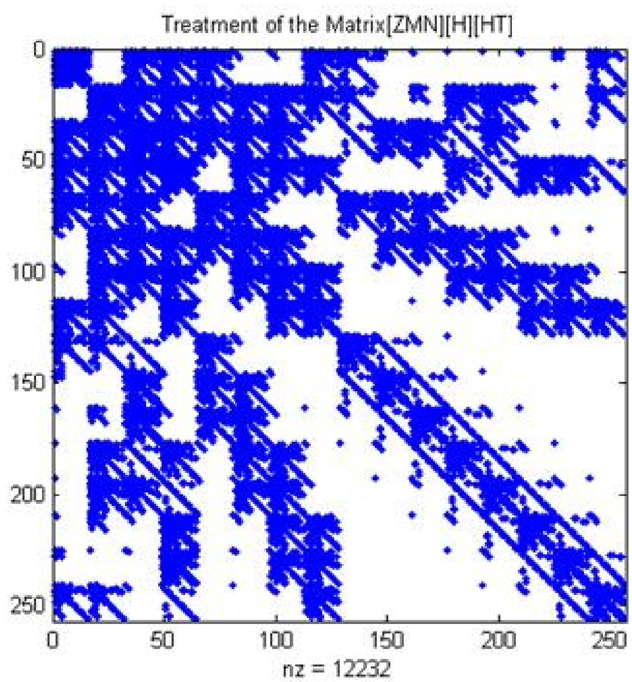
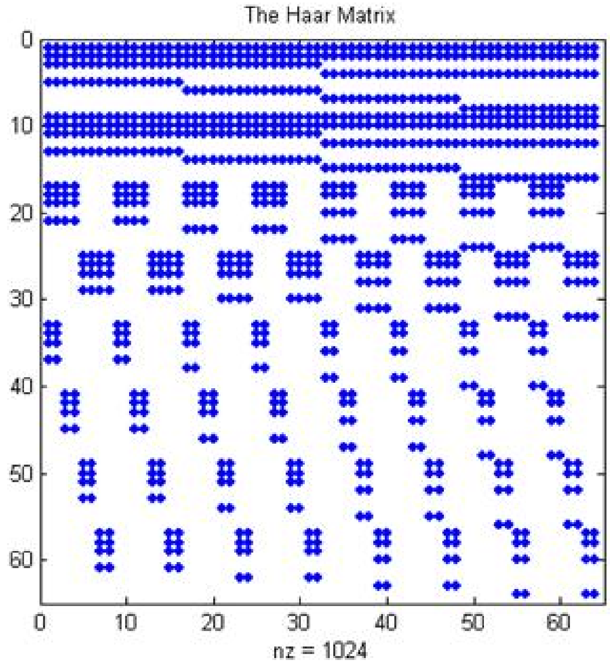


Fig.8. Video transmission over conductors.

Iteration steps use Haar wavelets and decoding of the video signal (Fig.8.)





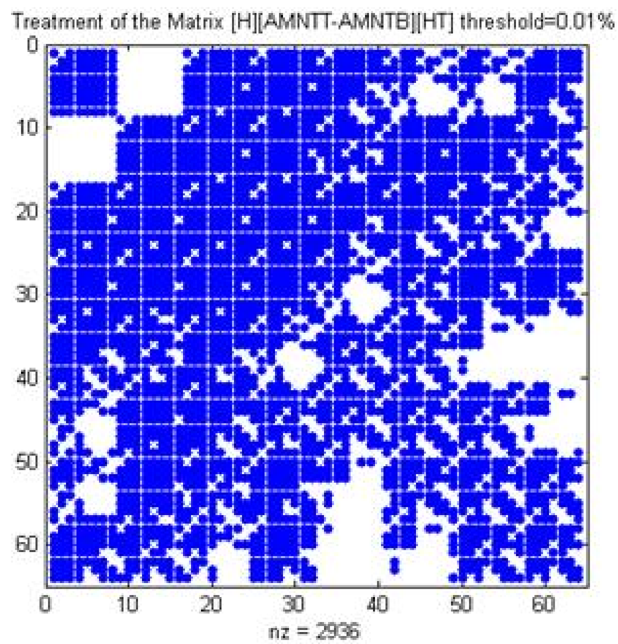


Fig.9. Image analysis using luminance histogram.

For image analysis of video sequences have been used the luminance histogram(Fig.9). Build histograms for color images for each channel and for grayscale images. Histogram - is a halftone image distribution graph in which the horizontal axis represents brightness, and the vertical relative-number of pixels with brightness value. (Histogram algorithm is given in the appendix)

Objective quality assessment was performed using reference methods " signal/noise ratio " and " structural similarity coefficient "(Fig.9). The first metric was chosen as the most common because of the ease of use. The second metric is used because it is the closest of the existing considers human visual system. Evaluation results using both metrics indicate that objective image quality (image change relative to the original) is not degraded when using the filter optimization. According to objective metrics, quality assessment, individual frames are of better quality after compression using the optimized filter than with a standard filter. The result of measuring the quality of frames of one of the sequences shown in Fig.11.

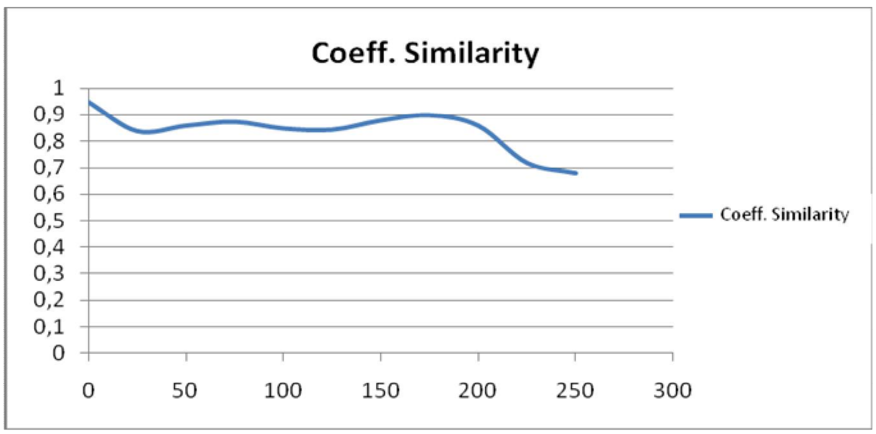


Fig.10. The coefficient of similarity, depending on the number of frames

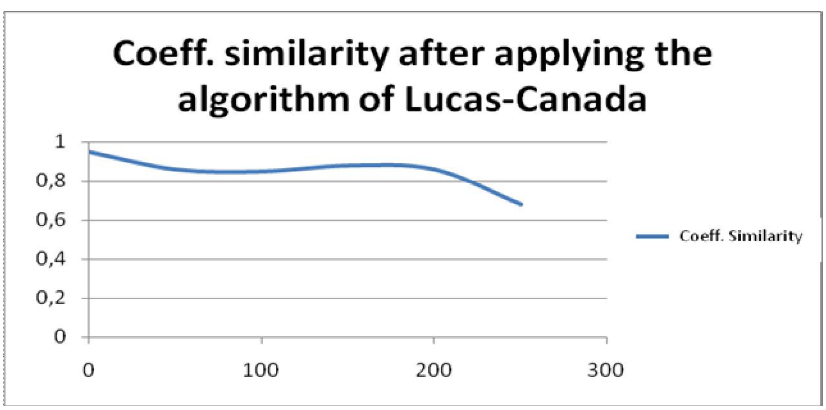


Fig.11. Evaluation of image quality due to the structural similarity algorithm after applying Lucas-Canada

In applying the algorithm optimized deblocking filter significantly reduces the time required to decode the video stream.

Summary of Chapter III

- The features of compression of video data;

- Diagrams of transition from one color space to another;

- Based on the algorithm of Lucas-Canada built using wavelet - transformation dependences showing the improvement of the quality of the decoded image

6- The time of decoding or deblocking reduced by optimizing based on wavelet transforms.

Conclusion

In this dissertation:

— An overview of the types of images;

— The analysis of existing video compression standards

— Compression methods studied video sequences;

— For differentiable bijective coordinate transformation used affine transformation;

— Based on the affine transformation and the method of Lucas-Canada describes the optical flow;

— Partial wavelet spectrum of a system of equations

$$\begin{bmatrix} V_x \\ V_y \end{bmatrix} = \begin{bmatrix} \sum_i W_x(q_i)^2 & \sum_i W_x(q_i)W_y(q_i) \\ \sum_i W_x(q_i)W_y(q_i) & \sum_i W_y(q_i)^2 \end{bmatrix}^{-1} \begin{bmatrix} -\sum_i W_x(q_i)W_t(q_i) \\ -\sum_i W_y(q_i)W_t(q_i) \end{bmatrix},$$

an optical flow of the video to the coordinates *x, y*, and time *t*, computed at point q*i* (*pixel*) (wherein $\mathbf{W}x(\mathbf{q}i)$,$\mathbf{W}y(\mathbf{q}i)$,$\mathbf{W}t(\mathbf{q}i)$ – partial derivatives of the wavelet spectrum image coordinates *x, y*, and time *t*, computed at point q*i*.)

— Above equations show that the analysis in the frequency domain provides advantages in assessing the noisy signal. To investigate the accuracy of estimating the parameters of geometric transformation studies were carried out on video sequences with noise. At each iteration, the test image was superimposed additive white Gaussian noise, with the ever increasing standard deviation

— The features video compression;

— Diagrams of transition from one color space to another;

— Based algorithm Lucas-Canada built using wavelet - transformation dependences showing the improvement of the quality of the decoded image;

─The time of decoding or deblocking reduced by optimizing based on wavelet transforms.

References

1. Гонсалес Р., Вудс Р. Цифровая обработка изображений.// Пер. с англ.- Москва.- Техносфера. – 2006. -1072 с.

2. Wang Z., Bovik A.C. Modern image quality assessment. – N.Y.: Morgan & Claypool, 2006. – 157 p.

3. Winkler S., *Digital Video Quality*. New York: Wiley and Sons, 2005.

4. Branden C.J., Costantini D.M., Sicuranza G.L., and Kunt M., "Quality assessment of motion rendition in video coding," *IEEE Trans. Pattern Anal. Mach. Intell.*, 1999. vol. 9, no. 5, pp. 766–782.

5. Wang Z, Lu L, and Bovik A.C, "Video quality assessment based on structural distortion measurement," *Signal Processing: Image Communication*, Feb. 2004. vol. 19, no. 2, p. 121–132.

6. Смирнов А. В. Основы цифрового телевидения: учебное пособие / Смирнов А. В.– М.: «Горячая линия – Телеком», 2001, 224 с.: ил.

7. Тропченко А.Ю., Курносенков И.Н. Анализ современных стандартов сжатия видеоданных// Научно-технический вестник СПбГУ ИТМО.-Вып. 32. - СПб. - СПбГУ ИТМО. – 2006. - с.17-21.

8. Снелл Родрик, Штейберг Виктор, Левков Максим "Контроль качества изображения и звука".2007. //Magazine 625.

9. Wang Z., Bovik A.C. Modern image quality assessment. – N.Y.: Morgan & Claypool, 2006.-157p.

10. Abdullaev D.A.,Varlamova L.P. Review of methods of assessing the quality of video sequences for multimedia applications.

11. Sheikh H.R. and Bovik A.C., "Image information and visual quality," *IEEE Trans. Image Process.*, 2006. vol. 15, no. 2, pp. 430–444.

12. Sheikh H.R., Bovik A.C., and G. de Veciana, “An information fidelity criterion for image quality assessment using natural scene statistics,” *IEEE Trans. Image Process.* , 2005. vol. 14, no. 12, pp. 2117–2128.

13. Sheikh H.R. and Bovik A.C.,, “An evaluation of recent full reference image quality assessment algorithms,” IEEE Trans. Image Process., November 2006. vol. 15, no. 11, pp. 3440–3451.

14. Bovik A., Sheikh H., Simoncelli E. Image Quality Assessment: From Error Visibility to Structural Similarity.// IEEE Transactions on image processing, 2004. vol. 13, no.4.

15. Graps A. An Introduction to Wavelets / Graps A. // IEEE Computational Sciences and Engineering. –1995. – Vol. 2, № 2. – P. 50–61.

16. Забровский А. Л. Критерий оценки качества образовательных мультимедийных потоков, транслируемых в реальном режиме времени // Труды Карельского научного центра РАН, 2013. Вып. 1. С. 26–32.

17. Лукьяница А.А. Цифровая обработка видеоизображений / Лукьяница А.А., Шишкин А.Г. –М.: Ай-Эс-Эс Пресс, 2009. – 518 с.

18. ITU-R Recommendation BT.500-11, Methodology for the subjective assessment of the quality of television pictures.// International Telecommunication Union, Geneva, Switzerland,2002.

19. Ватолин Д., Ратушняк А., Смирнов М., Юкин В. Методы сжатия данных. Устройство архиваторов, сжатие изображений и видео// -М. – Диалог-МИФИ. -2003. - 384 с.

20. Ричардсон Я. Видеокодирование H.264 и MPEG-4 – стандарты новогопоколения.// - М. – Техносфера. – 2005. - 368 с.

21. Сэломон Д. Сжатие данных, изображений и звука// – М. – Техносфера. -2004. – 368 с.

22. Тропченко А.А., Молчанов В.А. Особенности сжатия цветных изображений JPEG-подобными алгритмами// Научно-технический вестник СПбГУ ИТМО/ - Вып. 32. - СПб. - СПбГУ ИТМО. – 2006. -с.22-26.

23. Ватолин Д. Программный продукт оценки качества восстановленного изображения MSU Quality Measure [Электронный ресурс]. – режим доступа: http://compression.ru/video/quality_measure/video_measurement_tool.html. – 20.06.2009.

24. Брейсуэлл Р. Преобразование Хартли. Теория и приложения.// - М. - Мир, - 1990. – 192 с.

25. Room F. Steerable filters and the steerable pyramid [Электронный ресурс]. – режим доступа: http://www.filiprooms.be/research/steer/. – 16.05.2009.

26. Штойер Р. Многокритериальная оптимизация: теория, вычисления и приложения: пер. с англ. / под ред. Лотова А.В. – М.: Радио и связь, 1992. – 504 с.

27. Horn B.K. Determining optical flow / Horn B.K., Schunck B.G. // Artificial Intelligence. – 1981. –

28. Chandler D.M., Hemami S.S. VSNR: A Wavelet_Based Visual Signalto_Noise Ratio for Natural Images [Электронный ресурс]. –режим доступа: http://foulard.ece.cornell.edu/dmc27/vsnr/ vsnr.html. – 21.06.2009.

29. Блаттер К. Вейвлет-анализ. Основы теории.// – М. – Техносфера. - 2006, - 279 с.

30. Wang Z., Simoncelli E.P. Translation insensitive image similarity in complex wavelet domain // IEEE Inter. Conf. Acoustic, Speech and Signal Processing. – Philadelphia, 2005. – V. 2. – P. 673–676.

31. Сидоров Д.В. Тестирование метрик [Электронный ресурс]. –режим доступа: http://www.imq.tomsknet.ru/test.html. –21.06.2009.

32. Freeman W.T., Adelson E.H. The design and use of steerable filters// IEEE Trans. Pattern Analysis and Machine Intelligence. – 1991.– V. 13. – P. 891_906.

33. Room F. Steerable filters and the steerable pyramid [Электронный ресурс]. – режим доступа: http://www.filiprooms.be/research/steer/. – 16.05.2009.

34. Lucas B.D. An Iterative Image Registration Technique with an Application to Stereo Vision /

35. Lucas B.D., Kanade T. // Proceedings of the 7th international joint conference on Artificial intelligence. –1981. – Vol. 2. – P. 674–679.

36. Дьяконов В.П. Вейвлеты. От теории к практике. – М.: СОЛОН-Р, 2002. – 448 с.

37. Штойер Р. Многокритериальная оптимизация: теория, вычисления и приложения: пер. с англ. / под ред. А.В. Лотова. – М.:Радио и связь, 1992. – 504 с.

38. Ватолин Д.С. Алгоритмы сжатия изображений. Методическое пособие. Москва, Издательство МГУ. 1999, 82с.

39. Wallace G.K. 'The JPEG still picture compression standard' // Communication of ACM. Number 4 April 1991. Volume 34.

40. Smith B., Rowe L. 'Algorithm for manipulating compressed images.' // Computer Graphics and applications. September 1993.

41. Jacquin A. 'Fractal image coding based on a theory of iterated contractive image transformations' // Visual Comm. and Image Processing,1999. vol. SPIE-1360.

42. Pennebaker W.B., Mitchell J.L., Langdon G.G, Arps R.B., 'An overview of the basic principles of the Q-coder adaptive binary arithmetic coder' // IBM Journal of research and development, November 1988. Vol.32, No.6, pp. 771-726.

43. Huffman D.A. 'A method for the construction of minimum redundancy codes.' // Proc. of IRE val.40 1962 pp. 1098-1101.

44. Standardisation of Group 3 Facsimile apparatus for document transmission. CCITT Recommendations. Fascicle VII.2. T.4. 1980.

45. Ричардсон Я. Видеокодирование H.264 и MPEG-4 – стандарты нового поколения.// - М. – Техносфера. – 2005. - 368 с.

46. Сэломон Д. Сжатие данных, изображений и звука// – М. – Техносфера. -2004. – 368 с.

47. Тропченко А.Ю., Курносенков И.Н. Анализ современных стандартов сжатия видеоданных// Научно-технический вестник СПбГУ ИТМО.-Вып. 32. - СПб. - СПбГУ ИТМО. – 2006. - с.17-21.
48. Варламова Л.П., Абдуллаев Д.А. Разработка алгоритмов оценки качества видеорядов для мультимедиа-приложений. Тезисы докладов региональной научно-практической конференции молодых ученых и студентов города Ташкента и ташкентской области под девизом XXI век – век интеллектуального поколения, г.Ташкент, май 2014г., НУУз, том 4, стр 90-93.
49. Barron J.L. Performance of optical flow techniques / J.L. Barron, J.D. Fleet, S.S. Beauchemin // International Journal of Computer Vision. – 1994. – Vol. 12, № 1. – P. 43–77.
50. Singh A. Optic Flow Computation: A Unified Perspective // IEEE Computer Society Press. –1991. – P. 168–177.
51. Anandan P.A. Computational framework and an algorithm for the measurement of visual motion //International Journal of Computer Vision. – 1989. – Vol. 2. – P. 283–310.
52. Holliman M., Li E., Chen Y. MPEG Decoding Workload Characterization.// Proceedings of Workshop on Computer Architecture Evaluation Using Commercial Workloads, 2003.
53. Bovik A., Sheikh H., Simoncelli E. Image Quality Assessment: From Error Visibility to Structural Similarity.// IEEE Transactions on image processing, 2004. vol. 13, no.4.
54. ITU-R Recommendation BT.500-11, Methodology for the subjective assessment of the quality of television pictures.// International Telecommunication Union, Geneva, Switzerland, 2002.
55. Pinson M., Wolf S., Cermak G. HDTV Subjective Quality of H.264 vs. MPEG–2, with and without Packet Loss. // IEEE Transactions on Broadcasting, March, 2010.

Application

```
using System;
usingSystem.Collections.Generic;
usingSystem.ComponentModel;
usingSystem.Data;
usingSystem.Drawing;
usingSystem.Linq;
usingSystem.Text;
usingSystem.Threading.Tasks;
usingSystem.Windows.Forms;
namespace ZKRD
{
public partial class Form1: Form
    {
public Form1()
        {
InitializeComponent();
        }

double [,] u = new double [101, 101];
double [,] v = new double [101, 101];

double [,] u1 = new double [101, 101];
double [,] u2 = new double [101, 101];
double [,] v2 = new double [101, 101];

double [] y= new double [101];
```

```
double [] y1 = new double [101];
double [] y2 = new double [101];

double [] alf = new double [101];
double [] bet = new double [101];
double a, b, h, tau, p, n, m, k, l, q, t, gamma1, gamma2, beta, xmax;
int j, d, s, nn,i;
intnmax = 50;
public double uxy(double xx, double tt)
    {
double res = Math.Pow(t + tt, -gamma1);
double a1 = xx*Math.Pow(t + tt, -0.5);
      a1 = Math.Pow(Math.E, -a1 * a1 / 4);
res = res * a1;
return res;
    }
public double vxy(double xx, double tt)
    {
double res = Math.Pow(t + tt, -gamma2);
double a1 = xx * Math.Pow(t + tt, -0.5);
      a1 = Math.Pow(Math.E, -a1 * a1 / 4);
res = res * a1;
return res;
    }
public double fiu(int ii)
    {
double res = tau * Math.Pow(v [i-1,ii], p)+y [ii];
return res;
    }
```

```
public double ai(int ii)
        {
double res;
res = tau/(h*h);
return res;
        }
public double bi(int ii)
        {
double res;
res = tau / (h * h);
return res;
        }
public double ci(int ii)
        {
double res = ai(ii) + bi(ii) + 1;
return res;
        }

public double fiv(int ii)
        {
double res = tau * Math.Pow(u [i-1,ii], q) + y [ii];
return res;
        }

private void button1_Click(object sender, EventArgs e)
        {
            t = Convert.ToDouble(textBox2.Text);
            p = Convert.ToDouble(textBox3.Text);
            q = Convert.ToDouble(textBox8.Text);
            a = 10;
```

```
            gamma1 = (p + 1) / (q * p - 1);
            gamma2 = (q + 1) / (q * p - 1);

            h = a / nmax;
tau = t / nmax;
for (i = 0; i < nmax+1; i++)
            {
u [0, i] = uxy(i*h, 0);
            }
for (i = 0; i < nmax+1; i++)
            {
u [i, 0] = uxy(0, i*tau);
            }
for (i = 0; i < nmax+1; i++)
            {
u [i, nmax] = uxy(nmax * h, i*tau);
            }
for (i = 0; i <nmax + 1; i++)
            {
v [0, i] = vxy(i * h, 0);
            }
for (i = 0; i <nmax + 1; i++)
            {
v [i, 0] = vxy(0, i * tau);
            }
for (i = 0; i <nmax + 1; i++)
            {
v [i, nmax] = vxy(nmax * h, i * tau);
            }
booltr;
```

```
for (i = 1; i < nmax+1; i++)
        {
tr = true;
int it = 0;

for (int j1 = 0; j1 <nmax + 1; j1++)
           {
y [j1] = uxy(j1 * h, i * tau);
           }
while (tr==true)
           {
it = it + 1;
y2 [0] = u [i,0];
y2 [nmax] = u [i,nmax];

              //alf [0] = bi(0)/ci(0);
              //bet [0] = u [i,0]/ci(0);

alf [0] = 0;
bet [0] = y [0];

for (int j1 = 0; j1 <nmax; j1++)
              {
alf [j1 + 1] = bi(j1) / (ci(j1) - ai(j1) * alf [j1]);
              }
for (int j1 = 0; j1 <nmax; j1++)
              {
bet [j1 + 1] = (ai(j1)*bet [j1]+fiu(j1)) / (ci(j1) - ai(j1) * alf [j1]);
              }
for (int j1= nmax-1; j1 > 0; j1--)
```

```
{
y2 [j1] = alf [j1 + 1] * y2 [j1 + 1] + bet [j1 + 1];
}
tr = false;
for (int j1 = 0; j1 < nmax+1; j1++)
{
if (Math.Abs(y2 [j1] - y [j1]) >= 0.001) tr = true;
}
for (int j1 = 0; j1 < nmax+1; j1++)
{
y [j1] = y2 [j1];
}
}
for (int j1 = 1; j1 <nmax; j1++)
{
u [i, j1] = y2 [j1];
}
for (int j1 = 0; j1 <nmax + 1; j1++)
{
y [j1] = vxy(j1 * h, i * tau);
}
tr = true;

while (tr == true)
{
it = it + 1;
y2 [0] = v [i, 0];
y2 [nmax] = v [i, nmax];

//alf [0] = bi(0)/ci(0);
```

```
        //bet [0] = u [i,0]/ci(0);

alf [0] = 0;
bet [0] = y [0];

for (int j1 = 0; j1 <nmax; j1++)
        {
alf [j1 + 1] = bi(j1) / (ci(j1) - ai(j1) * alf [j1]);
        }
for (int j1 = 0; j1 <nmax; j1++)
        {
bet [j1 + 1] = (ai(j1) * bet [j1] + fiv(j1)) / (ci(j1) - ai(j1) * alf [j1]);
        }
for (int j1 = nmax - 1; j1 >= 0; j1--)
        {
y2 [j1] = alf [j1 + 1] * y2 [j1 + 1] + bet [j1 + 1];
        }
tr = false;
for (int j1 = 0; j1 <nmax + 1; j1++)
        {
if (Math.Abs(y2 [j1] - y [j1]) >= 0.001) tr = true;
        }
for (int j1 = 0; j1 <nmax + 1; j1++)
        {
y [j1] = y2 [j1];
        }
      }
for (int j1 = 1; j1 <nmax; j1++)
      {
v [i, j1] = y2 [j1];
```

```
            }
          }
for (i = 0; i < nmax+1; i++)
          {
for (j = 0; j <nmax + 1; j++)
u1 [i, j] = uxy(j * h, i * tau);
              }
for (i = 0; i < nmax+1; i++)
         {
for (j = 0; j < nmax+1; j++)
             {
u2 [i, j] = u [i, nmax - j];
u2 [i, j + nmax] = u [i, j];
             }
                }
for (i = 0; i <nmax + 1; i++)
      {
for (j = 0; j <nmax + 1; j++)
            {
v2 [i, j] = v [i, nmax - j];
v2 [i, j + nmax] = v [i, j];
             }
          }
       }
private void button2_Click(object sender, EventArgs e)
       {
          j = -1; d = -1;
          timer1.Enabled = true;
       }
private void timer1_Tick(object sender, EventArgs e)
```

```
        {
            j = j + 1; d = d + 1;
if (j >= nmax) timer1.Enabled = false;

chart1.Series [0].Points.Clear();
chart2.Series [0].Points.Clear();

for (i = 0; i < 2*nmax+1; i++)
            {
chart2.Series [0].Points.AddXY(-nmax*h+i * h, u2 [j, i]);
            }
for (i = 0; i < 2*nmax + 1; i++)
            {
chart1.Series [0].Points.AddXY(-nmax * h + i * h, v2 [j, i]);
            }
        }
private void button3_Click(object sender, EventArgs e)
        {
axOpenGL1.RemoveSurfaces();
axOpenGL1.AddSurface(u2);
axOpenGL2.RemoveSurfaces();
axOpenGL2.AddSurface(v2);
}
    }
}
```

An algorithm for constructing histograms

Строим массив, заполняем нулями. Обычно массив [0..255]

Цикл, для каждого пикселя:

Выделяем нужный цветовой канал или находим яркость по формуле. Пиксель -> значение

Полученное значение должно укладываться в диапазон индексов массива, например [0..255].

Увеличиваем значение элемента массив[значение] на 1.

Конец цикла.

Полученный массив и представляет собой гистограмму, элементы массива - означают высоты столбиков.