Method for Improving the Efficiency of Online communication Systems Based on Adaptive Multi-scale Transformation

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***Abstract*—The article considers the issues of the development of multi-scale analysis taking into account a spline as the basic function. The algorithm of image data compression with the adaptive calculation of the detailing coefficients is proposed. The estimation of its advantages and prospects of use was conducted.**

***Keywords*— spline, adaptive multi-scale spline transformation, image compression.**

I. INTRODUCTION

Development of modern society is characterized by such tendencies as globalization and informatization intensification, which leads to extension and simplification of international links and contacts. Expansion of the global Internet provides all services for international communication – from traditional correspondence to voice and video communication [8].

Total computerization of the world and the pursuit of new capabilities among developers, update and launch of new software products, attempts to make software compatible to the maximum with other computer tools and programs, other industrial and technical advance novelties and inventions introduce new items to the market almost daily, which should be described and translated into as many languages as possible to reach the end user and increase sales [8].

If we use the Internet, then we often use Internet-based communications to contact family, friends or co-workers. From sending an instant message to a friend, as well as to e-mailing with co-workers, and also to placing phone calls, to conducting video conferences, the Internet offers a number of ways to communicate.

Like all technologies (and especially technology tied to the Internet), the way we can communicate online is constantly evolving. In recent years, videoconferencing has become a popular form of distance communication in classes, allowing on a cost efficient way to provide distance learning, guest speakers, and multi-school collaboration projects. Videoconferencing provides a visual connection and interaction that can not be achieved with standard e-mail communications.

The online communication system is an environment that enables a network of co-workers to conduct meetings efficiently by using nothing other than online communication technologies. This system will bring geographically dispersed employees in different locations virtually together into the same workspace, thereby supercharging teamwork and cooperation between previously isolated resources through online sharing.

In signal processing, data compression, source coding, or bit-rate reduction is the process of encoding information using fewer bits than the original representation. Any particular compression is either lossy or lossless. Lossless compression reduces bits by identifying and eliminating statistical redundancy. No information is lost in lossless compression. Lossy compression reduces bits by removing unnecessary or less important information. Typically, a device that performs data compression is referred to as an encoder, and one that performs the reversal of the process (decompression) as a decoder.

The process of reducing the size of a data file is often referred to as data compression. In the context of data transmission, it is called source coding; encoding done at the source of the data before it is stored or transmitted. Source coding should not be confused with channel coding, for error detection and correction or line coding, the means for mapping data onto a signal.

Compression is useful because it reduces resources required to store and transmit data. Computational resources are consumed in the compression and decompression processes. Data compression is subject to a space–time complexity trade-off. For instance, a compression scheme for video may require expensive hardware for the video to be decompressed fast enough to be viewed as it is being decompressed, and the option to decompress the video in full before watching it may be inconvenient or require additional storage. The design of data compression schemes involves trade-offs among various factors, including the degree of compression, the amount of distortion introduced (when using lossy data compression), and the computational resources required to compress and decompress the data.

Presentation of Basic Material of the Research

The online communication system like Skype, Viber, Telegram and others are telecommunication applications that specialize in providing video chat and voice calls between computers, tablets, mobile devices, the Xbox One console, and smartwatches via the Internet. They allow users to communicate over the Internet by voice, using a microphone, by video using a webcam, and by instant messaging. Users may transmit text, video, audio and images.

Photos and videos are converted to a supported format on the client side before they are sent to the server.

An important image compression technique is the discrete cosine transform (DCT), a technique developed in the early 1970s. DCT is the basis for JPEG, a lossy compression format which was introduced by the Joint Photographic Experts Group (JPEG) in 1992. JPEG greatly reduces the amount of data required to represent an image at the cost of a relatively small reduction in image quality and has become the most widely used image file format. Its highly efficient DCT-based compression algorithm was largely responsible for the wide proliferation of digital images and digital photos.

Lempel–Ziv–Welch (LZW) is a lossless compression algorithm developed in 1984. It is used in the GIF format, introduced in 1987. DEFLATE, which is a lossless compression algorithm specified in 1996, is used in the Portable Network Graphics (PNG) format.

Wavelet compression, the use of wavelets in image compression, began after the development of DCT coding. The JPEG 2000 standard was introduced in 2000. In contrast to the DCT algorithm used by the original JPEG format, JPEG 2000 instead uses discrete wavelet transform (DWT) algorithms. JPEG 2000 technology, which includes the Motion JPEG 2000 extension, was selected as the video coding standard for digital cinema in 2004.

Since 1997, the work for creating a universal coding system which would remove all the restrictions imposed by JPEG has begun. It is also assumed a universal coding system could work effectively with all types of images: either black and white, grayscale, full color and multi-component, regardless of content (whether it will be photographs, rather small text or even drawings). Along with international standardizing organizations, such industry giants as Agfa, Canon, Fujifilm, Hewlett-Packard, Kodak, LuraTech, Motorola, Ricoh, Sony and others took part in its development.

Since the new algorithm claimed to be universal, it was additionally tasked with using various data transmission methods (in real time and with a narrow bandwidth), which is especially critical in multimedia applications, for example, in real-time broadcasts via the Internet.

Basic requirements for JPEG2000 format:

- The achievement of increased compression compared with JPEG.
- The support for monochrome images, which will allow it to be used to compress images with text.
- The ability to compress without any loss.
- The output images with a gradual improvement in detail (as in progressive GIF).
- The use of priority areas in the image for which the quality can be set higher than in the rest image.
- Real-time decoding (without delay).

Skype 4.0 uses a Skype-created audio codec called SILK, intended to be "lightweight and embeddable". Additionally, Skype has released Opus as an open-source codec, which integrates the SILK codec principles for voice transmission with the CELT codec principles for higher-quality audio transmissions, such as live music performances. Video codec VP7 is used for versions prior to Skype 5.5. As to the version 7.0, H.264, it is used for both group and one-on-one video chat, at standard definition, 720p and 1080p high-definition.

Telegram messenger also uses codecs. The X and Y dimensions of photo must not exceed **1280** each, and the photos must be compressed to JPEG with **0.87** compression ratio. Video dimensions must be set to **480x320** (320x480 for vertical videos), so H.264 and MPEG-4 are used as the codecs and containers.

The graphics compression is necessarily used for modern popular photo and video standards MPEG4, DivX 5.x, JPEG, JPEG2000. The main procedure in the process of lossy compression is the discrete cosine transform in the JPEG algorithm, or the wavelet transform in JPEG2000. Wavelet signal processing provides the ability to quite efficiently signals and data compression, their backing up with low quality loss, as well as signal filtering problems solving.

Thus, JPEG2000 objectively shows better results than JPEG only at high compression rates. There is not much difference in case of 10-20 times compressing. Can it crowd out or provide keen and tough competition with a widespread format? It is unlikely in the near future. In most cases, the quality / size ratio provided by JPEG is quite acceptable. And those 10-20% of additional compression that JPEG2000 gives with visually the same quality are unlikely to increase its popularity.

But the manufacturers of digital cameras are showing keen interest in the new format. Since the sizes of light-sensitive matrices are steadily increasing year by year, and it becomes more and more difficult to place images in memory. And then the new format will become more widespread, and who knows, maybe in some time JPEG2000 will become equal to JPEG. In any case, Analog Micro Devices has recently released a specialized chip in which compression / decompression using the new technology is implemented at the hardware level. At that time the US Department of Defense is already actively using the new format for recording photographs received from spy satellites.

The multiscale analysis within Wavelet transform and pyramid signal decomposition usage is the subject of the literature [1, 2, 3, 4, 5], which deals with image data compression technique. The article proposes to use spline multiscale transformation.

One of the main and brainwave of wavelet signal notation at different levels of decomposition consists of approximation to the signal layering into two groups: approximate one, which is structurally stable and is characterized by low-speed temporary time history, and the second, detail one, which is characterized by local and fast time history against the background of smooth history, with its subsequent mutilation and particularization at another levels of signal decomposition (analysis of multiple scales or multiscale analysis).

II. SPLINE MULTISCALE ANALYSIS

Theoretical framework of multiscale wavelet analysis constructing offers means for making use of configuration of pyramid signal notation for spline analysis also.

A composition of multiscale analysis (MA) and spline-functions, which are used for digital information recovery is supposed as a promising direction. In certain situations splines are characterized by better approximate characteristics, which provide with minimum error due to assigned dimensionality. In case of their use the volume of calculations is tangibly reduced. G. Alberg, E. Nilson, S.B. Stechkin, Yu. Subbotin, Yu.S. Zavialov, B.I. Kvasov, M.P. Korniychuk and others made a great contribution to spline theory investigation.

So far as splines are piecewise polynomial functions, they can be easily used in the calculation of the number of holes. In fact, the algorithms for graphically representing curves using splines and for calculating their polynomial components are particularly adequate [2]. Moreover, as far as splines are characterized by the least possible support, the local interpolation schemes for function approximations in $C \cap L^2(\mathbf{R})$ using any spline subspace may be used.

Consider the procedure for building a spline. Let on the line segment $[a,b]$ in the points $X = \{x_i\}_{i=1}^{N}$ the values $Y = \{y_i\}_{i=1}^{N}$ of some smooth function are given (Fig.1). You need to find a grid $\Delta_r = \{\tilde{x}_j\}_{j=0}^{r}$ $(r < N)$, where you can build a spline $S(x) \in C_{[a,b]}^{k}, k = 1,2,\ldots$, that has continuous derivatives up to *k*th order (including). According to the formulation of the problem, the grids Δ_N i Δ_r does not coincide, that is, on each section of the grid Δ_r there may be several points, which will determine the behavior of the desired dependency.

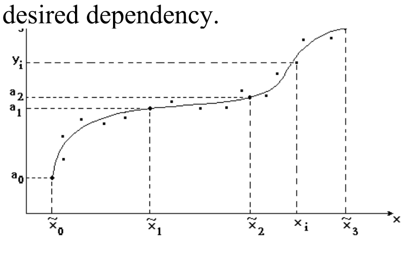


Fig. 1. The smooth function example

The ordinates value of «gluing» points of spline elements (elements of the matrix $\hat{A}$) will be found by the formula: $\hat{a}_i = \sum_{j=0}^{r} C_{ij}^{-1} b_j$, $i = \overline{0,r}$.

The value of the Hermitian cubic spline at an arbitrary point $x \in [\tilde{x}_{j-1}, \tilde{x}_j]$, $j = \overline{1,r}$, is calculated due to the formula:

$$S_3(x_i) = \hat{a}_{j-2}\,{}^1X_{ij} + \hat{a}_{j-1}\,{}^2X_{ij} + \hat{a}_j\,{}^3X_{ij} + \hat{a}_{j+1}\,{}^4X_{ij}, \qquad (1)$$

$i = \overline{1+m_{j-1}, m_j}$, $j = \overline{1,r}$, $a_{-1} = a_{r+1} = 0$.

The accuracy of approximation of the desired quantity correspondence with the help of the chosen spline is based on the least value of the sum of the residuals squares of points ordinates observation from function found.

$$d = \sum_{j=1}^{r} \sum_{i=1+m_{j-1}}^{m_j} \left[y_i - S_3(x_i)\right]^2$$

This method was described in the literature in more detail [6, 7].

Let us consider spline multiscale decomposition method.

Let given data is represented by *N* sampling. The assumed function *f (t)* (Fig. 2) will be determined by the formulas (1) with the help of spline approximation.

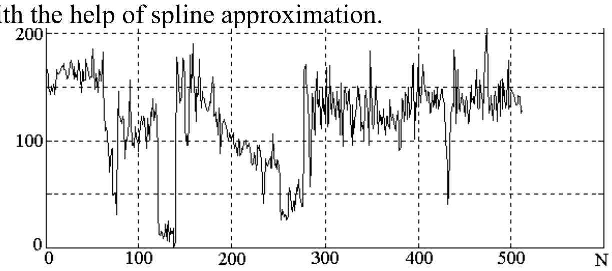
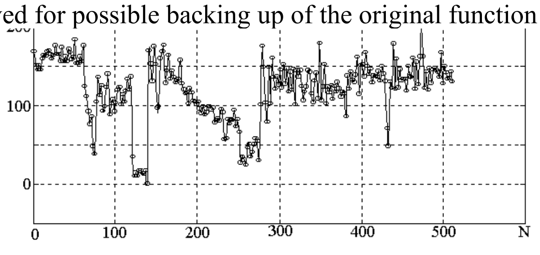


Fig.2. Signal processed.

At the beginning let`s consider the example of spline decomposition with multiplicity 2. The first step will be "gluing" knots of spline decimation twice, i.e. there will be $N/2$ knots. The approximation of function values in such $N/2$ knots will represent the similar function, but, with some errors, of course. In order to save the information about measure of inaccuracy, we should find the difference between the values of the initial and new functions in *N* knots. Some of these differences will be small enough to be neglected. In other words, you need to set a threshold below which the values of the differences are taken equal to zero. The number of significant (i.e., nonzero) detailing coefficients of the first level is denoted as $\det_1$. Then the result of the first step of decimation will be $N/2 + \det_1$ of the values, which must be saved for possible backing up of the original function (Fig.3).



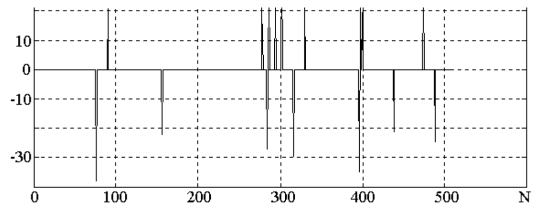


Fig.3. Spline approximation of the signal and detail coefficients after the first step.

The second step. Once again the "gluing" knots of the spline obtained after the first step are similarly decimated. Then instead of $N/2$ values there will be $N/4+\det_2$. After the second step, there will be $N/4+\det_2+\det_1$ coefficients for saving (Fig.4).

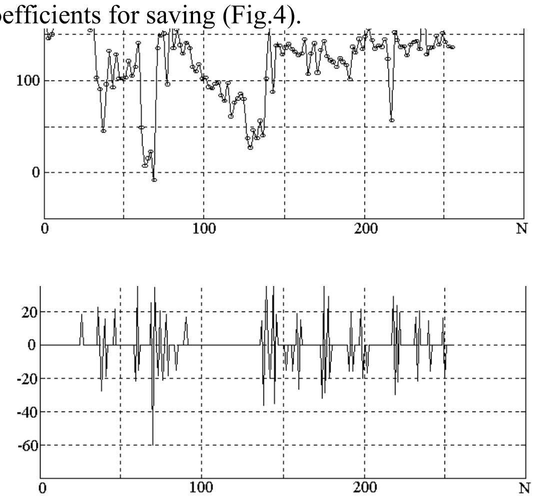
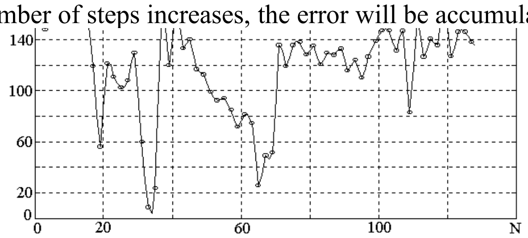


Fig.4. Spline approximation of the signal and detail coefficients after the second step.

It is easy to observe that, similarly to the above algorithm, one can construct an algorithm with a different multiplicity. The big advantage is that such procedure allows you to change the multiplicity from one step to another (for example, you can reduce the multiplicity at each step).

Accordingly, the third step will give us $N/8+\det_3+\det_2+\det_1$ values (Fig.5). After any step, we can immediately reestablish the original data. Of course, if the number of steps increases, the error will be accumulated.



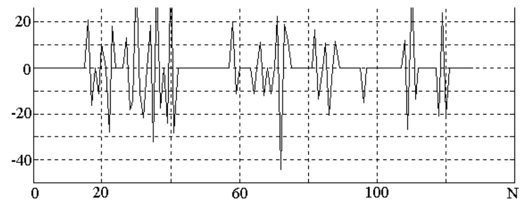


Fig.5. Spline signal approximation and detail coefficients after the third step.

III. The adaptive compression Method

Let us consider the adaptive compression method. Let the initial data be represented by *N* discrete samples. Using the spline approximation by formulas (1), we can find the initial function. The adaptive compression algorithm contains the following steps:

1. Thinning of "gluing" knots of a spline twice, that's why we will get $N/2$ knots. We will carry out this manipulation for all *n* lines

2. Repeat this procedure for all *n* columns. In other words, the number of matrix elements decreases from N^2 till $N^2/4$. The spline is constructed in such way that the sum of the squared deviations of the spline from the approximated points would be minimal.

3. Again, the data obtained after the first step is thinned out similarly. Now, instead of $N^2/4$ values, we will obtain $N^2/16$ coefficients.

4. Accordingly, the third step will give us $N^2/64$ values.

5. Then we will restore the matrix of the second level ($N^2/16$ coefficients) by interpolating of $N^2/64$ elements. To save the information, we should find the differences between the values of the compressed and reconstructed matrices. A significant part of such differences will be small enough to be neglected.

6. A threshold below which the value of the differences is taken equal to zero should be set. The number of significant (i.e., nonzero) detailing coefficients of the first level will be denoted as $\det_3$.

7. Then we calculate the matrix of the first compression level, using interpolation of $N^2/16$ values. It will differ from the matrix obtained by compression in the second step. This is due to the errors introduced by zeroing the small coefficients $\det_3$. Then they are transferred to the values of the coefficients in the spline gluing nodes and to the reestablished data after the interpolation.

8. After that we find the difference in the values of the matrices found in Sec. 2 and reestablished at each of $N^2/4$ points. They will be the values of the detailed coefficients, taking into account the error correction, which we will denote as $\det_{2k}$.

9. We should set the initial signal, using spline interpolation of $N^2/4$ values of the matrix reestablished in Sec. 7.

10. Similarly to Sec. 8, we will calculate the corrected coefficients of detail in $N \times N$ points, we denote them as det_{1k}.

11. The values of the function in the spline gluing nodes $N^2/64$ detailing the coefficients det_3 and adapted to this function det_{2k} и det_{1k}: $N^2/64 + \det_3 + \det_{2k} + \det_{1k}$ are remained for saving. The total number of values, which will be saved in the memory: $\frac{N^2}{64} + \frac{N^2}{16} + \frac{N^2}{4} + N^2$. But since the most of the detailing coefficients are equal to zero, in fact, saving of the weighty data requires less memory.

In order to restore the signal, you need to save the gluing knots of the last transformation layer and non-zero samples of the detailed coefficients.

The correction of detailed coefficients in Sec. 8 and 10 allows you to "tune" them for a specific example of a function (or discrete data) in order to minimize the error, i.e. the algorithm is adapted to a specific example. Therefore, this compression is called "adaptive."

IV. Comparative Analysis

Let us compare the obtained method with the photo codec JPEG2000. The Figure 6 shows the original photo of 1.8 MB in size.

The Figure 7 shows the image restored after compression by the photo codec JPEG2000 up to 90 kB (PSNR = 40 dB). The Figure 8 shows the image recovered after compression by the new method up to 64 kB (the quality indicator is the same).

Fig.6. An example of a color digital image.

Fig.7. Image restored after compression by cubic Hermitian splines and calculating detail coefficients.

Fig.8. Image restored after compression by cubic Hermitian splines with a "wish on" link between the knots where "gluing" these splines and calculating the detail coefficients.

V. Conclusions

The article sets out the task of developing an adaptive two-dimensional spline multiscale transformation, which is used to compress the difference and brightness components of a colour image. This approach allows you to vary the algorithm over a wide range by selecting its parameters for each type of signal so that the result would be the best.

In addition, while using splines, the amount of calculations is significantly reduced. After all, they are the simple functions with a small medium, which are the most effective both for their software and hardware implementation.

The graphic data compression algorithms based on the developed spline multiscale analysis with adaptive calculation of detailed coefficients make it possible to improve the quality of the reestablished images or to increase the compression ratio with the same quality up to 40%.

In addition, a comparative analysis showed that the proposed algorithm need the less time of the main decompression operation, compared with the fastest JPEG technology today, so it can be successfully used for online photo, video information on-line transmission systems.

Finally, this development will have a positive effect in various application areas, such as: medicine, education, linguistics, legal proceedings, etc.

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