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Design of Virtual Microscope System using Wavelet Transform

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Abstract— *The Virtual Microscope System is being implemented by a computer software system that performs highly realistic digital simulations of an analog, mechanical light microscope; the system aims to provide high-resolution digital images of a patient's tissue sample on the Internet. The main difficulty in providing that function consists in the efficiency of dealing with the extremely large quantities of data required for a large collection of slides. The Virtual Microscope software system is to simply emulate the usual behavior of a physical microscope, replacing cabinets full of slides of medical institutions with a digital storage system. This paper proposes an effective variable-block-based image compression technique using wavelet transform. To compress the wavelet transformed data, the proposed algorithm quantizes the wavelet coefficients using scalar quantizer for LL sub-band and vector quantizer for other sus-bands to increase the compression ratio and then uses arithmetic coding for entropy coding. The proposed system is a distributed system consisting of 3 parts: a client/user interface, which allows a user to view slides over a network, a data server, which retrieves the slide image data, and a network server, which allows the other two parts to communicate. The three parts, being mutually independent, exchange messages according to certain communication rules. The proposed system can apply to not only remote diagnosis and treatment but also remote meetings, conferences, and classrooms that need a virtual microscope.*

Keywords— *Virtual microscope system: image processing: wavelet transform: data compression.*

I. Introduction

Recently, due to the rapid increase in demand for images, many researches are being carried out actively to encode a vast amount of image information so that it can be searched for quickly with a minimum storage space. Along with the continuously improving network transmission speed and developing web-based multimedia in many fields, technologies to store and transmit data efficiently with a reduced number of bits has become more important. A virtual microscope (VM) is a software system implemented on a computer to perform digitally the functions of a high-performance optical microscope [1]. Such a software system is supposed to be equipped with some new types of functionality. For example, it can be applied to an educational environment so that multiple users can access and view the same slide at the same time and manipulate it. Also, it presents a platform of telemedicine and remote conference on which doctors in different regions can share slides and communicate with many medical specialist as well as their co-workers.

However, the main difficulty in providing the functions of a VM system consists in how to handle massive amounts of data in an efficient way. If a spot magnified 200 times generates a grid of 1000×1000 pixels, a slide image may consume several giga bytes of memory. Therefore, it requires a huge storage space and causes a difficulty in achieving several types of fast response times from the database system.

The proposed scheme presents a way of complementing the disadvantage of the EZW (Embedded Zero-tree Wavelet) in the aspect of computational cost [2], which shows a fairly high performance in terms of the compression rate and image quality. It uses a new bit allocation algorithm to exploit the characteristics of wavelet coefficients in the wavelet block-based compression algorithm. The purpose of the variable-block-based wavelet transform compression technique is to make a no-loss compression so that there is no difference between the original image and the one obtained by combining the decomposed images, resulting in no loss during the process of compressing and restoring image data.

The VM system [1] for microscopic observation of medical images is a software system that implements the optical microscope on a computer. Since the client program of this system was developed using Java, it runs in any environment where the JVM (Java Virtual Machine) is installed. The server program stores, retrieves, and processes the image data of the microscope. Since it was developed on UNIX as C/C++ language, it runs on a high-performance computer such as Solaris Workstation, Server for Linux, IBM SP2 with AIX, or Alpha Workstation Cluster of Digital. The server is divided into two parts, the network server and the data server. Receiving a query from the client program, the network server transmits it to multiple data server processes, and the data server store and retrieve slide image data responding to the client's query, and then transmit the requested image data to the client process.

The VM system should have the following abilities: quick browsing of slides to find the area of interest, areal browsing to observe the area around the current screen, adjusting of magnification and focal plane, etc.

In Section 1 of this paper, we describe the background and purpose of the works. In Section 2, the wavelet-band variable block-based compression technique is divided for explanation into two parts, one is the compression algorithm and the other the quantizer for each sub-band. Section 3, we briefly describe the design of a client program that provides a user interface and two servers, a network server and a data server, as part of the VM system design. In Section 4, experiments and evaluations have been performed, and finally in Section 5, conclusions are made with an introduction of future works.

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II. VARIABLE-BLOCK-BASED COMPRESSION TECHNIQUE USING WAVELET TRANSFORM

Although many different compression algorithms have been proposed (e.g., JPEG), VM systems require both high compression rates and low information loss. This necessity has inspired many researches to find new compression techniques in various ways, one of which is the wavelet transform technique [3] that we have used in this paper.

The compression technique using wavelet transform has two useful features.

First, it maintains locality in the data. If a user requests a small neighboring part of the entire image, the system calculates the corresponding region from the compressed and stored image, and search only a few neighboring stored images. This characteristic has good implications for the performance of the VM system, because it means that the number of data blocks to retrieve from the disk is always proportional to the size of the output image to be displayed to the user, not the size of the entire stored image.

Second, it is a multi-resolution compression technique that saves the micrographs as images with resolution varying continuously with the magnification.

The algorithm used in the proposed scheme performs wavelet transform using a Coiflets5 filter [4], makes a lossy compression using a scalar quantizer and a vector quantizer using variable-blocks for each sub-band, and then makes a lossless compression using entropy. Thus the image can be reconstructed with no loss by making a lossless compression of the difference image between the source image and the image synthesized from the decomposed images.

More specifically, the proposed scheme first applies a lossy compression technique through quantization of wavelet coefficients, and then makes a lossless compression using the entropy of the quantization coefficients and map data information is performed where an arithmetic entropy encoding method is used.

Wavelet transform is performed in three levels where sub-bands showing a good directionality use a vector quantizer with a variable-block and the remaining sub-bands use a scalar quantizer. Also, based on the identical statistical properties and energy concentration characteristics of the wavelet coefficients, the coefficients whose values are below the threshold value are set to 0 and this location information is sent as binary map data, and only the values of non-zero coefficients are passed through the quantizer to improve the efficiency of encoding. The variable block is set in consideration of the directionality, which is one of the characteristics of wavelets, and its size is changed according to the characteristics of the image [5].

The characteristic of the image data to which the wavelet transform is applied is that only the highest-level data maintains the original statistical properties of the image, and the rest of the bands have a lot of data close to zero, so the boundary information of the image becomes concentrated with high energy. Data continuity represents the horizontal, vertical, and diagonal directionality of each band.

Image data obtained from the three-level wavelet transform is shown in Fig.1.

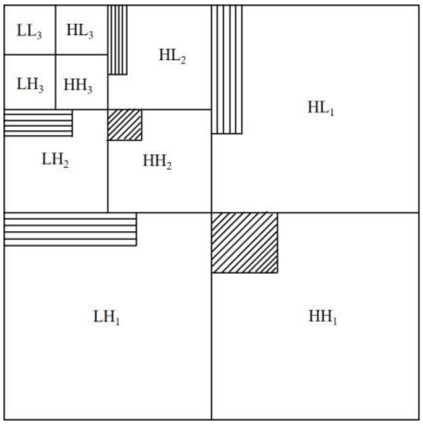

Fig. 1. Image data after adapting 3 level wavelet transform

Since the LL_3 sub-band with the lowest frequency has the same statistical distribution with the original image data, many bits are allocated for compression. The sub-bands of the 3rd level apply scalar quantization without decomposing them into blocks, because they occupy a small spatial area and contain a lot of relatively important information.

On the other hand, the sub-bands of the 1st and 2nd levels are decomposed into variable-blocks having the directionality of each sub-band because they contain relatively little important information that are sufficient to indicate the spatial directionality [6-7]. That is, the sub-bands of the second level are decomposed into blocks having a size of 1×4, 4×1, and 2×2, respectively, and the sub-bands of the first level are decomposed into blocks having a size of 2×8, 8×2, and 4×4, respectively. After the decomposition into blocks, coding is performed if the number of non-zero values in the block is greater than or equal to each threshold value and otherwise, it is set to 0. If the image has a clear boundary component with directionality, it is efficient to select a large variable-block size. This information is appended to the front of the compressed data.

The flowchart of the proposed algorithm is shown in Fig. 2.

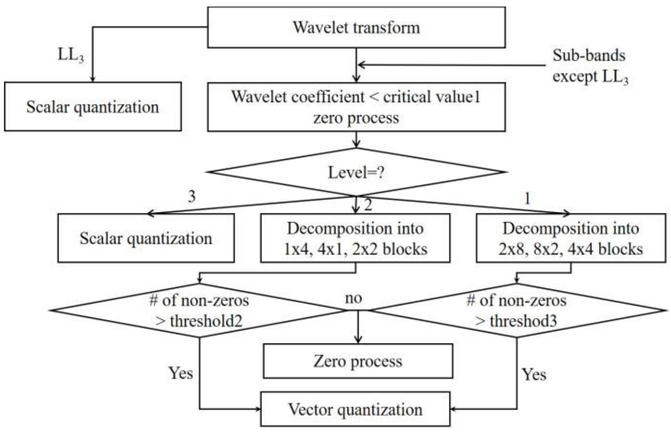

Fig. 2. The flowchart of the proposed algorithm

The method commonly used to make a vector quantization codebook is the Linde-Buzo-Gray (LBG) [8] algorithm, which

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is a generalization of the Lloyd-Max [9-10] algorithm used in scalar quantizers.

The LBG algorithm is shown in Fig. 3.

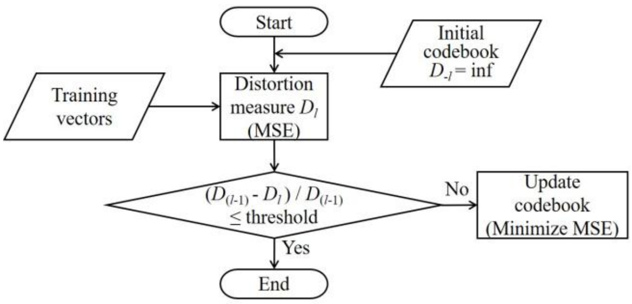

Fig. 3. The flowchart of LBG algorithm

The steps of the data compression process are briefly shown in Fig. 4.

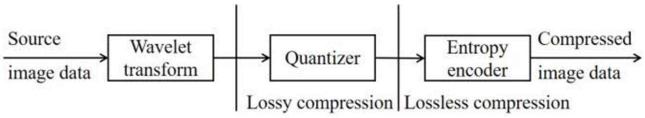

Fig. 4. Steps of the data compression process

III. Design of the Virtual Microscope System

The VM system is a distributed system composed of three parts. Specifically, it consists of a Client/User Interface that enables users to view slides through the network, a Data Server that can retrieve for slide image data, and a Network Server that allows two different parts to communicate. The modularity of these systems allows each part to be independently optimized and developed. So, the Client Interface can be designed to be user-friendly, web-friendly and portable, and the Data Server can be finely tuned according to the capabilities of the server computer.

The system environment on the client side is independent of hardware, and Java is used as the programming language. The system environment on the server side uses Solaris2.6 of Sun Ultra Sparc1 as the operating system, and C/C++ is used as the programming language.

IV. Experiment and Evaluation

In this section, the resulting image data of the proposed scheme for image data compression is compared with those of the existing methods. It also shows the client user interface of the VM system, and presents a table showing the comparison of the source image and the image obtained using the VM system.

We used MATLAB 5.2 on a Windows NT 4.0 Pentium PC to make the data compression experiments for an image with an 8-bit resolution and a size of 256×256 or 512×512 pixels.

Table I shows the performance evaluation by comparing the proposed scheme with the existing methods in terms of the number of zeros after compressing the image data in percent (%). The image files have been tested with 7 images, namely prostate, breast1, breast2, breat3, liver, 'fetalhand', and babyface. The energy retention of the test images after compression has turned out to be 100.00, 99.98, 99.96, 99.98, 100.00, 100.00(%), respectively, where the notations db10, bior6.8, and sym8 denote daubechies 10 [11], biothogonal 6.8 [12-13], and Symlets 8 wavelets, respectively.

TABLE I. Comparison of the proposed algorithm with the existing methods in terms of the number of zeros after the compression [%]

Sample name	Harr	Db10	Bior6.8	Sym8	Proposed Algorithm
Prostate	45.86	45.10	49.96	47.41	51.11
Breast1	44.00	45.36	48.71	47.08	49.72
Breast2	43.78	47.38	50.78	48.97	52.16
Breast3	43.66	47.13	50.48	48.76	51.33
Liver	52.64	59.71	60.28	59.67	63.14
Fetalhand	45.00	54.07	58.09	56.71	60.13
Babyface	44.14	58.52	61.78	59.63	64.33

Table II summarizes the comparison of the proposed scheme with the existing methods in terms of MAD (Mean Absolute Deviation) values. This shows that compared the existing methods, our scheme has a comparable MAD performance with a larger number of zeros after compression as shown in Table I.

TABLE II. Comparison of the proposed algorithm with the existing methods in terms of MAD values

Sample name	Harr	Db10	Bior6.8	Sym8	Proposed Algorithm
Prostate	30.82	30.82	30.82	30.82	30.82
Breast1	32.20	32.18	32.16	32.18	32.18
Breast2	35.38	35.31	35.29	35.32	35.31
Breast3	26.24	26.20	26.19	26.20	26.20
Liver	53.56	53.56	53.56	53.56	53.56
Fetalhand	62.50	62.51	62.51	62.51	62.51
Babyface	55.98	55.98	55.98	55.98	55.98

Fig. 5 shows an image that has been synthesized after the decomposition using the three-level wavelet transform [14]. The upper left, lower right, lower left, and upper right of this figure show the original image, the three-level wavelet decomposition, the synthesized image, and the image enlarged by selecting the LL_3 band.

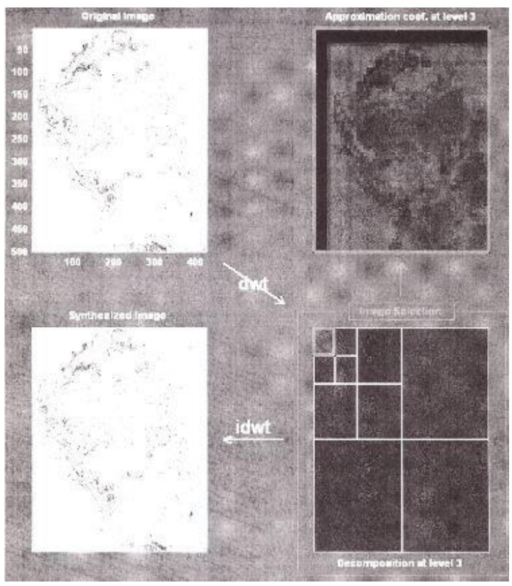

Fig. 5. Decomposed/synthesized image using the 3-level wavelet transform

Fig. 6 shows the original image for the sample source image prostate and the image after compression in the proposed scheme.

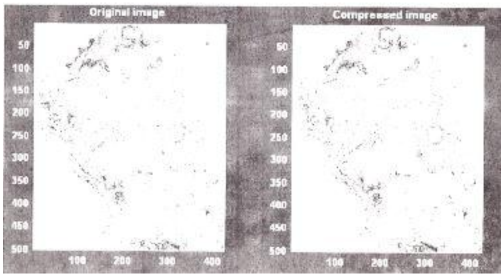

Fig. 6. A sample source image prostate and the image after compression

Fig. 7 shows the client user interface on the VM system.

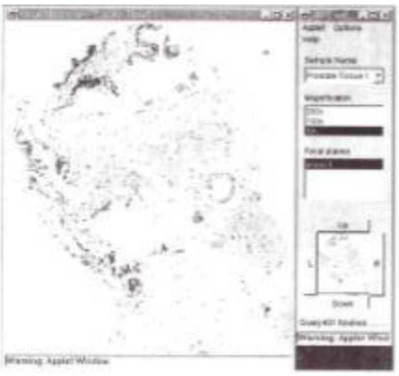

Fig. 7. User interface on the client side

Fig. 8 shows a display screen where you can select the magnification of an image on the VM system. It illustrates the magnification of Fig. 7 by 100 times.

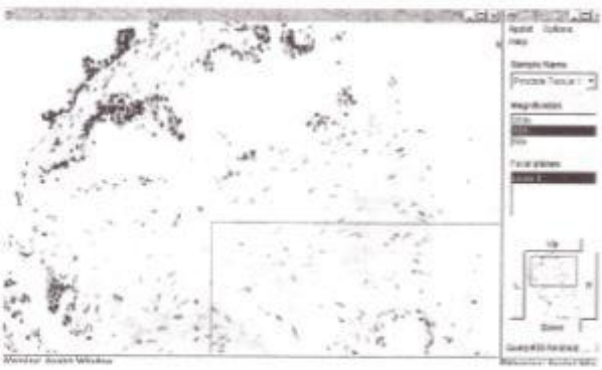

Fig. 8. Display screen with a magnification option selected

Fig. 9-1 and Fig. 9-2 are the images used in the experiment. From the left, the sample image names are prostate, breast1 to breast3, liver, 'fetalhand', and babyface.

Fig. 9-1. Sample images

Fig. 9-2. Sample images 2

Table III shows the comparison of the source images and compressed images on the VM system. They differ in that the former is local in data access, while the latter is available at remote locations. Since the latter can be compressed, the size of the stored data is reduced to about 1:8. It can be seen that on the VM system [15], a data can be stored with a small magnification and displayed with a large magnification.

TABLE III. Comparison of source image and the image on the VM system

	Source image	**Image on the VM system**
Data access	local	remote
Compression	no	yes
Storage data size	200~300MB, 50MB or so	25~40MB, 6MB or so
Magnification rate	x 400→ x 200→ x 100→ x 50 or x 200→ x 100→ x 50→ x 25	x 50→ x 100→ x 200→ x 400 or x 25→ x 50→ x 100→ x 200

V. CONCLUSION

The proposed scheme describes a VM system of a client server model, which is a software system that implements the functions of a real-world optical microscope on a computer. The purpose of the scheme is to actually perform telemedicine and teleconferencing functions, and ultimately to provide high-resolution digital images of patient tissue samples through the Internet, thereby replacing the cabinets full of slides in medical institutions or medical research institutions with a digital storage system. The proposed scheme uses the variable-block-based wavelet transform to compress the images without loss and preserves the difference image between the source image and the image obtained by synthesizing the decomposed images to prevent the data loss when reconstructing the image.

Further researches will focus on the performance of the server using new image compression techniques that can improve the response time of the client system and the availability of the server. Besides, some additional image-related functions will be considered, such as an image analysis function to count the number of cancer cells from the user's point of view, a statistical processing function, and a function to add, store, and retrieve doctors' opinions.

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