ARCHIVING AND CONTENT PROTECTION OF VISUAL MEDICAL INFORMATION WITH INVERSE PYRAMID DECOMPOSITION

Roumen Kountchev

Technical University of Sofia
Bul .Kl. Ohridsky 8, Sofia 1000
Phone: +3592 965 3283;
E: rkountch@tu-sofia.bg

Roumiana Kountcheva

T&K Engineering Co.
Mladost 3, Sofia 1712, POB 12
Phone: +3592 983 4541
E: kountcheva_r@yahoo.com.

Abstract

The paper presents new technique for archiving and content protection of visual medical information. For this is developed a special format based on new decomposition, named Inverse Pyramid. The images are archived with highest quality, but their restoration is performed in accordance with the application. The method permits the regions of interest to be visualized with lossless visual quality. The image content is protected by inserting multiple fragile watermarks, which could be extracted by authorized users only. The fragile watermark is inserted as additional decomposition layer and does not influence the image quality. This approach permits the creation of archiving systems with hierarchical access control.

1. INTRODUCTION

Hospitals and other healthcare institutions have recently to maintain significant number of electronic files: images, ECGs, EEGs, scanned documents, and many others. Two main problems exist when this information is archived and stored: how to archive it efficiently so that to create databases of size as small as possible, retaining the visual quality unchanged, and how to ensure the needed confidentiality. The first problem is solved using some kind of image and data compression. Images are usually compressed using some kind of lossy compression [1-3]. The most famous standard, used for medical images, is DICOM [4] (based on the JPEG standard). This is a high-efficient compression, which offers restored images with retained visual quality, but it does not involve watermarking tools.

The second problem (the image content protection) is based on some kind of watermarking, encryption, etc. The watermark insertion is usually performed in the frequency domain, but this results in lower quality of the restored images [5,6].

In this paper is presented a method for image content protection based on new decomposition (Inverse Pyramid Decomposition, IPD), which permits fragile watermark insertion without image quality deterioration.

The paper is arranged as follows: in Section 2 are given the basic principles of the IPD and the method for multi-layer watermark insertion; Section 3 presents the structure of a database with hierarchical access control, based on the new decomposition, and Section 4 is the Conclusion.

2. BASIC PRINCIPLES OF IPD AND MULTI-LAYER FRAGILE WATERMARK INSERTION

The IPD essence is presented here in brief for 8-bit grayscale images as follows. First, the digital image (B) is processed with two-dimensional (2D) direct Orthogonal Transform (OT) using limited number of low-frequency coefficients only. The values of these coefficients build the lowest pyramid level (S). The image is then restored, performing Inverse Orthogonal Transform (IOT) for the retained coefficients' values only. In result is obtained the first, coarse approximation of the original image, which is then subtracted pixel by pixel from the original. The difference image (E), which is of same size as the original, is divided into 4 sub-images and each is processed with 2D OT again. The values of the retained coefficients build the second pyramid level. The processing continues in similar way with the next (higher) pyramid layers. The set of coefficients of the orthogonal transform, retained in every pyramid layer, can be different and defines the restored image quality (more coefficients naturally give higher image quality). The image decomposition is stopped when the needed quality of the approximating image is obtained – usually earlier than the last possible pyramid layer. The values of the coefficients got in result of the orthogonal transform from all pyramid layers are then quantizated, sorted in accordance with their spatial frequency, arranged as one-dimensional sequence, and losslessly compressed. For practical applications the decomposition is usually "truncated", i.e. it does not start from the lowest possible layer but from some of the higher ones and for this, the discrete original image is initially divided into sub-blocks of size $2^n x 2^n$. Each sub-block is represented by an individual pyramid, whose elements are defined with recursive calculations. The mathematical description of the IPD method is given in detail in earlier publications of the authors [7].

On the basis of IPD was created new format for the compressed images. It contains information about the number of decomposition layers, the size of the initial sub-image, the kind of orthogonal transform used, the color transform (for color images), the number of transform coefficients for every layer, the quantization values, etc. This new format can comprise additional information, necessary for the efficient arrangement and search in the medical database, for example: personal information about the patient: age, place of birth, etc.; information about the disease(s); etc.

One fragile watermark (WM) could be inserted between any couple of consecutive IDP layers as an additional one. In result the volume of the coded visual information is slightly increased, but compared with the volumes of the protected images, the enlargement is negligible. For this is necessary to have a set of pre-prepared grayscale WM images. In order to make this additional data as small as possible, the watermark image is losslessly compressed. Two kinds of fragile watermarking are possible: visible and invisible. The visible WM is visualized together with the protected image: the WM is overlapped on the original. In result, the most important information (the Region of Interest, ROI) could be inaccessible (hidden). The WM removal is permitted for authorized users only. The invisible WM is not visualized together with the protected image, but it could be visualized using a password or other similar techniques. In each decomposition layer could be inserted individual WM (visible or not).

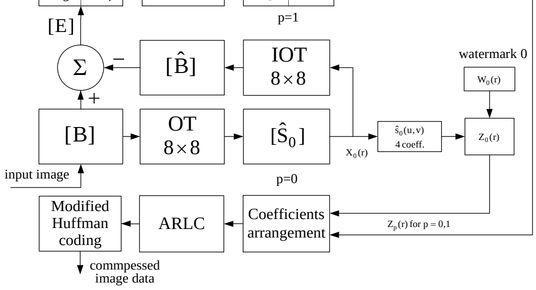

Fig. 1. Block diagram of 2-layer IP coder for one sub-block

The block diagram of the 2-layer IP coder for one sub-block of size $2^n x 2^n$ pixels with fragile WM insertion is presented in Fig.1. In the coded image data are inserted 2 watermarks. The decoding is performed in reverse order.

The mathematical representation of the watermarking method is given in earlier publications of the authors [8].

3. DATABASE SYSTEM WITH HIERARCHICAL ACCESS CONTROL

On Fig. 2 is shown the block diagram of a system with hierarchical access control, whose management is based on the IP decomposition. The decomposition comprises N layers, but in practice are usually used 2 or 3 layers only. This approach offers significant abilities for efficient transfer and visualization, because in the lowest layer the compression ratio obtained is usually 100 or higher, if 4 transform coefficients are used. The quality of the restored image is not high, but it is good enough for the user to evaluate if he/she is interested with this information. In case that the user does not need the information, further data transfer is not necessary. Additional advantage of the new decomposition is that it offers interactive abilities and permits the user to set Regions of Interest (ROI) in the visualized image. In this case, the selected part only is further transferred with highest quality (Fig. 3). Both options enhance significantly the system performance.

In the system, shown on Fig. 2, the access request starts from the lowest decomposition layer and continues to the higher ones. The access permission for any of the lower layers, each of the next ones needs the permission from the preceding layer together with the permission for the current layer (a password). For layers, where permission is not obtained, the corresponding information is not visualized and the image is restored with the quality of the highest layer.

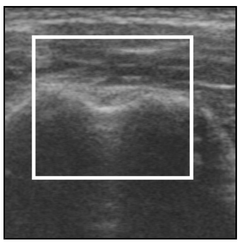

Fig. 3. Medical test image with selected example ROI

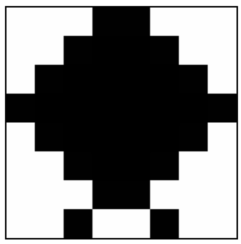

Fig. 4. Example WM image 256 x 256 pixels, greyscale

The example image in the lowest layer is overlapped by the visible WM of size 256 x 256 pixels, shown in Fig. 4. After using the special lossless compression, developed by the authors [7], the size of the compressed file is 751 B only. In the proposed IPD compression the additional information, added to the metadata is this of the compressed WM image (i.e. 751 B). The WM image from Fig. 4 is just an example - in principle, any image could be used as a fragile WM. The basic requirements are the image to be relatively simple and to consist of comparatively large areas, which to resist the basic compression standards (JPEG, etc.).

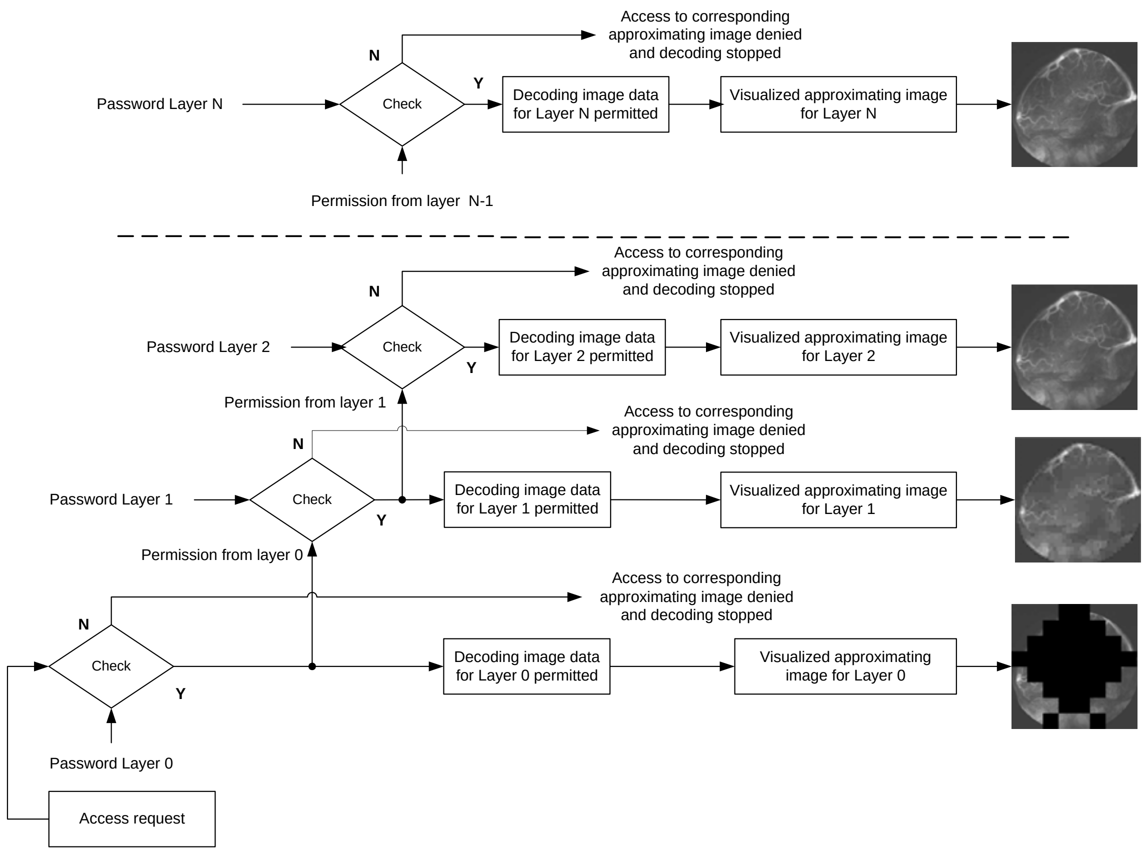

Fig. 2. Block diagram of a system with hierarchical access control

4. CONCLUSIONS

The main advantages of the IPD method are:

- It permits the processed images to be transferred layer by layer, with increasing quality. In result, the image transfer could be stopped any time, when required image quality is obtained;

- It permits the insertion of fragile and resistant watermarks in the processed visual information, on the basis of which to be developed special tools for data access management;

The main *application areas* of the method are:

– Creation of medical databases which to contain the global patients' information.

– Creation of tools for hierarchical access control in image databases.

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