W-CORE: A Wavelet-Based Compression/Reconstruction Technique

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***Abstract* - During medical images transmission and storage, the big size of these files becomes a big obstacle to the implementation of Telemedicine systems. A lot of effort has been done to solve this problem by compressing the medical images with minimum loss of information.**

Wavelet transform changed the way we represent the image into a collection of details at several different levels. That gave us the ability to choose the highest effective details in the image and get rid of others. With some additional techniques of saving space and correcting the artifacts produced by the reconstruction process, we were able to get some excellent results that reduced the image file size to less than a half without changing the file format which made these images still accessible to most of the commonly used image processing algorithms.

I. Introduction

One of the most commonly encountered problems during the implementation of Telemedicine is the big size of medical data, which will require more space and time during the transmission and the storage of these files or data packages.

Medical images are probably the biggest medical data type in size. Therefore, the compression of these images became one of the major challenges in the field of telemedicine.

Many methods have been developed for better image compression including the PNG, JPEG…etc. These methods were very successful in reducing the image file size in very small ratios, 20:1 and sometimes even less. However, these techniques have some disadvantages, especially from a medical point of view. For example, JPEG compression does not provide superior results. Sometimes the compression ratio is as low as 5:1, with a high loss of picture integrity. This happens because the JPEG compression scheme compresses similar hues well, but does not work as well with sharp differences in brightness or solid areas of color, which is the case in medical images. Plus, very few of the image processing algorithms and softwares that are used in hospitals and clinics support these types of format.

These problems have defined a clear image of what the compression method should do: it has to be able to convert the image into a set of numbers or data packages that can be reconstructed later (for example, in the remote site) into the original image with the minimum possible loss of information. Plus, the reconstructed image has to be in the machine format (i.e. able to get processed by the most commonly used image processing algorithms).

II. Methodology

Image transforms might be a good point to start with. In general, transforms will convert the image into a bunch of numbers (coefficients) that will represent the information as levels of details (frequencies). Reconstructing the image with only a portion of these coefficients will return an image with the information represented by these coefficients. Therefore, the reconstructions of the image with the highest absolute values of these coefficients will return the image with the highest effective details that are included in the original one.

This is the baseline of the technique presented in this paper. Earlier work has been done using the Fourier transform and it gave some brilliant results [1,2,3]. Almost 93% of the energy in the original image was retained in the reconstructed image using only the highest 10% of the coefficients. There were some problems with using the Fourier transform; its coefficients are not localized in space.

The wavelet transform is one of the most useful transforms not only in the image processing, but also in the one-dimensional waveforms. This gives us an idea about the frequencies contained in the image and their location within this image. Something that solved the previously mentioned problems with the Fourier based method.

Also, the wavelet transforms introduced the idea that these coefficients are derived at different levels of detail. This means that there will be a classification of the details into "important" details and some other "not so important" details. This gives us the ability to choose from the vertical, horizontal and diagonal details at several levels.

After this procedure, the compressed data contain only the required highest coefficients and their locations within the transform representation.

The positions of these coefficients are very important to put each detail in its right place. Depending on the transform function output, the coefficients might be arranged in a two-dimensional format (in this case each position will be defined by two values; X, Y), or it might be arranged in a one-dimensional format (the position will be defined by a single value).

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In order to save even more storage space, a better way to define the positions without saving their actual coordinates is to represent each location in the wavelet transform representation as a bit which will take the value "1" or "0". This will create a "bit-matrix" (that is different from the windows images file format), this bit-matrix will point out the locations of the saved coefficients in the wavelet representation which may be used later to reconstruct the original image, by putting these coefficients in the "1" locations respectively.

The required space to save this bit-matrix in bits will be the number of pixels in the image. For example, for a 256×256 image, the bit-matrix size will be 65536 bits, which means 8192 bytes. This means that for this image, the highest coefficients positions can be saved in an 8.2 KB variable, which is small compared to the required space to save the coordinates of each position. Also, for small percentages of the saved coefficients, it has been noticed that these coefficients are located only in the first half of the wavelet representation, a thing that will allow us to take only a bit-matrix of the first half and ignore the second one. Thus, the bit-matrix could also be divided by two.

III. Results

Fig.1 shows the reconstructed images using different values of percentages for the highest saved wavelet coefficients.

As far as we can see, with only 20% of the coefficients, we can get an excellent result; the reconstructed image at this level and the original one are almost identical. With some additional image correction techniques we can totally eliminate the artifacts produced by the reconstruction process and get much better results at even lower percentages.

IV. Discussion

As previously explained, the components that are needed to reconstruct the original image are the highest saved coefficients and the bit-matrix that will define the positions of the coefficients.

To calculate the compression ratio of this method related to the percentage of the saved coefficients, we need first to calculate the sum of spaces required to save the data,

For an M×N image, the original image size would be M×N Bytes (for a 256 levels grayscale image). As for the size of the bit-matrix, it would be M×N bits = M×N/8 Bytes. This means that the space required to save the bit-matrix would be 0.125 of the size of the original image size.

As for the coefficients, for a percentage (α), the space required to save them would be space required to save $\alpha \times M \times N$ coefficients. For the best approximation that satisfies both precision and disk space, each coefficient will be stored in a 2 Bytes format. This means that the space required to save the highest α% coefficients would be $2 \times \alpha \times M \times N$ Bytes. And the final compression ratio of this method (R) will be defined by the formula:

$$R = 0.125 + 2 \times \alpha \quad (1)$$

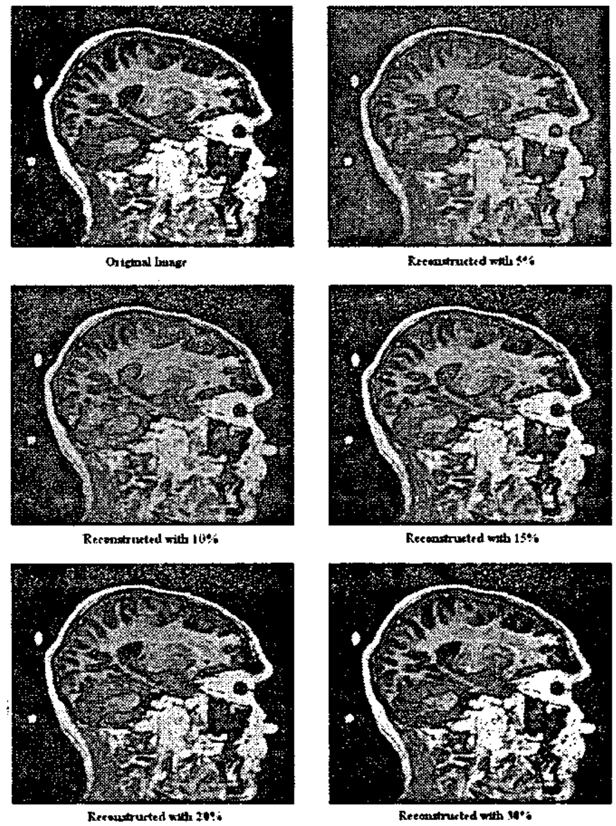

Fig.1: Reconstructed images at different percentages of saved coefficients

Ironically, for those values of (α) above a certain limit (43%) the compression ratio will have values more than 1. This means that after this limit, the method will "expand" the image instead of compressing it. This is because each coefficient is saved using 2 Bytes of the disk space, as for the original image, each pixel was saved in only one byte. At its present form, this method is only useful for the Percentages below 43%, at which we can get a great result. As seen earlier, 20% of the coefficients returned a great image that is almost identical to the original one.

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