Lossless performance of image compression using 2D DWT

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Abstract: With the increasing growth of technology and the entry into the digital age, we have to handle a vast amount of information every time which often presents difficulties. So, the digital information must be stored and retrieved in an efficient and effective manner, in order for it to be put to practical use. Wavelets provide a mathematical way of encoding information in such a way that it is layered according to level of detail. This layering facilitates approximations at various intermediate stages. These approximations can be stored using a lot less space than the original data. Here a low complex 2D image compression method using wavelets as the basis functions and the approach to measure the quality of the compressed image are presented. The 2D discrete wavelet transform (DWT) has been applied and the detail matrices from the information matrix of the image have been estimated. The reconstructed image is synthesized using the estimated detail matrices and information matrix provided by the Wavelet transform. The quality of the compressed images has been evaluated using some factors like Compression Ratio (CR), Peak Signal to Noise Ratio (PSNR), etc.

INTRODUCTION
The use of digital images is increasing rapidly. Along with this increasing use of digital images comes the serious issue of storing and transferring the huge volume of data representing the images because the uncompressed multimedia (graphics, audio and video) data requires considerable storage capacity and transmission bandwidth. Though there is a rapid progress in mass storage density, speed of the processor and the performance of the digital communication systems, the demand for data storage capacity and data transmission bandwidth continues to exceed the capabilities of on hand technologies. Besides, the latest growth of data intensive multimedia based web applications has put much pressure on the researchers to find the way of using the images in the web applications more effectively. Internet teleconferencing, High Definition Television (HDTV), satellite communications and digital storage of movies are not feasible without a high degree of compression. As it is, such applications are far from realizing their full potential largely due to the limitations of common image compression techniques.

2D DWT

Wavelet-based compression algorithms.
• Wavelet coding schemes at higher compression avoid blocking artifacts.
• They are better matched to the HVS (Human Visual System) characteristics.
• Compression with wavelets is scalable as the transform process can be applied to an image as many times as wanted and hence very high compression ratios can be achieved.
• Wavelet based compression allow parametric gain control for image softening and sharpening.
• Wavelet-based coding is more robust under transmission and decoding errors, and also facilitates progressive transmission of images.
• Wavelet compression is very efficient at low bit rates.
• Wavelets provide an efficient decomposition of signals prior to compression.

Classification of Compression Technique:
There are two ways that we can consider for classifying compression techniques-lossless vs. lossy compression and predictive vs. transform coding.
Lossless vs. Lossy compression:

In lossless compression schemes, the reconstructed image, after compression, is numerically identical to the original image. However lossless compression can only achieve a modest amount of compression. An image reconstructed following lossy compression contains degradation relative to the original. Often this is because the compression scheme completely discards redundant information. However, lossy schemes are capable of achieving much higher compression. Under normal viewing conditions, no visible loss is perceived (visually lossless).

Wavelets for image compression

Wavelet transform exploits both the spatial and frequency correlation of data by dilations (or contractions) and translations of mother wavelet on the input data. It supports the multi-resolution analysis of data i.e. it can be applied to different scales according to the details required, which allows progressive transmission and zooming of the image without the need of extra storage. Another encouraging feature of wavelet transform is its symmetric nature that is both the forward and the inverse transform has the same complexity, building fast compression and decompression routines. Its characteristics well suited for image compression include the ability to take into account of Human Visual System’s (HVS) characteristics, very good energy compaction capabilities, robustness under transmission, high compression ratio etc. The implementation of wavelet compression scheme is very similar to that of sub band coding scheme: the signal is decomposed using filter banks. The output of the filter banks is down-sampled, quantized, and encoded. The decoder decodes the coded representation, up-samples and recomposes the signal. Wavelet transform divides the information of an image into approximation and detail sub signals. The approximation sub signal shows the general trend of pixel values and other three detail sub signals show the vertical, horizontal and diagonal details or changes in the images. If these details are very small (threshold) then they can be set to zero without significantly changing the image. The greater the number of zeros the greater the compression ratio. If the energy retained (amount of information retained by an image after compression and decompression) is 100% then the compression is lossless as the image can be reconstructed exactly. This occurs when the threshold value is set to zero, meaning that the details have not been changed. If any value is changed then energy will be lost and thus lossy compression occurs. As more zeros are obtained, more energy is lost. Therefore, a balance between the two needs to be found out.

DISCRETE WAVELET TRANSFORM

The Discrete Wavelet Transform, which is based on sub-band coding, is found to yield a fast computation of Wavelet Transform. It is easy to implement and reduces the computation time and resources required. The discrete wavelet transform uses filter banks for the construction of the multiresolution time-frequency plane. The Discrete Wavelet Transform analyzes the signal at different frequency bands with different resolutions by decomposing the signal into an approximation and detail information. The decomposition of the signal into different frequency bands obtained by successive high pass $g[n]$ and low pass $h[n]$ filtering of the time domain signal. The combination of high pass $g[n]$ and low pass filter $h[n]$ comprise a pair of analyzing filters. The output of each filter contains half the frequency content, but an equal amount of samples as the input signal. The two outputs together contain the same frequency content as the input signal; however the amount of data is doubled. Therefore down sampling by a factor two, denoted by 2, is applied to the outputs of the filters in the analysis bank.

Reconstruction of the original signal is possible using the synthesis filter bank. In the synthesis bank the signals are up sampled $(\uparrow 2)$ and passed through the filters $g[n]$ and $h[n]$.

Perfect reconstruction is defined by the output which is generally an estimate of the input, being exactly equal to the input applied. The decomposition process can be iterated with successive approximations being decomposed in return, so that one signal is broken down into many lower-resolution components. Decomposition can be performed as ones requirement.

The Two-Dimensional DWT (2D-DWT) is a multi level decomposition technique. It converts images from spatial domain to frequency domain. One-level of wavelet decomposition produces four filtered and sub-sampled images, referred to as sub bands. The sub-band image decomposition using wavelet transform has a lot of advantages. Generally, it profits analysis for non-stationary image signal and has high compression rate. And its transform field is represented multi resolution like human’s visual system so that can progressively transmit data in low transmission rate line. DWT processes data on a variable time-frequency plane that matches progressively the lower frequency components to coarser time resolutions.
and the high-frequency components to finer time resolutions, thus achieving a multi-resolution analysis. The Discrete Wavelet Transform has become a powerful tool in a wide range of applications including image/video processing, numerical analysis and telecommunication. The advantage of DWT over existing transforms, such as discrete Fourier transform (DFT) and DCT, is that the DWT performs a multi-resolution analysis of a signal with localization in both time and frequency domain. 2D-DWT is applied on grayscale image. It transforms an image into sub-bands such that the wavelet coefficients in the lower level sub-bands typically contain more energy than those in higher level sub-bands.

CONCLUSIONS

In this paper, high speed and area efficient DWT processor based Image Compression model has been presented. The pipelined partially serial architecture is introduced to enhance the speed and area efficiency. The proposed design can operate at a maximum frequency of 231 MHz by consuming 117mW power at 28°C junction temperature. An improvement of 15% in speed has been achieved by consuming considerably less number of resources.

REFERENCES

