Application of Medical Image Data Characteristics for constructing DCT-based compression algorithm.

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Abstract: We present the methods of improving the efficiency of Block DCT -based compression algorithm in the application to medical images archiving. The decrese of bit rate: for CR images up to 6%, for scintigraphy images up to 35%, for USG images up to 7% was achieved (in comparison to JPEG algorithm). Also the evaluation of the effectiveness of other well-known image compression techniques was made. Objective and subjective methods of diagnostic accuracy evaluation was used. The estimated values of acceptable compression ratios for scintigraphy images are about 50, for CT images used in radiotheraphy over 30, for MRI images - 12 and for diagnostic CT images - 14.

INTRODUCTION

The lossy compression methods permit much higher compression ratio by eliminating redundant data that has little visual impact. In medicine acceptable compression ratio values (diagnostic accuracy is preserved) depend mostly on imaging modalities. In spite of many techniques specifically tailored to each imaging modality a single data compression technique that works well with all images produced in the medical imaging environment is desirable. Quality and quantity characteristics of medical image data from different modalities and determining diagnostic accuracy allow to describe a priori information for constructing effective image compression algorithm.

This a priori information is as follows:

- noise characteristics - SNR, 1D or 2D power spectrum (comparison of noise and signal power spectrum),
- resolution (cross-correlation, 1,2 - order entropy),
- data dynamics (global and local histograms, first-order gray-level statistics),
- diagnostically important image features - fidelity of particulars, sharp edge reconstruction (MSE in high frequency domain) and local or global structure shapes (area, local displacement).

Following features of effective medical image compression algorithm are desired: a) adaptivity (using a posteriori information), b) preserving important high frequency image coefficients, c) reduction of noise, artifacts and diagnostically unimportant information.

DCT-MED ALGORITHM

The basic block DCT algorithm with the adaptive procedures and techniques was used. We applied a apriori information for choosing proper methods of DCT coefficients quantization and coding (the most efficient for each kind of medical images). Spectral distribution of signal and noise, and HSV (human visual system) contrast sensitivity function was used to the suitable quantization technique selection. The choice of DCT coefficient coding method was based on the analysis of statistic distribution of these data. These quantization and coding methods are as follows:

A. DCT coefficients quantization:

- threshold sample selection (with applying quantization table):
- a single global value of quantization table elements - for scintigraphy images,
- HSV contrast sensitivity function (similar to proposed in JPEG standard) - specified normalization array of quantization table elements - for ultrasound, MR and CR images,
- adaptive quantization table (this table is varied as a function of DCT coefficient distribution in each block) - for high quality MR and CT images. The variance of the transform coefficients are modelled as the following function:

  $$\tilde{k}(u,v) = k(0,0)\exp(-(a\cdot u + b\cdot v)), \quad a,b \geq 0,$$

  where $k(0,0)$ is the lowest-order transform coefficient, and a and b are modelling constants which are used for creating quantization table shape (these constants are added to compressed data file).

B. DCT coefficients coding:

- DPCM-coding of d.c. coefficients (3-order linear prediction with correlation coefficient value of 0.5),
- 1-st and 2-nd order arithmetic coding of run-length coded data; applying higher-order Markov source as image source model is too complex and ineffective,
- interframe coding algorithm (reducing redundancy at DCT domain - coefficients of the blocks are difference coded relative to the coefficient of the proper block in the previous image).

The main disadvantage of block compression method is blocking effect. The ways of reducing this effect and improving the compression efficiency applied here are as follows: a) constant quantization step size for d.c. coefficients (quantizer value is not changed for different image distortion), b) combined-transform coding techni-que; the original image is first divided into two sets that exhibit different stochastic properties. The upper image set which contains the most significant information and correlation is compressed losslessly, and the lower image set containing less-significant information is coded by conventional block transform coding schemes.

RESULTS AND CONCLUSIONS

We have tested real examinations from hospitals: the 11-bit MRI examinations (256x256, 512x512, single or sequences, 16-bit scintigraphy images - static thyroid examinations (128x128, 256x256), dynamic gated examinations of heart (sequences of 64x64 pictures), 8-bit digital radiography and US images, 12-bit CT images (512x512).

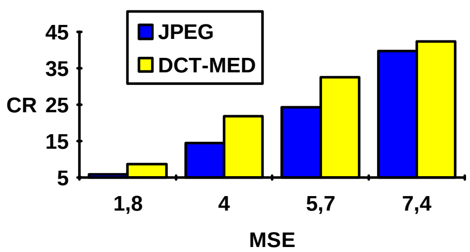
A comparison of the DCT-MED and other techniques effectiveness was conducted. The decrease of bit rate was noticed, specifying in comparison to:

- JPEG technique: for CR images up to 6%, for sci-ntigraphy images up to 35%, for US images up to 7%,
- fractal technique (presented at [2]): for scintigraphy images up to 85%, for X-ray images up to 65 %,
- vector quantization technique [3]: for MR images up to 50%,
- EPIC wavelets technique [4]: for MR images up to 30%.

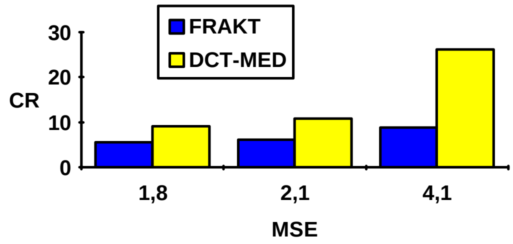
The effectiveness of DCT-MED algorithm and wavelet technique presented by Tilo Strutz (approachable at the Internet) is comparable at higher compresion ratios (over 20), but at lower CR the wavelet method efficiency was greater - up to 10% for MR and up to 30 % for US images. The examples of the comparisons of these lossy comp-ression techniques are presented on fig. 1.

Diagnostic accuracy of compressed images was estimated. Objective method of diagnostic accuracy evalua-tion based on the analysis of changes of the diagnostic parameters values was used [5]. The values of acceptable compression ratios for scintigraphy images are about 50, for CT images used in radiotherapy over 30. The results of subjective (by physician) evaluation of diagnostic quality of the compressed images are as follows: acceptable comp-ression ratios for MR images - 12 and for CT images - 14. The critical criterion used in this method consists of 2 elements: a) acceptable - means a lack of noticeable degra-dation of image features which are important in diagnosis, b) image quality - evaluated in psychovisual way - is comparable with the origin (even better). It allows for the increase of objectivity and safety of estimated compression ratios which could be acceptable for diagnosis. The tests were made in 5 medical centers in Warsaw with the help of 9 doctors. Applying a priori and a posteriori information for constructing of DCT-based compression techniques allows to improve medical image compression efficiency. The main advantage of presented DCT-MED method is that it can be used for archiving and transmission of wide class of medical images with great effectiveness.

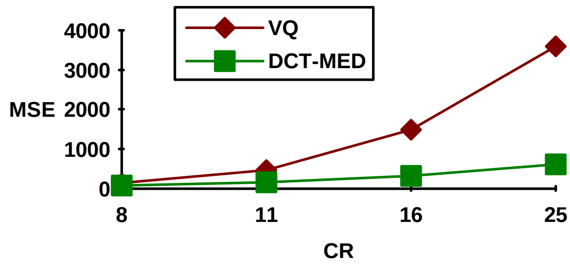
a)



b)



c)



d)

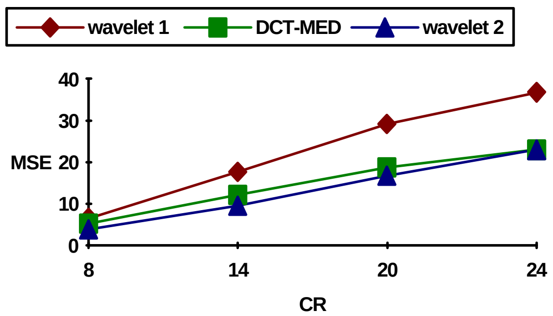


Figure 1. The comparison of the compression effectiveness of the following techniques: DCT-MED (presented in this paper), JPEG (standard technique with adaptive coding), FRAKT - fractal technique, wavelet (subband wavelet coding, 1 - EPIC, 2 - Strutz). CR - mean compression ratio, MSE - mean square error between original and compressed images. Compressed medical images are as follows: scintigraphy (a), radiography (b), MR - 11-bit data (c) and 8-bit data (d).

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