USING A PRIORI INFORMATION FOR IMPROVING THE COMPRESSION OF MEDICAL IMAGES

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Summary: *This paper presents the methods of improving the compression efficiency by incorporating a priori information in compression process. The characteristic of medical images can be used for choosing proper procedures of compression algorithm and constructing suitable new data conversion techniques for increasing the compression effectiveness and better preserving diagnostic accuracy. As an example of applying a priori information, lossless DPCM-based and lossy block DCT-based algorithms are used. Achieved increasing of compression efficiency is from 6 to 35 % for different medical modalities and up to 50 % for the sequences of US images.*

A class of medical images has not specific features which could be used for improving the lossless compression efficiency. Modeling the marginal probabilistic distribution of the medical images, often taken as the first step in obtaining more sophisticated image models and improved compression efficiency, does not allow to achieve satisfactory results. The relative lack of structure of the histogram and large variations among the various image-formation processes make the above efforts neither robust nor satisfactory [1].

The effective natural image lossless compression techniques are also effective in the applications to medical image systems. The limit of achievable compression ratios is about 4. Techniques based on linear prediction methods are largely the most effective in reduction of spatial redundancy [2]. Arithmetic coding and Huffman coding are the most efficient in encoding DPCM-decorrelated data.

Characteristic of medical image data as a priori information is based on: a) statistical and Fourier transform characteristics of medical images from different modalities (examples on fig. 1), b) analysis of image features which are important for determining the quality and diagnostic accuracy. This information may be used for estimating the desired features of the effective image compression technique and even for construction the concrete algorithmic solutions.

A priori information is as follows: a) noise characteristics - SNR, 1D or 2D power spectrum (comparison of noise and signal power spectrum), b) resolution (cross-correlation, 1,2 - order entropy), data dynamics (global and local histograms, first-order grey-level statistics), c) diagnostically important image features - fidelity of particulars, sharp edge reconstruction (MSE in high frequency domain) and local or global structure shapes (area, local displacement), d) temporal redundancy of a sequence of images from tomography or US and scintigraphy modalities (displacement estimation and compensation, affinity operators, motion vectors).

The following features of effective medical image compression algorithm are desired: a) adaptability (using a posteriori information), b) preserving the frequency image coefficients which represents diagnostically important information, c) reduction of noise, artifacts and diagnostically unimportant information.

To realise effective algorithm, lossless DPCM-based technique and lossy block DCT-based algorithm with the adaptive procedures and techniques (elaborated to use a posteriori information) is applied.

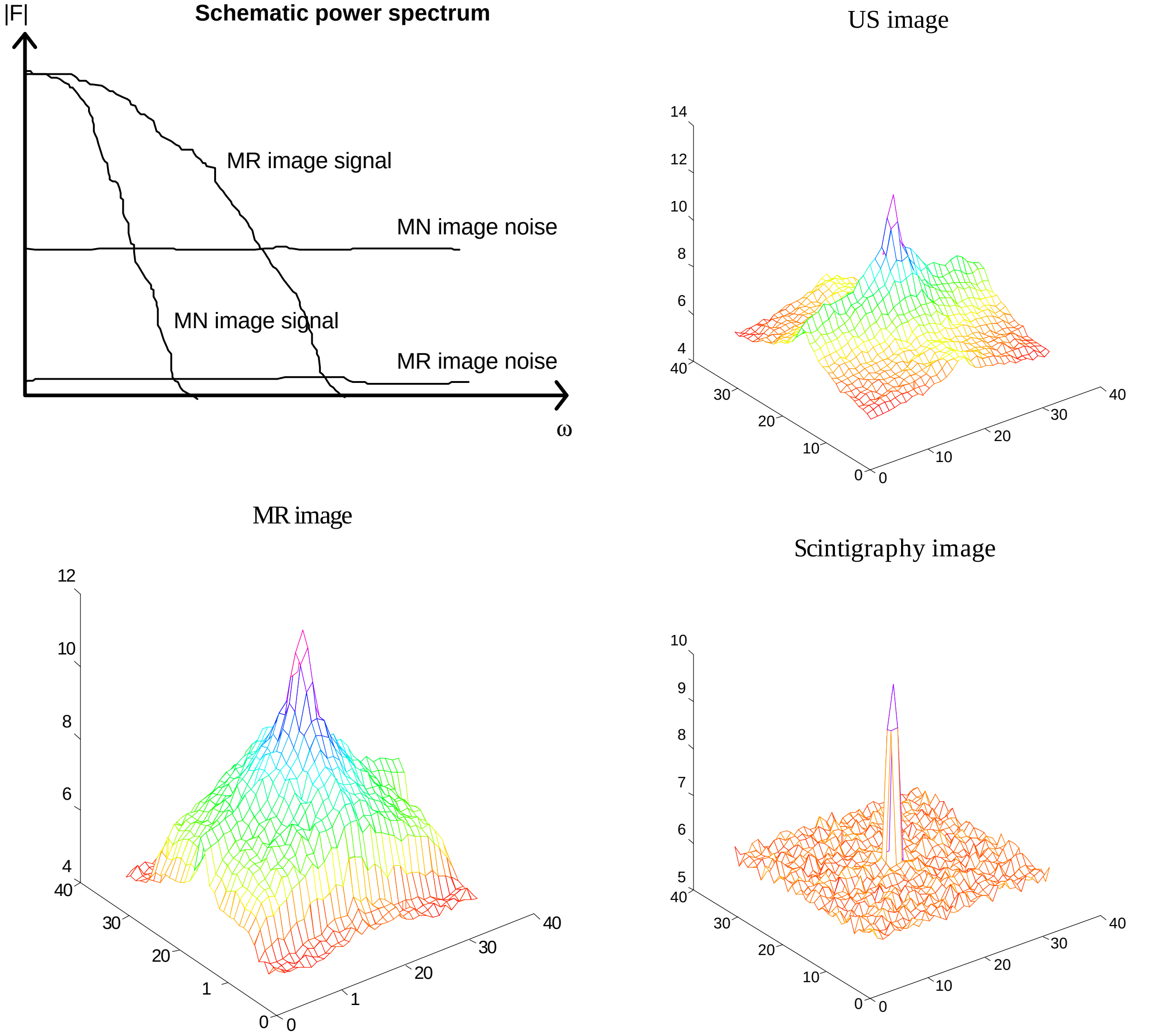

Fig.1. Schematic example of power spectrum which ilustrate an idea of using the power spectrum differences in compression process and the examples of real power spectrum of the MR, US and scintigraphy images.

The information about a noise level and spatial data correlation is needed for proper construction of linear predictor in DPCM coding. 1-st order Markov model of the images with the values of correlation coefficients: 0.1 for scintigraphy, 0.4 for US and 0.5 for radiography allows to achieve the best compression [3]. An optimisation of prediction model allows to decrease bit rates of about 10%.

We applied a priori information for choosing proper methods of DCT coefficients quantization and coding (the most efficient for each kind of medical images) [3]. The a priori information from spectral distribution of signal and noise, and HVS (human visual system) contrast sensitivity function was used to the suitable quantization technique selection. The analysis of DCT coefficients values allows to choice the best coding method. The quantization and coding methods are as follows: a) threshold sample selection (with applying quantization table) with a single global value of quantization table elements - for scintigraphy images, with

HVS contrast sensitivity function (similar to proposed in JPEG standard) - specified normalization array of quantization table elements - for US, MR and CR images, with adaptive quantization table (this table is varied as a function of DCT coefficients distribution in each block) - for high quality MR and CT images. The variance of the transform coefficients is modeled as a 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 modeling constants which are used for creating quantization table shape (these parameters are added to compressed data file), b) DPCM-coding of d.c. coefficients (3-order linear prediction with correlation coefficient value of 0.5), c) 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.

The sequences of images from some medical exams like for example echocardiography have to be interframe correlated. The analysis of the correlation between images in sequences and characteristic of image data based exams allow to achieve an increasing compression efficiency in two ways of interframe coding: a) with reducing the redundancy at DCT domain - coefficients of the blocks are difference coded relative to the coefficient of the proper block in the previous image), b) with reducing the redundancy at spatial domain - motion vector estimation with minimum absolute block difference criterion. The difference is determined by the sum of the absolute values of the pixel-to-pixel difference throughout the block. The greatest compression efficiency was achieved with: small range of search area, 16×16 block size, interframe model coding based on interpolation (bi-directional prediction) of sequent images (with reference frames intra-coded or predicted-forward or backward) (fig. 2).

a) b)

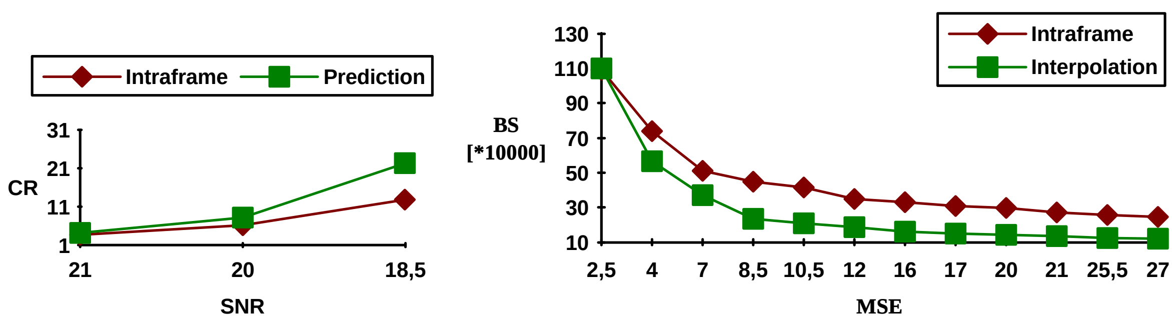

Fig.2. The effectiveness of interframe coding in relatio to intraframe technique; a) - prediction in DCT domain, sequence of scintigraphy images is compressed; b) - interpolation in spatial domain, sequence of US images is compressed. CR-compression ratio, BS -bit size of data set, MSE-mean square error, SNR-signal-to-noise ratio.

Conclusions: The results show that increasing compression efficiency by taking into account a priori information is possible and even promising. Proper choice of quantization and coding techniques allows to decrease bit rate of compressed images for CR images up to 6%, for scintigraphy images up to 35%, and USG images up to 7%. The compression efficiency improving by applying interframe coding technique is up to 50% for US images sequence. As a result of using additionally the a priori information about diagnostically important image features for improving the compression, the following values of acceptable compression ratios are achieved: for scintigraphy images about 50, for CT images used in radiotherapy over 30, for MR images - 12 and for CT images - 14.

References:

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