WP4, Deliverable 17: Report on current methods of microscopic image compression.

IRSES Project 247091 MIRACLE

November 16, 2011

Image compression and image coding are well-established and deeply researched fields in the signal processing and communication communities, respectively. Although challengeable in terms of optimality and resultant fidelity, the DCT-based "lossy" JPEG standard [1] has proven to be the most widely accepted technique in modern day applications, thus making the very term JPEG a household name. JPEG, however, was designed and performs best for so-called "natural" images. In fact, its design was heavily inspired by the function of the human visual system (HVS). For other, most notably medical, applications its performance may not be at an acceptable level. Still, because of limited bandwidth and memory in e.g. telepathology, compression of images in those areas is desireable. For the above mentioned reasons, this literature survey aims at establishing today's state of the art in the area of microscopic image compression for medical purposes.

The first question that arises is if image compression is in fact suitable for medical applications. Several studies deal with this question. In [2] the effect of image compression on expert readings of pathology images was studied. The study comes to the following conclusion :"There was no statistically significant difference in the diagnostic accuracy between noncompressed (bit map) and compressed (JPG) images. There were also no differences in the acceptability, confidence level, and perception of image quality." In [3] the feasibility of lossy compression of digitized images of chromatic microscopic pathology specimens and their clinical assessment was investigated. Int this study "the effect of compression was measured under two distinct perceptual criteria, just noticeable difference (j.n.d.) and largest tolerable distortion (l.t.d.), differing in the involvement required from subjects, who were experts in pathology." The authors note: "The results of this study suggest that (...) there is relatively good agreement among expert observers when asked to indicate how much compression is tolerable before the diagnostic essence of an image has been compromised. This study also indicates that remarkably high compression ratios are tolerable in diagnostic telepathology and that the tolerance for compression varies across subspecializations." [4] evaluates the specific properties of microscopic images versus so-called "natural" images. One interesting point the authors develop is the following: "We found that pathological microscopic images have much wider chrominance-component spectrums (spatial frequency) than do general images. This indicates that when compressing pathological microscopic images, a large color difference is produced as a result of subsampling chrominance components. Such results have also been confirmed by subjective tests." All of the above mentioned studies indicate that compressed microscopic images can be used in clinical assssment.

In the following some papers that develop original comprssion algorithms for microscopic images are reviewed: Okurma et al. [5] studied the characteristics of pathological microscopic images (PMI). Although colorless by nature, sample images are prepared by using special dyes producing color. When comparing these sample images with natural images based on CIE chromaticity diagrams, it can be shown that PMI are more concentrated around specific color components than their natural counterparts. Moreover, after converting PMI to YUV colorspace, its U and V components are positively correlated and are distributed in a wide area in the U-V plot. Further analysis yields that the spatial-frequency band of the chrominance components in PMI is remarkably wider than in natural images. The authors show that downsampling these components as in JPEG results in untolerable color distortion, and therefore discard JPEG as a coding candidate for PMI.

Nakachi et al. [6] developed a full-grown coding scheme for PMI. They avoid the effects of chrominance downsampling by using a Karhunen-Loève Transform (KLT), its main advantages being to reduce correlation between RGB colorcomponents and biasing the signal energy between the transformed components. Ladder networks are used to implement KLT. Experiments show that the KL-transformed images have lower entropy than their RGB or YCbCr counterparts. The actual coding process involves a S+P transform followed by a SPIHT coder for each transformed component. Simulation results prove that PSNR values of the developed method are significantly higher than the respective values for JPEG over different Bits/Pixel rates. Compression ratio values are in the range of 1.7:1 for the chosen image dataset. To the best of our knowledge, there have been no follow-ups to the research described in this paper.

A much larger branch of research activities on efficient coding of medical images involve wavelet approaches to the problem. [7] offers a clear introduction to the field.

Manduca [8] presented a study comparing the performance of JPEG, standard wavelet (using run-length and arithmetic coding) as well as wavelet transform followed by a SPIHT coding method. For four different images ('Lena', MRI, CT and X-ray) and compression ratios from 10:1 up to 40:1, the RMS errors of the three methods was compared resulting in a distinguishably better performance of SPIHT, followed by standard wavelet compression and lastly normal JPEG.

Arya et al. [9] use a vector quantisation approach for coding medical image sequences. Using interframe correlation by applying a 3-D vector scheme yields significantly higher PSNR values than baseline H.261 video codec. Since our future research will be dedicated to single images and not sequences of such, an approach like this doesn't seem feasible for our goals.

Gormish et al. introduced their CREW compression system in [10]. This system is lossless and idempotent, using a customised reversible colortransform, a wavelet transform and a quantization via alignment routine, in which the frequency bands are "aligned" following a selectable rule. CREW has a tagged file format, that also contains information about importance levels of certain regions and not only pixel data. Experimental results show a compression gain of about 10% in Bits/Pixel. Note that this study aims not particularily at medical, but general high quality images.

Zamora et al. [11] worked on a particular problem, namely compression of images showing osteoporotic bone. They exploit certain properties of the image data, namely its small variance in color. For that reason run-length coding is a well-suited approach to coding these types of images. Data given by the authors confirms that run-length coding, though quite a simple technique, is competible with adaptive arithmetic coding, which again can achieve entropy values very close to the input data's entropy. Assuming a six-color model for the input data compression ratios can go up to 100:1 with low computational effort. Again, the models used in this study are not easily transferable to our problem formulation.

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