Q6) Research paper details.
Title : Low Complexity Image Compression of Capsule Endoscopy Images .
Author List : Aviv Barabi, Dvir Sason and Rami Cohen
Venue: Signal and Image Processing Lab (SIPL) Department of Electrical Engineering Technion - Israel Institute of Technology Technion City, Haifa 3200000, Israel

a) Capsule endoscopy is a procedure that uses a tiny wireless camera to take pictures of your digestive tract. A capsule endoscopy camera sits inside a vitamin-size capsule you swallow. As the capsule travels through the digestive tract, the camera takes thousands of pictures that are transmitted to a recorder the persons wears on a belt around the waist.Capsule endoscopy helps doctors see inside the small intestine — an area that isn't easily reached with more-traditional endoscopy procedures . Capsule endoscopy can reveal areas of inflammation in the small intestine , diagnose cancer. Capsule endoscopy can show tumors in the small intestine or other parts of the digestive tract.

Reason of using compression : Although the transmission of the image data occupies about 90% of the total power in the capsule endoscopy, the data should be first compressed to reduce the power of the image data transmitting and the communication bandwidth. Yet, it is necessary to save the resolution of the constructed image because the images may be distorted while physician applies zooming to perform detailed diagnosis. Hence there is need of compression.
Source : google searches (Mayo clinic) and the paper mentioned .

b) The images are captured using a Bayer filter mosaic. In the paper , they adapted the JPEG algorithm for compressing Bayer images. They used transformation to the YCgCo color space and appropriate optimization of parameters to achieve significant improvement over the standard JPEG. Baeyer images capture only one of RGB colour per pixel so they decompose the image to different colours and compress them seperately.
The unique color distribution pattern in the Bayer image is well captured by representing it in the YCgCo color space so they used a transformation matrix (linear) to convert RGB to YCgCo space.
Bayer images are composed of 2 times more green value pixels than red and blue, where the green color contributes most to luminance information hence Y (upper left and lower left luma) was twice as much as Cg and Co.
A more hardware efficient version of DCT called integer DCT (ICT) was used for JPEG. This transform requires multiplication of the pixel values by powers of two, which can be implemented efficiently using shift operations. Varying block sizes such as 4×4, and 8×8 were used.

The quality measure used is the peak signal-to-noise ratio (PSNR) measured in dB
$\mathrm{PSNR} = 10 \log \frac{255^2}{MSE}$
where MSE denotes the mean squared-error between the original Bayer endoscopy image and its reconstructed version

Reconstruction Technique (Optimisation function)

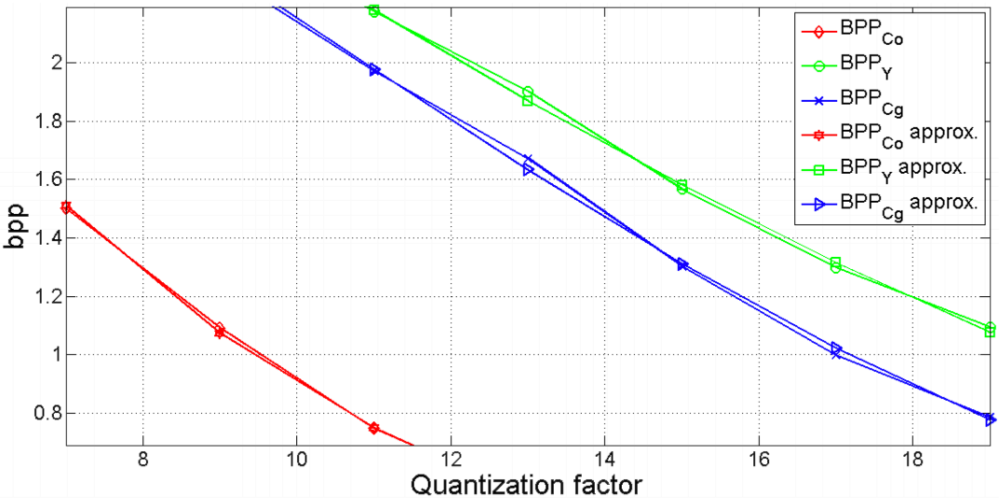
Since different colours were processed independently , so they require different quantization factors (to be used in jpeg decompressing) according to the importance of the colors to the reconstructed image quality. To get the appropriate quantization factor for each color component, expressions for PSNR and bit-per-pixel (bpp) as a function of the quantization factor of each color component are used.

The bpp of the total Bayer image is: bpp $=\frac{1}{2} bpp_Y + \frac{1}{4} bpp_{Cg} + \frac{1}{4} bpp_{Co}$

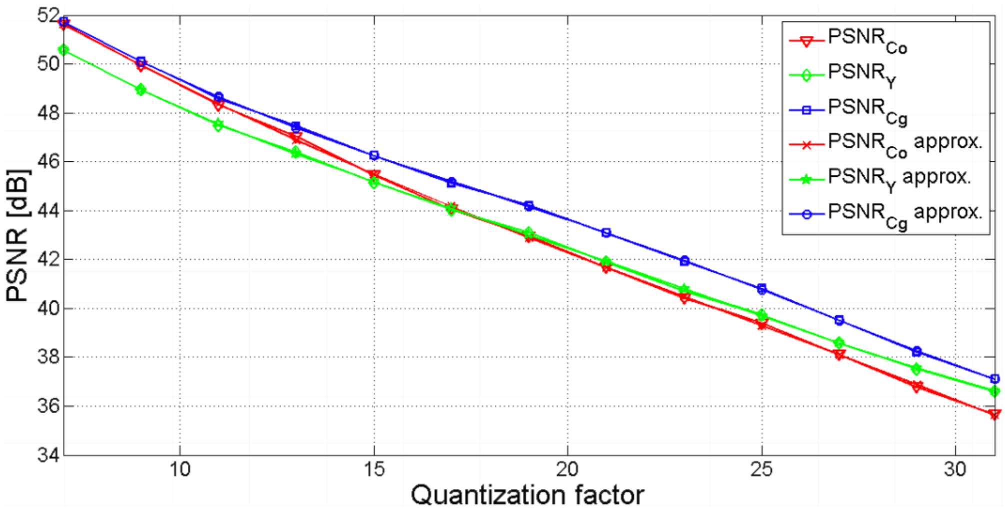
$$PSNR = -10\ log(\frac{1}{2}.10^{\frac{-PSNR_y}{10}} + \frac{1}{4}.10^{\frac{-PSNR_{Cg}}{10}} + \frac{1}{4}.10^{\frac{-PSNR_{Co}}{10}})$$

The function to minimize is the bpp , where the quality constraint is a PSNR value higher than a predefined threshold. The variables are the three quantization factors Q_Y, Q_{Cg}, Q_{Co} for each colour component.
The resulting optimization problem is:
Variables Q_Y, Q_{Cg}, Q_{Co}
minimize bpp (Q_Y, Q_{Cg}, Q_{Co})
s.t. PSNR $(Q_Y, Q_{Cg}, Q_{Co}) \geq$ Threshold.

For solving this optimization problem, the empirical bpp and PSNR curves were approximated as a function of each quantization factor to degree 5 polynomials using sample Bayer images (approximation shown in figure below)
These polynomials were then used for providing expressions for bpp and PSNR in the optimization problem.
The optimization problem could then be solved analytically using Lagrange multipliers or optimization tools such as CVX(tool for Convex Optimisation).



(a) bpp.



(b) PSNR.