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Digital Image fundaments through Visible Spectrum

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Abstract— **In this paper we are going to analyze the images of the complete visible spectrum (400-700 nm) and images on specific wavelengths. The images are made through standard digital image processing method in separation of specific wavelenghts. In software package Matlab and VC Demo obtained images are analyzed through SPIHT and JPEG compression with different bit rates (bpp), then the analysis is performed through Entropy of the image and the SSIM algorithm. EZW and JPEG compression are selected as typical representatives of DCT and Wavelet compression, respectively. As a scientific contribution there are some of analysis of the quality of compression between three compression algorithm, and also it determines and in which part of the spectrum is the greatest potential (entropy) and which part of the spectrum has the highest structural similarity with the complete spectrum.**

Keywords - Spectroscopy; Visible Spectrum; Bit per pixel (bpp); Digital Image Processing

I. INTRODUCTION

Spectroscopy was originally the study of the interaction between radiation and matter as a function of wavelength (λ) [1]. In fact, historically [2], spectroscopy referred to the use of visible light dispersed according to its wavelength, e.g. by a prism. Later the concept [3] was expanded greatly to comprise any measurement of a quantity as function of either wavelength or frequency. Thus it also can refer to a response to an alternating field or varying frequency (v). A further extension of the scope of the definition added energy (E) as a variable, once the very close relationship $E = hv$ for photons was realized (h is the Planck constant). A plot of the response as a function of wavelength - or more commonly frequency -is referred to as a spectrum; see also spectral line width.

Visible light lies in the wavelength range (4–7)*10^{-7} m. To keep the numbers more manageable it is usually quoted in nanometers (10-9 m) so that the range becomes 400–700 nm [4], [5]. When light is absorbed by a material, valence (outer) electrons are promoted from their normal (ground) states to higher energy (excited) states [6], [7].

II. PARAMETERS FOR IMAGE ANALYSIS

A. JPEG

The JPEG method is used for the compression of still images and it belongs to the group of "intra-frame" compression methods. The similar standard – MPEG is used for the compression of moving images and it belongs to the group of “inter-frame” compression methods. In order to meet the diverse needs of many applications, the JPEG standard includes two basic compression methods: a DCT (Discrete Cosine Transformation) based method for "lossy" compression and a predictive method for "lossless" compression [8]. The "lossy" compression - called Baseline method - is the most widely implemented JPEG method. In the baseline mode, the image is divided into 8x8 pixel blocks and each of these is transformed using the DCT. The "power" of compression lies in the quantization of DCT coefficients with a uniform scalar quantizer, zig-zag scanning of the block and entropy coding using the Huffman code. Standards like JPEG [9] are very well established, including hardware and image editing software support [10]-[12].

B. SPIHT

SPIHT is computationally very fast and among the best image compression algorithms known today [13]. According to statistical analysis of the output binary stream of SPIHT encoding, propose a simple and effective method combined with Huffman encode for further compression [14]-[16].

C. EZW

EZW (Embedded Zero-tree Wavelet) algorithm enables the progressive transmission of a compressed image. By using this algorithm, it is possible to stop the encoding process at any moment when the desired bit-rate is achieved. In the wavelet decomposition, the image is divided into sets of frequency/spatial hierarchical sub-bands. The important premise of the zero-tree algorithm is that substantial redundancy exists between the "parent" and "child" samples within the sub-band hierarchy [17].

EZW algorithm has very good PSNR (peak signal to noise ratio) performance compared to other compression algorithms with low bit-rates. It keeps significant coefficients in all levels. The main drawback of the EZW algorithm is its complexity, which impacts calculation resources [18], [19]. The EZW algorithm is used as a base for development of large number of similar compression methods. One of the most popular methods is SPIHT (Set Partitioning In Hierarchical Trees). In the original EZW method, arithmetic coding of the bit streams was essential in order to compress the ordering information as conveyed by the results of the significance tests.

Unlike the EZW, SPIHT doesn't use arithmetic coding. The subset partitioning is so effective and the significance information so compact that even binary un-coded transmission achieves similar or better performance than EZW. The reduction in complexity from eliminating the arithmetic encoder is significant [20].

D. Entropy

According to Shannon who uses probability theory to model information sources, i.e., the data produced by a source is treated as a random variable. The information content, Shannon's entropy of a discrete random variable X that has a probability distribution px= (p1, p2,…,pn) is then defined as

$$H(X) = H(p_x) = \sum_{i-1}^{n} p_i \log\left(\frac{1}{p_i}\right) \tag{1}$$

The term log 1⁄pi indicates the amount of uncertainty associated with the corresponding outcome. It can also be viewed as the amount of information gained by observing that outcome. Thus, entropy is merely a statistical average of uncertainty or information [21].

Shannon also provides an axiomatic derivation of: This is the only function of p that is continuous with p; increases with n; and is additive, i.e., the entropy of two random variables is the sum of the entropy of the first and the entropy of the second given the first. Yet, this derivation is not the key reason that entropy plays a central role in today's information theory. Using previous equation, many information-theoretic results can be derived concisely. For example, it is known that a uniquely decipherable code required for X has a minimum average length bounded by H(X) and H(X) + 1 [22].

Entropy is the greatest when all samples are equally likely, i.e., H ((p1, p2,…, pn)) ⩽ log n [23].

E. Index of structural similarity (SSIM)

Index of structural similarity (SSIM - Structural Similarity Index) is one of the more popular algorithms for assessing of image quality. The algorithm is based on the idea that the images of natural scenes are very structured (highly structured) and that the human eye is sensitive to structural distortions [24], [25]. This means that samples of image signal is very dependent on each other, especially if they are spatially close.

SSIM values are defined in the window moves pixel by pixel from the upper left portion of the image to the lower right. In this way a map of SSIM values, it can be viewed as a map image quality that is being assessed. Summary, quality is defined as the mean quality maps and obtained medium SSIM (Mean-SSIM) and MSSIM index gives a value for the quality of the whole image

$$MSSIM(\mathrm{X},\mathrm{Y}) = \frac{1}{M}\sum_{j=1}^{M} SSIM(\mathrm{x}_j,\mathrm{y}_j) \tag{2}$$

Where X and Y are the original and test images, respectively, xj and yj parts of image in the j-th window and M is number of windows [26].

III. SYSTEM MODEL

For analysis we used the original non-compressed images in TIFF format with a resolution of 512x512 and 24 bit-depth, and 72 dpi for horizontal and vertical resolution, as shown at Fig. 1.

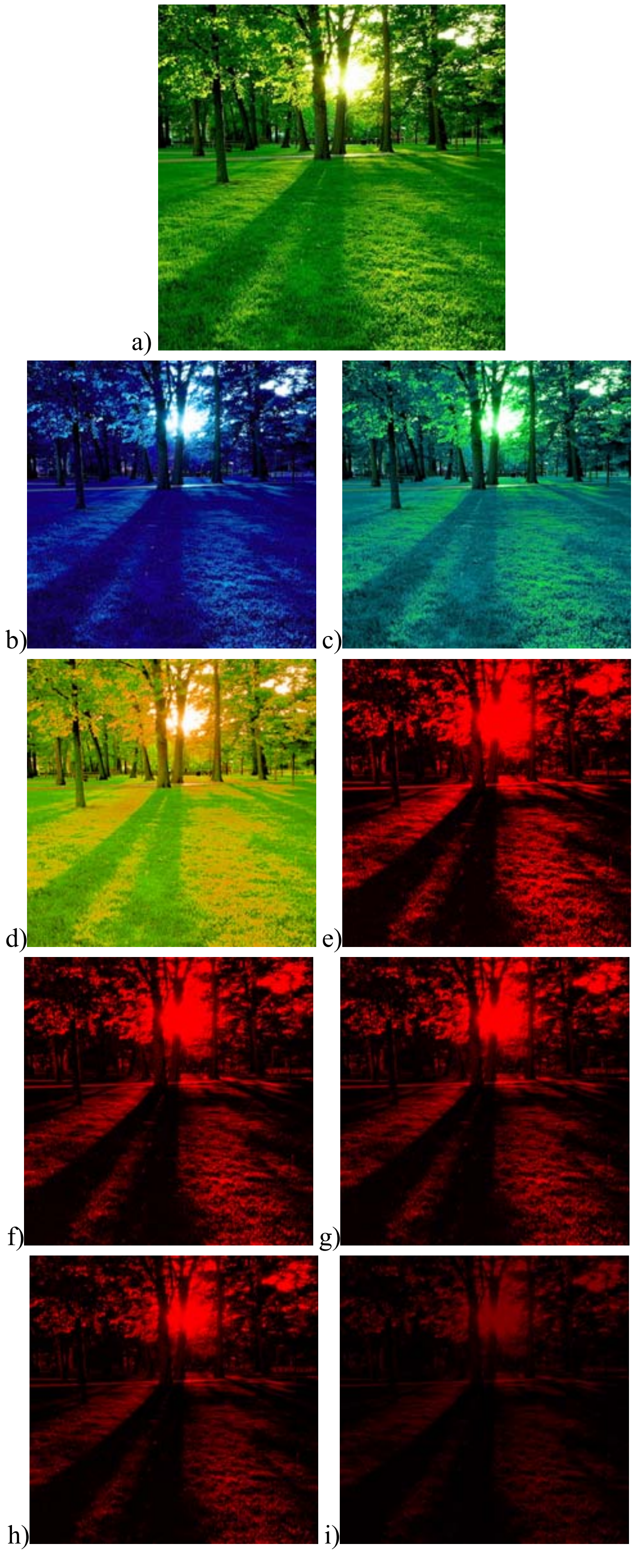
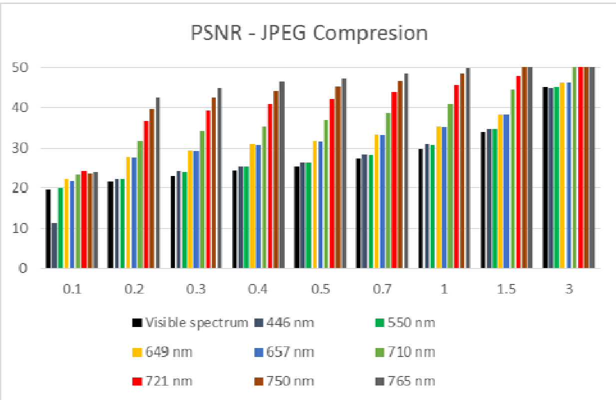


Figure 1. a) The full visible spectrum, filtered through b) 446 nm, c) 550 nm, d) 649 nm, e) 657 nm, f) 710 nm, g) 721 nm, h) 750 nm, i) 765 nm

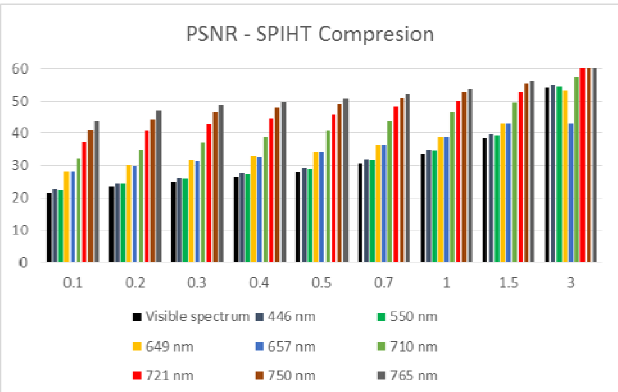
Obtained image was analyzed through VC Demo software and with software options JPEG, SPIHT and EZW compression in order to get PSNR, MSE and SNR for different bit rates (bits per pixel - bpp). Bit rate values are taken like 0.1, 0.2, 0.3, 0.4, 0.5, 0.7, 1, 1.5 and 3 bpp. Based on this measurement we will determine compression quality, and which of the three compression gives better results for image processing. In the next step by a software package Matlab we analyzed the Entropy of all the images individually, in order to determine which part of the spectrum have the greatest potential. Also, with the help of the software package Matlab, and used SSIM algorithm to determinate relationship between the images of full visible spectrum (400-700 nm), and images on a single wavelength. This will determine the structural similarity of images full visible spectrum image in a particular wavelengths.

IV. Results and Discussion

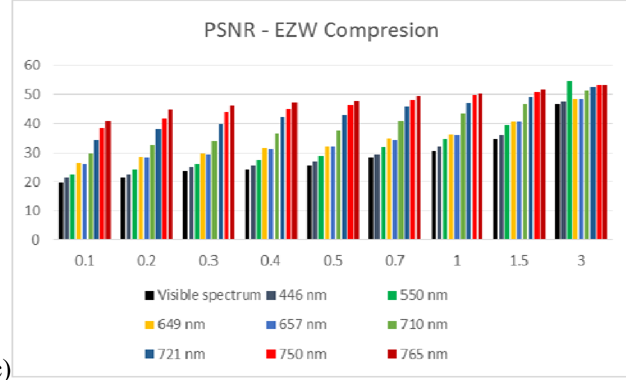
To have a better representation in quality compression differently filtered images is determined by the peak signal to noise ratio (PSNR) [27] and its change is graphically presented according to the change of bpp. Fig. 2 is a graphic representation of PSNR for various values of bpp when using JPEG algorithm, SPIHT algorithm and EZW algorithm, respectively. Compression algorithms are applied over the entire visible spectrum and images filtered by different wavelengths.



a)



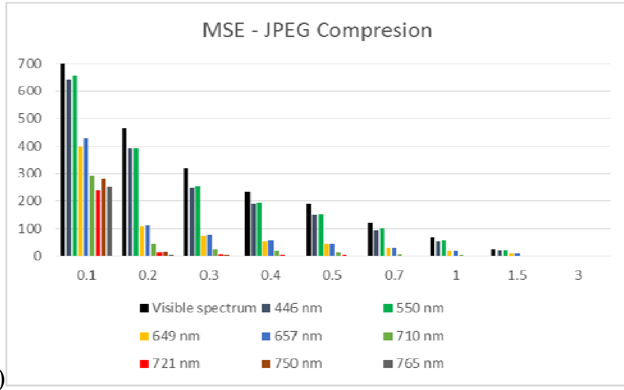
b)



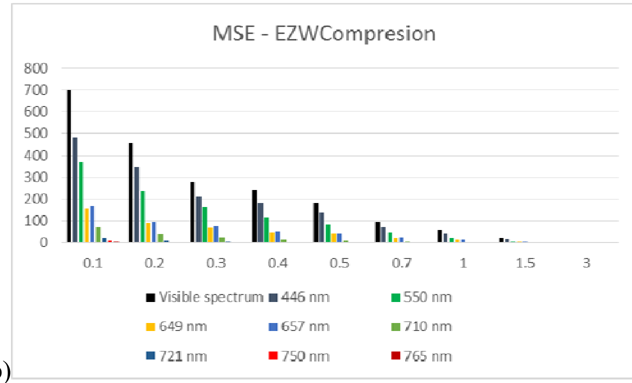
c)

Figure 2. Change PSNR for compression with, a) JPEG, b) SPIHT and c) EZW algorithm

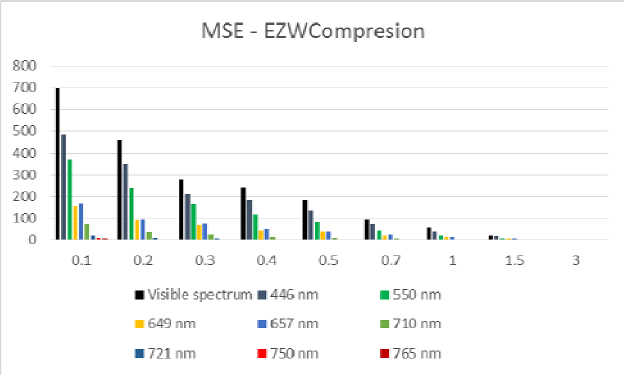
According to Fig. 2a, Fig. 2b and Fig. 2c, the PSNR [28] algorithm analysis shows the ratio of JPEG, EZW and SPIHT compression at different wavelengths. The analysis results show that the best results in the observing range bpp provides SPIHT compression, compared to EZW and JPEG compression. At extremely low bit rate (0.1 bpp) extremely bad results showing JPEG compression. While when it comes to the relationship between JPEG and EZW at the entire observed range EZW provides slightly better results. It should also be keep in mind that "lossy" compression algorithm possible results PSNR is between 20 and 55 dB [29].



a)



b)

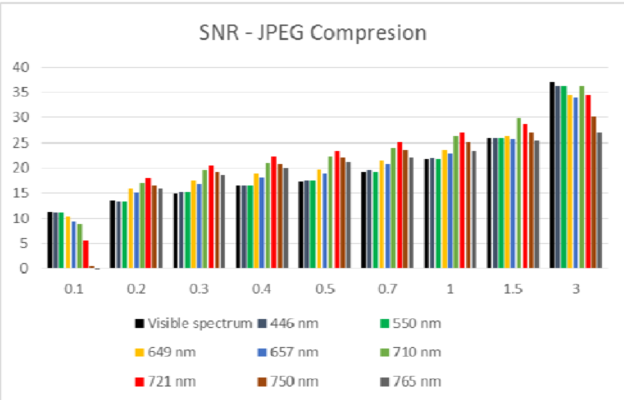


c)

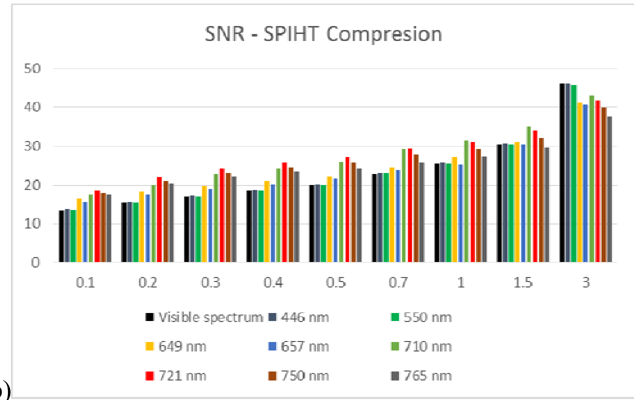
Figure 3. Change MSE for compression with, a) JPEG, b) SPIHT and c) EZW algorithm

From Fig. 3a, Fig. 3b and Fig. 3c it can be seen that with the increase bpp reduces mean squared error (MSE) on images with full visible spectrum and on the image filtered through a specific wavelength. Mean square error for the observed range bpp is more visible in JPEG compression, and better results given in wavelength 650 nm and higher, especially in SPIHT compression. While the largest mean square error particularly at lower bit rates bpp provides JPEG compression.

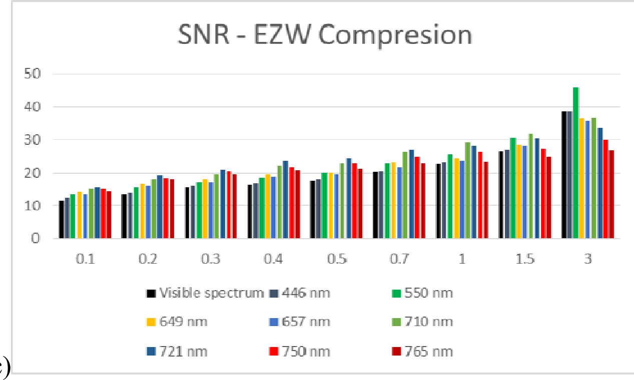
According to the same law as in PSNR algorithm changes SNR value. As shown in Fig. 4a, Fig. 4b and Fig. 4c with the increase bpp causes an increase signal to noise ratio (SNR). This rule change applies to all forms of compression algorithms. In JPEG compression can be concluded that the increase in SNR values for image filtering higher wavelengths are expressed more than SPIHT compression.



a)



b)



c)

Figure 4. Change SNR for compression with, a) JPEG, b) SPIHT and c) EZW algorithm

Analysis of the relationship between compression at different wavelengths was found that SPIHT algorithm on the entire observed range provides the best results. Except at extremely low bit rate (0.1 bpp) where JPEG provides a bad result, the rest of the spectrum JPEG provides almost the same value as the EZW compression. Fig. 5. is a graph which presents the entropy values for all the analyzed image. It may be noted that the potential of image, the most in the beginning part of the visible spectrum that defines the red color, and decreases towards approaching the borders of the visible spectrum. SSIM algorithm determines the similarity between two images by comparing their illumination. Comparison was made between Fig. 1a and images at different wavelength. The results in Fig. 6 show that with increasing wavelength SSIM drastically decreases.

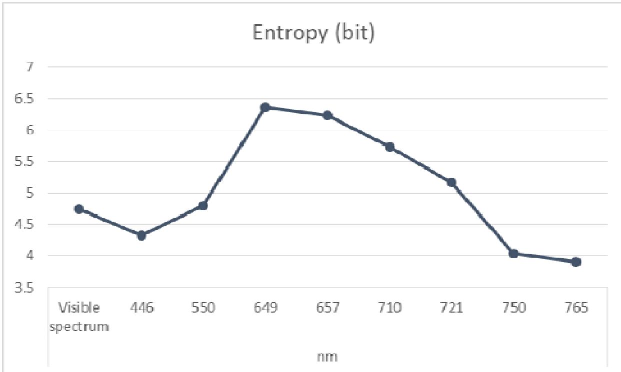


Figure 5. Values of entropy for analyzed image

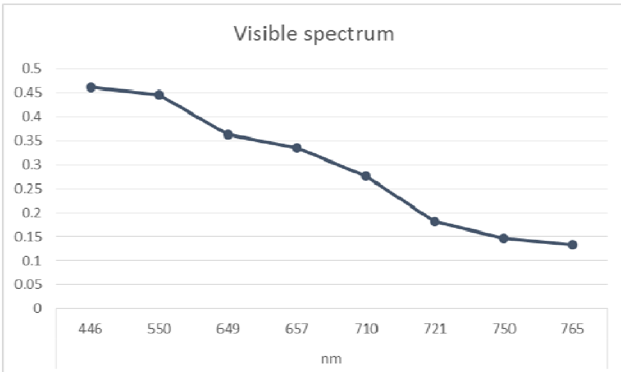


Figure 6. SSIM values of the analyzed image

V. CONCLUSION

For PSNR algorithm at extremely low speed (0.1 bit / picture element) compression quality is extremely better at higher wavelenghts with SPIHT compression. While generally when comparing PSNR analysis algorithm for JPEG, SPIHT and EZW compression, SPIHT compression gives insignificantly better results. Based on the results mean square error (MSE) can be concluded that the image quality at higher values of wavelengths and at low speeds the transmission better in SPIHT compression. As in the previous two cases with SNR, SPIHT compression algorithm gives insignificantly better results compared to JPEG compression and EZW compression. In terms of compression method, the analysis of all images with different wavelengths SPIHT compression produces better results as compared to the JPEG and EZW compression method. Entropy is given insight into the potential of images from different wavelengths, and provides insight into the potential (entropy) images of the highest in the beginning part of the visible spectrum that defines red color. Specifically, in this analysis at wavelengths 649 and 657 nm. The analysis of the SSIM algorithm confirms the theory that an increase in the wavelength decreases energy [30].

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