The Effect of the Contrast Enhancement Processes on the Structural Entropy of Colonoscopic Images

Gábor Csizmadia[1] and Szilvia Nagy[1]

Abstract – **Gastroenterological cancers, especially the colorectal cancers are in the top four lethal cancer types, appearing in both the male and female population. Colonoscopy is the usual way to diagnose the malign polyps in the colonic or rectal section of the enteron. A trained gastroenterologist can identify the potentially malign polyps, which need to be removed, and sent to biopsy only from the topology of the endoscopic image taken of the excrescence, and the structural entropy based analysis is one of the candidates to be included as a property in evolutional or learning algorithms, that help the decision of the medical staff members.**

In this paper we analyze, whether contrast enhancing algorithms change the type of localization of the image. Usually the colonoscopic images are of not good quality, practically only the shades of pink are present, so contrast enhancement is necessary, and if these processes have influence on the structural entropy of the image, then they should not be applied in the evolutional algorithms.

Keywords – **Colonoscopy, image processing, structural entropy, contrast enhancement.**

I. Introduction

Colorectal polyps are defined as lesions of the mucosa in the colonic or rectal tract of the bowels, that are protruding into the lumen [1]. About 60 % of the population gets polyps in their colorectum, however, most of these polyps are benign and have no possibility to develop into a benign lesion: the rate of the colorectal cancer is around 5-6 % in the population. One can think, that it would be a safe - though costly - solution to remove all the polyps detected in the bowel, or at least all those of larger size, but some of these lesions have tendency to remain safe, and/or regress, if left in situ, but removing them can cause unwanted side effects as all the invasive operations. The colorectal polyps are usually classified into several classes, even the ones protruding into the bowel. (The non-protruding ones can be slightly elevated, flat or depressed, of those the latest is considered to be potentially carcinogenic, the flat ones are mostly harmless.) The protruding lesions are classified as benign, pre-malign and malign, of those the distinction of the pre-malign and benign polyps is the more complicated task, and the early diagnosis significantly increases the chance of survival. Unfortunately, in most of the countries there is no organized testing of the population.

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The pre-malign lesions can be classified as adenomas and serrated polyps, each group having several sub-groups. The diagnosis is based on biopsy results, and in the last few decades, as the microscope-, or at least higher zoom-aided endoscopy developed, the topology of the patterns is also helpful. Kudo and his coworkers have introduced a classification scheme based on the patterns of the pits on the surface of the polyps [2-4]. Narrow band imaging (NBI) can also increase the chance of detecting malign or pre-malign parts of the polyp, as well as the use of chromoendoscopy, where the lesion is sprayed with a bright blue dye (0.2-0.4 % solution of indigo carmin), which sits into the pits of the structure [1,5]. A polyp with normal, high-zoom endoscopy, with NBI and one with chromoendoscopy can be seen in Fig. 1

The Kudo classification scheme starts with Class A1, where the pits are round, regular, and A2, with stellar, asteroid, or papillary shaped pits. This class is usually considered as non-adenomous, and these polyps are mostly light in color in the NBI. Class B has three subclasses, they are indicating adenomas. B3 is either tubular, with large or small patterns - classes $B3_L$ or $B3_S$ -, or into the later class, round pits, that are smaller than the regular size can be classified. Usually in these cases, the NBI shows darker parts, too. The class B4 contains dendritic, branched, gyrus- or sulcus-like pit-structure, whereas B5 has irregular shaped patterns. Most of these patterns are dark in NBI.

Distinguishing the classes above needs a qualified eye [6,7], but the gastroenterologist could be helped with several image-processing algorithms. As it can be seen in Fig. 1, most of the images are of not good quality, the contrast is small, especially in case of white-light images, even though the dynamic range is large die to the black background patterns at the corners of the image and the reflections of the light from the surface of the wet bowel. Edge detection algorithms can also be applied, and learning algorithms based on various image properties could also be developed to help the diagnostitian.

In this article we present a possible candidate, the structural entropy based localization analysis, for the qualification of the images and study, how the localization type changes after histogram stretching, and reflection filtering.

II. Contrast Enhancement and Reflection Filtering

As a first step, we have prepared the images for further analysis. After separating the color channels, we received histograms like the one shown in Fig. 2, where after the peak around the 0 value, we received a valley, then the valuable part of the histogram, and after another depression, the peak

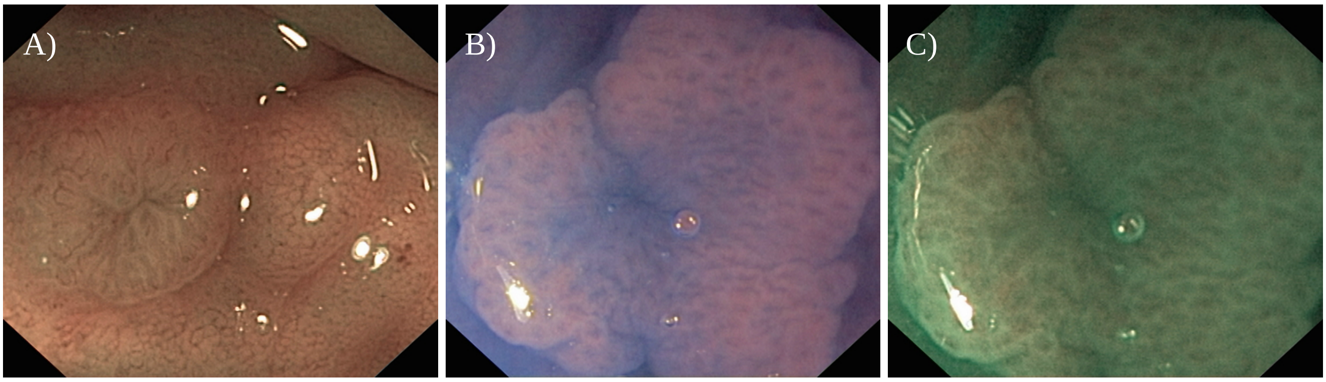

Fig. 1. White-light (A), chromoendoscopy (B) and narrow-band imaging (C) pictures of colorectal polyps. Pictures were taken at the Petz Aladár Hospital Győr, Hungary

due to the reflections followed around the lightness value 255. As a first step we detected the borders of the valuable part of the image, then stretched that part of the histogram to the 0 to 255 domain, and substituted all the reflection and background shades that were out of the valuable part of the histogram with 0. The resulting image can be seen in Fig. 3. A). The contrast enhancement is clearly visible compared to Fig. 1. A).

It is clearly visible, that although the shapes were more detectable on the picture, the places of the reflections still had a bright frame, that can disturb all later algorithms, thus we deleted them by a selective substitution algorithm: if the average of the first and second nearest neighbors of the pixel - altogether 24 pixels - differed from the brightness value of the pixel itself by more than a threshold, we substituted the pixel value either by the average of the neighbors, or by 0. The first substitution is more suitable for later edge-detecting algorithms, whereas the second is more appropriate for structural entropy based further studies. Both images can be seen in Fig 3. B) and C), respectively.

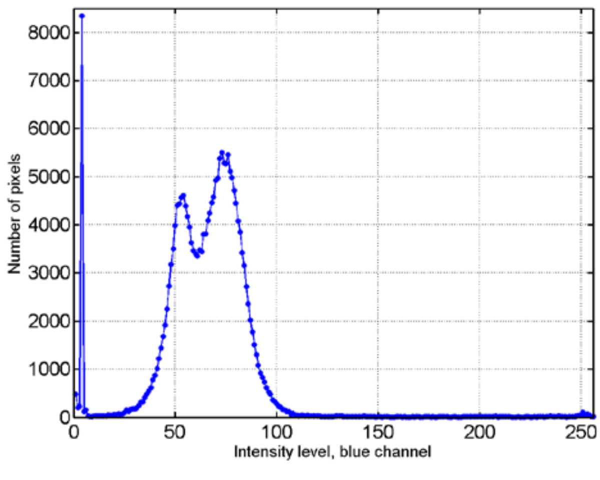

Fig. 2. The histogram of the blue color channel of the picture in Fig. 1. A). The valuable part between approximately 25 and 110 is detectable. The value of the background is around 15-20, so a level of 20 for the lower, and 30 for the higher end was set as thresholds in the algorithm that detected the borders of the valuable part of the histogram. The other two color channels, as well as the grayscale transformed image have similar characteristics

III. Structural Entropy and the Localization

The structural entropy based localization characterization was developed for quantum mechanical purposes, namely for describing electron density distributions [8], and applied for detecting structures and superstructures in mezoscopic systems [9-11]. Later the method was introduced to scanning electron microscopy image processing [12], and it proved to be suitable for characterization of the surface roughness - and thus the catalyzing ability - of gold catalyzers [13].

The structural entropy and the spatial filling factor can be introduced by using the *n*th Rényi entropies

$$S_n = \frac{1}{1-n} \ln \left(\sum_{i=1}^{N} I_i^{\,n} \right), \tag{1}$$

where I_i denotes the normalized pixel intensity, and N the number of pixels. The pixel intensities should be normalized to 1, as the entropies are defined for probability distribution, i.e.,

$$\sum_{i=1}^{N} I_i = 1. \tag{2}$$

Of course, all the intensities should be non-negative, $I_i \geq 0 \quad \text{for } i = 1, \ldots, N$.

The first Rényi entropy is the well known Shannon entropy, $S_1 = \sum_{i=1}^{N} I_i \ln I_i$, it describes the general disorderedness of the system, whereas the second of the Rényi entropies, $S_2 = \ln \sum_{i=1}^{N} I_i^{\,-2}$, is practically the logarithm of the average number of light pixels. The difference of the two values it the structural entropy, it is the measure of the “disorder” in the shape of the distribution, without the spatial “disorder” (i.e., without S_2). If we select other two Rényi entropies, the result will be also suitable for characterizing some kind of shape of the distribution.

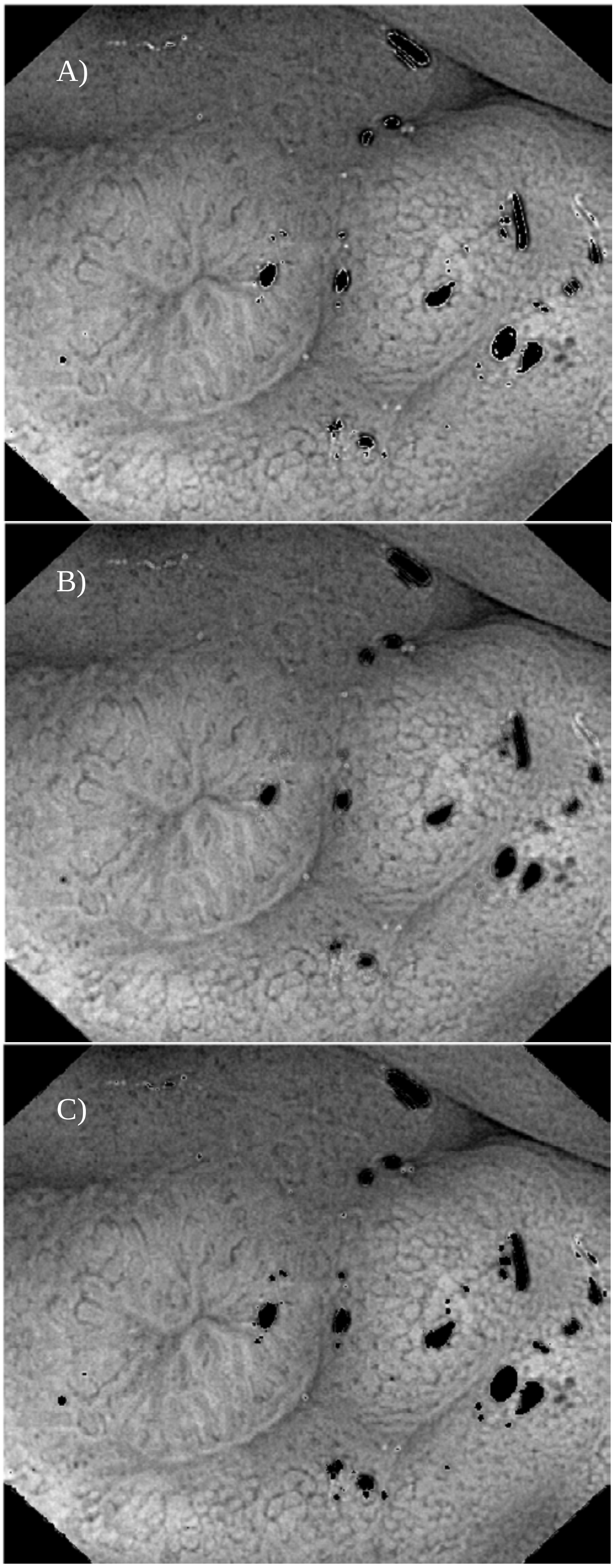

Fig. 3. Processed result examples of the blue channel of the image in Fig. 1. A). Subfigure A) shows the result of the histogram stretching, B) shows the results of the reflection filtering, if the substitution value is the average of the neighboring pixels, and C) the reflection filtered image with substitution value 0. The white frames around the former reflection spots are significantly decreased

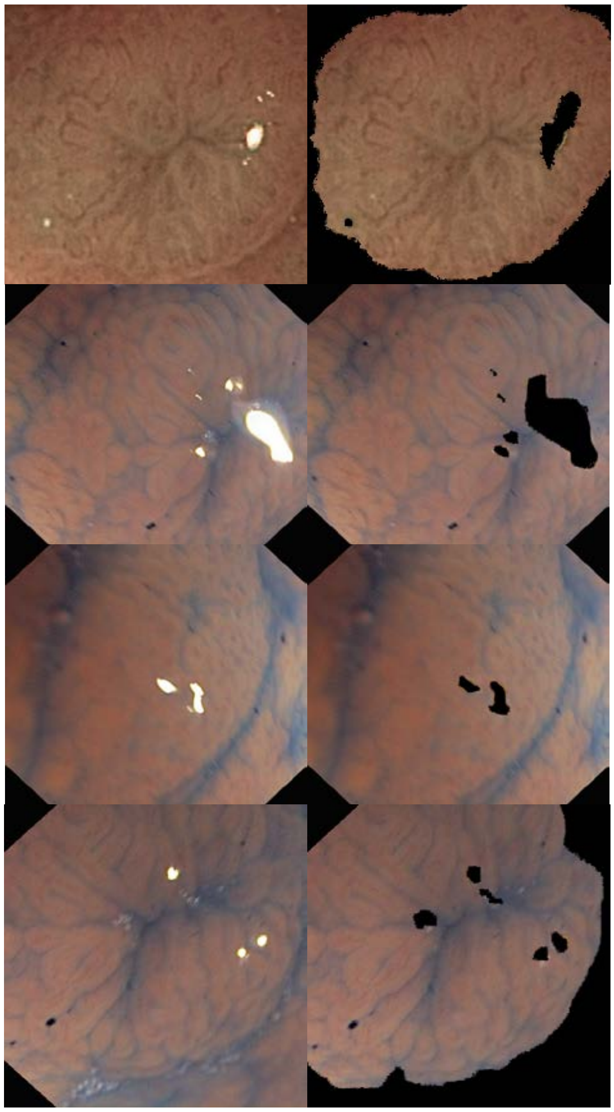

Fig. 4. Some of the studied images. left hand side column shows the original images, the right hand side column the image masked manually. Pictures were taken at the Petz Aladár Hospital Győr, Hungary

Usually the following two of these Rényi entropy differences are studied:

$$S_{str} = S_1 - S_2, \tag{3}$$

$$-\ln q = S_0 - S_2, \tag{4}$$

where q is a quantity in quantum mechanics, called spatial filling factor. The structural entropy vs. the spatial filling factor of the images are plotted, thus receiving a localization map. On this map, each localization maps have well distinguishable curves. If the distribution has a given type of localization, e.g., it decreases to zero according to a Gaussian function, then the image's $S_{str}(q)$ point will take place on the curve corresponding to the Gaussian localization type.

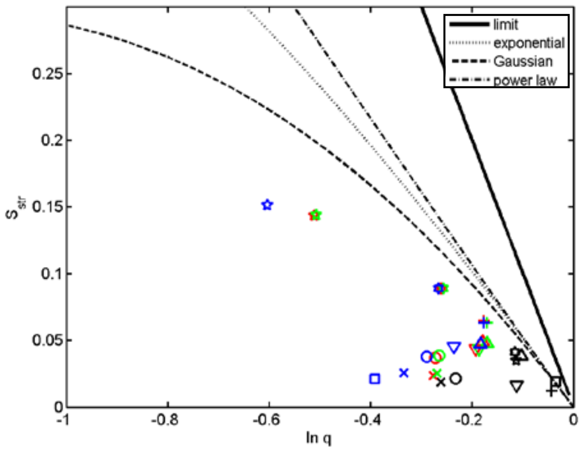

Fig. 5. The changing of the localization type of the images in Fig. 4. Blue color channel. The 1st row in Fig. 4 is denoted by ○ and □, the second one by × and +, the third by triangles, and the last one by pentagram and hexagram. The colors mean the following: black: original, red: histogram stretched, green: filtered with substitution of the average of the pixels, blue: filtered with substitution of 0

IV. Localization Types

Images, like the one in Fig. 1. A), and in Fig. 3. are studied at various stages of the procession. The results are compared to the original images' localization type as well as to the localization types of images processed by hand: to images where the reflection spots were covered by a black mask. The analyzed pictures are shown in Fig. 4, the results for a typical colour channel are summarized in Fig. 5.

V. Conclusion

In case of most of the images, the contrast enhancement does not change much the localization types, compared to images with the reflection masked by hand, if the masking by hand is not too extensive, i.e., the background is not masked on a large surface. Although the reflection boundaries that are left by the automatic histogram stretching distort the localization type to a quicker one, the local reflection filtering techniques move them back to approximately the localization type of the manually reflection-masked image.

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References

[1] K. Søreide, B.S. Nedrebø, A. Reite et al., „Endoscopy Morphology, Morphometry and Molecular Markers: Predicting Cancer Risk in Colorectal Adenoma", Expert Rev. Mol. Diagn, vol. 9, pp. 125-137, 2009.

[2] S. Kudo, S. Hirota, T. Nakajima, et al., "Colorectal tumours and pit pattern". J Clin Pathol, vol. 47, pp.880-885, 1994.

[3] S. Kudo, S. Tamura, T. Nakajima, et al. "Diagnosis of colorectal tumorous lesions by magnifying endoscopy". Gastrointest Endosc, vol. 44, pp. 8-14, 1996.

[4] S. Kudo, C.A. Rubio, C.R., Teixeira, et al. "Pit pattern in colorectal neoplasia: endoscopic magnifying view". Endoscopy, vol. 33, pp. 367-373, 2001.

[5] J. J. W. Tischendorf, H. E. Wasmuth, A. Koch, H. Hecker, C. Trautwein, and R. Winograd, "Value of magnifying chromoendoscopy and narrow band imaging (NBI) in classifying colorectal polyps: a prospective controlled study", Endoscopy, Volume 39, Thieme, Stuttgart-New York, 2007, pp. 1092-1096.

[6] J. R. Jass, "Classification of colorectal cancer based on correlation of clinical, morphological and molecular features", Histopathology, Volume 50, Wiley, 2006, pp. 113–130.

[7] I. Rácz, M. Jánoki, and H. Saleh, "Colon Cancer Detection by 'Rendezvous Colonoscopy': Successful Removal of Stuck Colon Capsule by Conventional Colonoscopy", *Case Rep.* Gastroenterol., Volume 4, Karger, 2010, pp. 19–24.

[8] J. Pipek and I. Varga, "Universal classification scheme for the spatial localization properties of one-particle states in finite *d*-dimensional systems", *Phys. Rev. A*, Volume 46, APS, Ridge NY-Washington DC, 1992, pp. 3148--3164.

[9] J. Pipek and I. Varga, "Scaling behavior of energy functionals of highly complex distributions", Int. J. Quantum Chem., Volume 70, Wiley, 1998, pp. 125-131.

[10] I. Varga and J. Pipek, "Rényi entropies characterizing the shape and the extension of the phase space representation of quantum wave functions in disordered systems", *Phys. Rev. E*, Volume 68, APS, Ridge NY-Washington DC, 2003, 026202.

[11] I. Varga, E. Hofstetter, and J. Pipek, "One-parameter Superscaling at the Metal-Insulator Transition in Three Dimensions", Phys. Rev. *Lett.*, Volume 82, APS, Ridge NY-Washington DC, 1999, 4683-4686.

[12] L. M. Molnár, Sz. Nagy, and I. Mojzes, „Structural entropy in detecting background patterns of AFM images", Vacuum, Volume 84, Elsevier, Amsterdam, 2010, pp. 179-183.

[13] A. Bonyár, L. M. Molnár, G. Harsányi, "Localization factor: a new parameter for the quantitative characterization of surface structure with atomic force microscopy (AFM)", *MICRON*, Volume 43, Elsevier, Amsterdam, 2012, pp. 305-310.