# STRUCTURAL ENTROPY BASED PROCESSING OF COLORECTAL POLYP IMAGES

**András Fehér, Ádám Békefi, Szilvia Nagy**

Széchenyi István University
Egyetem tér 1, H-jjuuu9026 Győr, Hungary
T. +36 96 613 693; F. +36 96 613 694; E. nagysz@sze.hu.

***Abstract***

*The colorectal tumors are the third or fourth most common cancers in the world, and colonoscopy or virtual colonoscopy are the methods for diagnosing this illness. Most of the colorectal polyps are not malign and do not have the potential to develop into an adenoma, thus taking samples of these polyps and biopsy of these tissue samples are unrequired inconvenience for the patients and unnecessary cost for the medical institutions. Usually a specialist of gastroenterology can distinguish the potentially malign polyps from the benign ones by visual diagnosis, as the topologies are different.*

*The Rényi entropies based structural analysis is a method for characterizing the topologies of any kind of distribution. It is mostly used in solid state physics. With some examples we show, that the structural entropy can be capable of distinguishing polyps, thus determining the localization type of the polyp can help to draw the attention of the gastroenterologist to a possibly malign polyp, or later be a characterizing quantity in genetic or neural network-based algorithms.*

## 1. INTRODUCTION

During colonoscopy a CCD or fiber optic camera, which is placed to the end of a flexible tube, takes live images about the wall of the large bowel. Besides optical visual diagnosis it is also possible to take tissue samples for biopsy and remove malign polyps.

Unfortunately, the images got from colonoscopy are not of very good quality, as the inflated bowel moves continuously, the light-source reflects from the wet surfaces and the lining of the bowel and the polyps are shades of pink colour. Narrow band imaging (NBI) can increase the contrast between veins and the other tissues, and spraying of blue paint - chromoendoscopy - can enhance the topological unevenness [1], as it can be seen in Figure 1.

Colorectal polyps have more types, and only biopsy can decide the true lass of the polyp, but usually morphological characteristics give a very good initial guess [2]. Besides Colonoscopy capsular colonoscopy is also used [3], during these takes, the live video pictures are usually necessary in order to get distance and size information, from single pictures these informations can not be taken, thus any image processing applied during this diagnostic method should be live or last not longer than a couple of seconds.

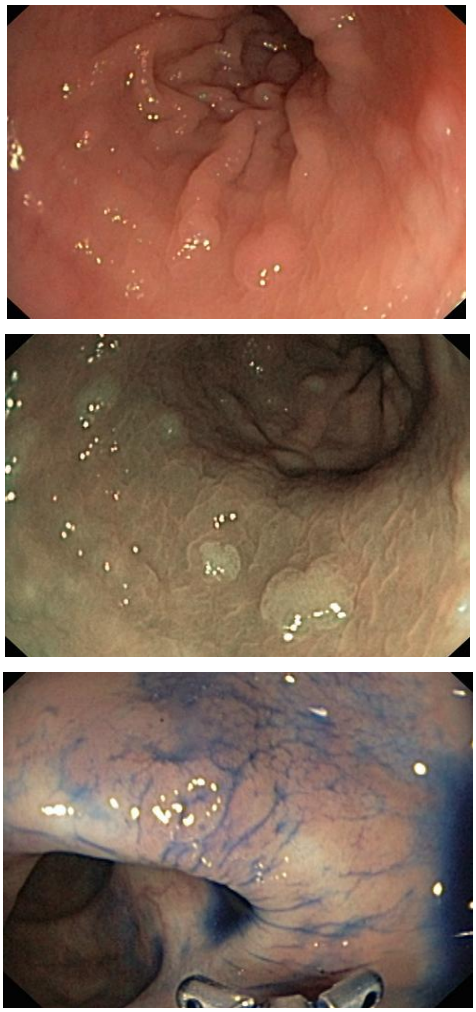


Figure 1. White-light, narrow-band imaging and chromoendoscopy pictures of a patient's colon. Picture taken at the Petz Aladár Hospital Győr.

## 2. STRUCTURAL ENTROPY AND LOCALIZATION

The structural entropy-filling factor based localisation measure was developed by Pipek and Varga [4] for characterizing quantum mechanical electron density distributions [5-7].

The most straightforward method for introducing structural entropy is the following. The *n*th Rényi entropies

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

of a distribution $\{ I_i \mid i = 1, ..., N \}$ are the generalizations of the Shannon entropy

$$S = \sum_{i=1}^{N} I_i \, ln \, I_i . \qquad (2)$$

The distribution should fulfil the properties of a probability distribution

$$I_i \geq 0 \quad \text{for } i = 1,\ldots,N, \qquad (3)$$

$$\sum_{i=1}^{N} I_i = 1, \qquad (4)$$

thus if images are studied, the quantities $I_i$ is the - according to Eq. (4) – normalized pixel intensity corresponding to the *i*th pixel.

The differences of various level Rényi entropies characterize the structure of the distribution. The quantity

$$S_{str} = S_1 - S_2 \qquad (5)$$

is the structural entropy, it consists of two parts, the *S* Shannon entropy gives the general disorder in the studied image, whereas the second Rényi entropy gives the entropy of a system that has a two-valued distribution and the same square-norm as the original system. This results that the structural entropy of two-coloured systems is zero. The difference of the second and zeroth Rényi entropy

$$-\ln q = S_0 - S_2 \qquad (6)$$

is also needed for proper characterisation of the structure: images with e.g. an overall Gaussian or exponentially decreasing characteristic are situated on a given line at the $S_{str}(S_2-S_0)$ plot. Each type of decreasing has different lines. The variable $q$ is known in solid states physics as the filling factor. These $S_{str}(\ln q)$ maps are used also for characterising scanning microscope images and separating superstructures in these pictures [8, 9].

Note, that this type of localization study does not take into account the position of the pixels, just their intensity values, so an image with one large (e.g. Gaussian) structure can have the same dot on the $S_{str}(\ln q)$ map as an image with several smaller structures.

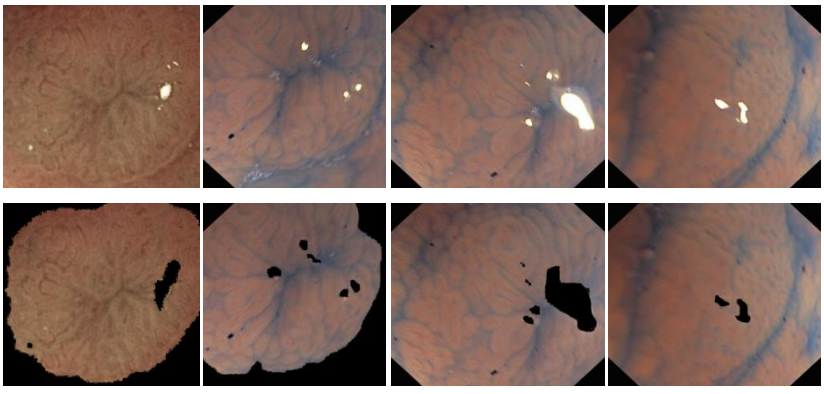
## 3. SAMPLES

The images were taken at the local hospital from two patients. Both patients were on a control examination after removal of pre-malign or malign polyps. The polyps were photographed in the colon with various zoom options, by white-light and NBI, with and without paint liquid, as it can be seen in Fig. 1.

From the images the polyps were cut out and a solid black colour was used to mask out the background bowel tissue, the bubbles and the light reflections. No other image processing method was carried out, except for the normalizing according to (4).

## 4. RESULTS

The sample images are shown in Fig. 2. Both the masked and the unmasked images were studied, in all the three colour channels. Note, that the bowel tissue is visible only on a very small part of the image, and it is approximately of uniform colour.



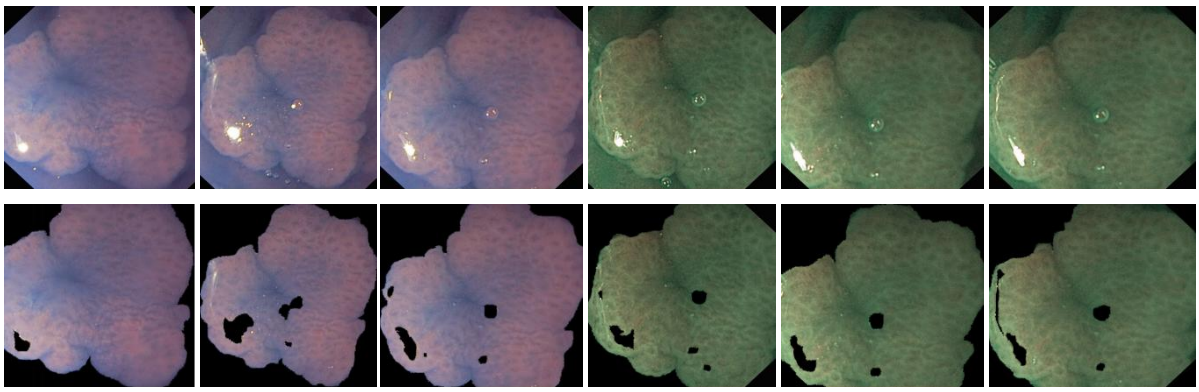


Figure 2. Endoscopy pictures of two patient's colonal polyps. The picture numbers are in the upper row *s1i15* (white light image), *s1i22*, *s1i24* and *s1i28* (dyed white-light images), in the lower row *s2i12*, *s2i17*, *s2i19* (dyed white-light images), *s2i23*, *s2i24* and *s2i25* (NBI images). Pictures taken at the Petz Aladár Hospital Győr.

### 4.1. Localization type of the images

The structural entropy vs. filling factor images can be seen in Fig. 3.

In case of the white-light image s1i15, the red channel gives practically no information about the localization type of the image probably because of the very low variation of the intensity, thus very small localization factor. The blue and green channels are more informative. In case of the dyed images the two types of polyps can be distinguished, the first has a more slope localisation - it fits to a lower line on the $S_{str}(S_2-S_0)$ map - than the second, especially in the blue and green images, both in the background masked and the non masked cases. The NBI positions the image to a more favourable part of the $S_{str}(S_2-S_0)$ map, where the tendencies are more distinguishable, so it seems to be the ideal candidate for basis of structural entropy calculations.

All the calculations were carried out in Matlab environment ant the calculation time is for the 20 images was less than 3 seconds on a 2.27 GHz processor with a code including the plotting.

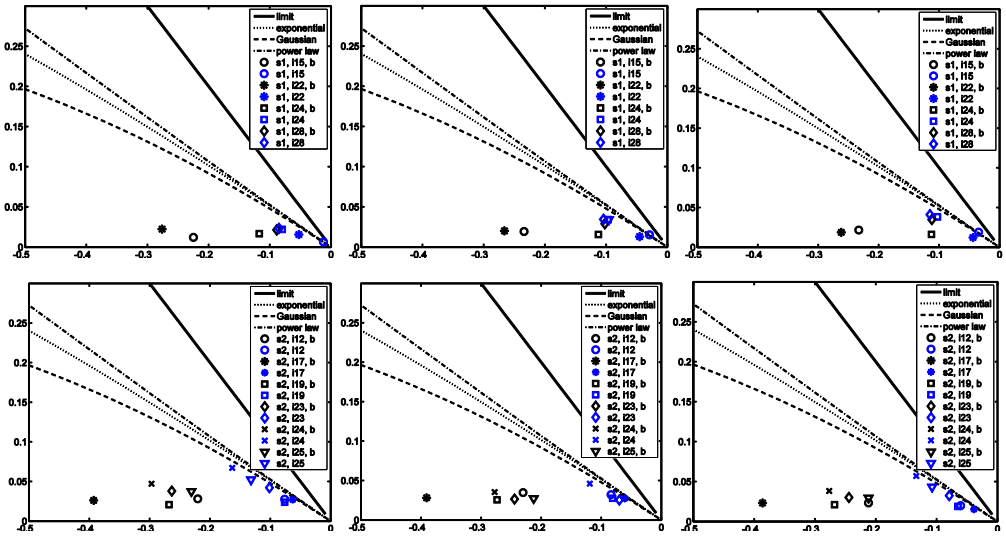



Figure 3.Structural entropy $S_{str}$ vs. the filling factor $S_0-S_2$ maps of the images from Fig. 2. The results for one set of images (s1 and s2) are plotted into the same row, the three colour channels r, g, and b are in the first, second and third column subplots. The blue markers indicate the original images, the black markers the masked ones.

## 5. CONCLUSION

Localization types of the studied colonal polyp images are slower than Gaussian. The different colour channels of the images give different information, thus it is worth to keep all the three channels for calculations. Usually the NBI images are the best candidates for further processing, especially in the blue and red colour channels. Preprocessing of the images significantly alter the localization type of the image, and increases the calculation time.

As the calculation time is significantly less than the time needed for taking a still image from the live colonoscopic feed, and it has a possibility to distinguish polyp types, the method seems to be a good candidate for helping the medical staff.

## 6. ACKNOWLEDGMENTS

The authors gratefully thank Professor István Rácz and his group at the Division of Gastroenterology at the Petz Aladár County Educational Hospital for the guidance and the images. Fruitful discussions with Professor Zoltán Horváth and his co-workers from the Széchenyi University are also gratefully acknowledged.

## References

[1] 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.

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

[3] 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.

[4] 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.

[5] 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.

[6] 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.

[7] 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.

[8] 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.

[9] 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.