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The use of point information gain for maximization of the information yield from the microscope

Dalibor Štys, Renata Rychtáriková and Kirill Lonhus

Laboratory of Experimental Complex Systems, Institute of Complex Systems, Faculty of Fisheries and Protection of Waters, University of South Bohemia in České Budějovice, ImageHeadstart ATCZ215

Difference of two Rényi entropies is the point information / point divergence gain

$$\Omega_{\alpha}^{(L\rightarrow M)} = \frac{1}{1-\alpha}\log_2\sum_{i=1}^{j}\left(p_i^{(L\rightarrow M)}\right)^{\alpha} - \frac{1}{1-\alpha}\log_2\sum_{i=1}^{j}(p_i)^{\alpha}$$

i – value of intensity
M – pixel intensity in the first image (I)
L – pixel intensity in the following image (I+1)
j – number of intensities occupied in the image
p_i – probability of the occurrence of intensity i in the image

n_i – number of the occurrence of intensity i in the image
α – the Rényi dimensionless coefficient ($\alpha \geq 0$, $\alpha \neq 1$)
$C_{\alpha} = \sum_{i=1}^{j} n_i^{\alpha}$ – constant for intensity distribution of image (I)

Point Information/Divergence Gain Entropy (PIE/PDG, I_{α})

$$I_{\alpha}(\mathbf{I}_a;\mathbf{I}_b) = \sum_{i=1}^{n}\left|\Omega_{\alpha}^{a_i\rightarrow b_i}\right| = \sum_{L=1}^{j}\sum_{M=1}^{j} n_{lm}\left|\Omega_{\alpha}^{L\rightarrow M}\right|$$

Point Information/Divergence Gain Entropy Density (PIED/PDGED, P_{α})

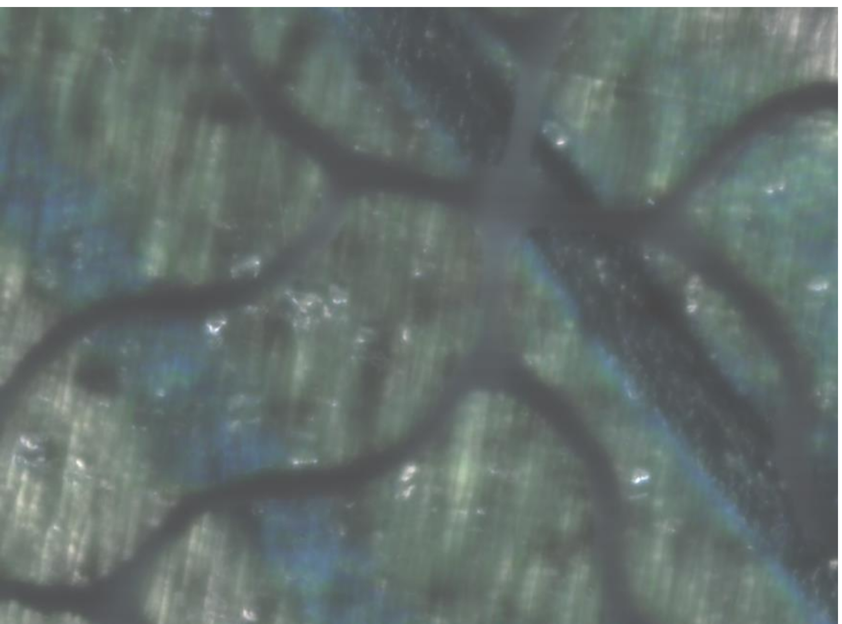
$$P_{\alpha}(\mathbf{I}_a;\mathbf{I}_b) = \sum_{L=1}^{j}\sum_{M=1}^{j} X_{lm}\left|\Omega_{\alpha}^{L\rightarrow M}\right|$$

$$X_{lm} = 1,\ n_{lm} \geq 1$$
$$X_{lm} = 0,\ n_{lm} = 0$$

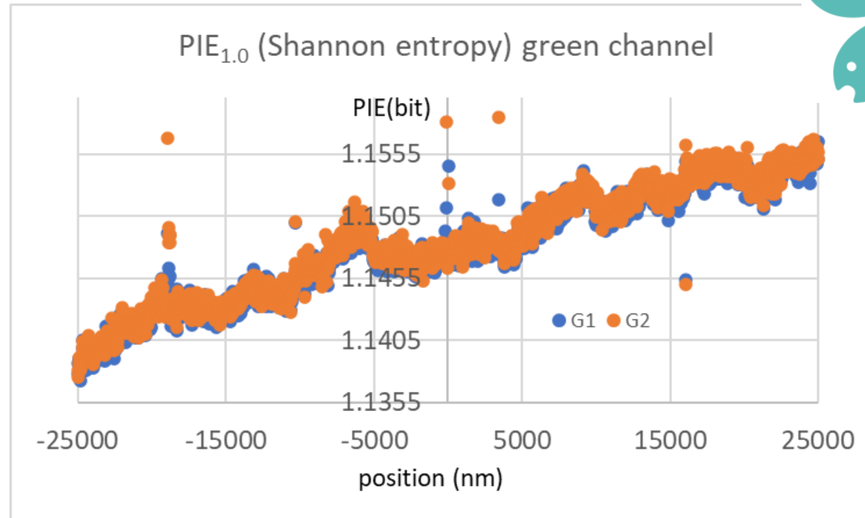
$\mathbf{I}_a = \{a_1, \ldots, a_n\}$ and $\mathbf{I}_b = \{b, \ldots, b_n\}$ – two consecutive one-dimensional data frames with pixel indices a_i and b_i, respectively.
n_{lm} – number of substitutions $l \rightarrow m$ at transformation $\mathbf{I}_a \rightarrow \mathbf{I}_b$

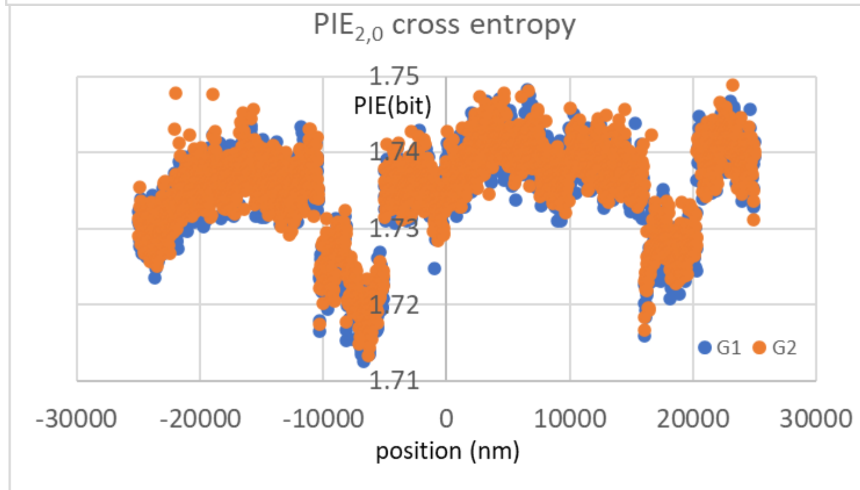
Focal positions of different colour prints at the ID card identified by $PIE_{2.0}$

To find the image in focus in the range of 100 µm is possible by naked eye. To find the best focused image among those which are 25-nm apart along the optical axis is a task for information science. The most in-focus image has highest information content.



Movie of the z-stack (shift along microscope optical axis, focusing) of images of an identity card within 50 µm with the step 1,25 µm

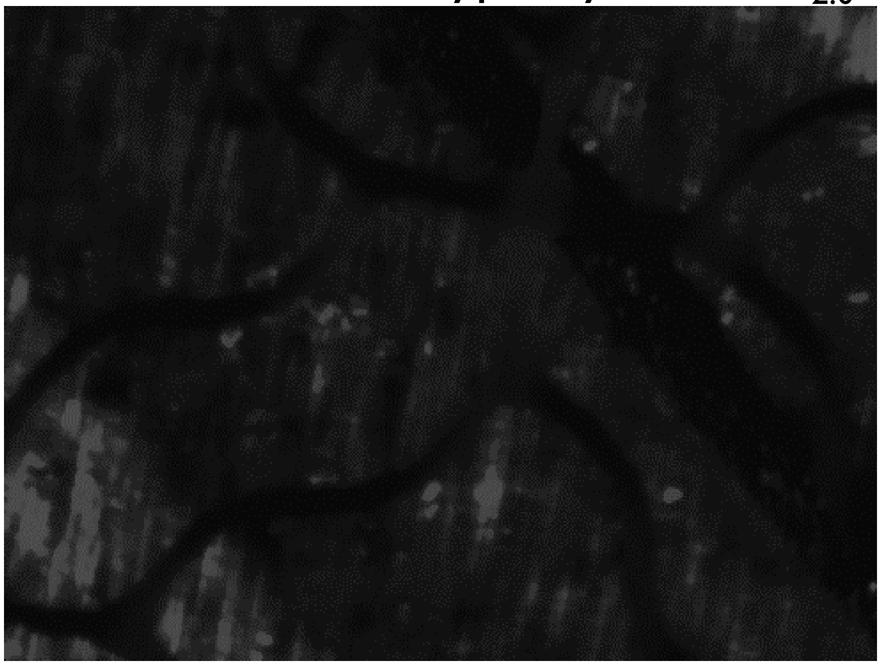


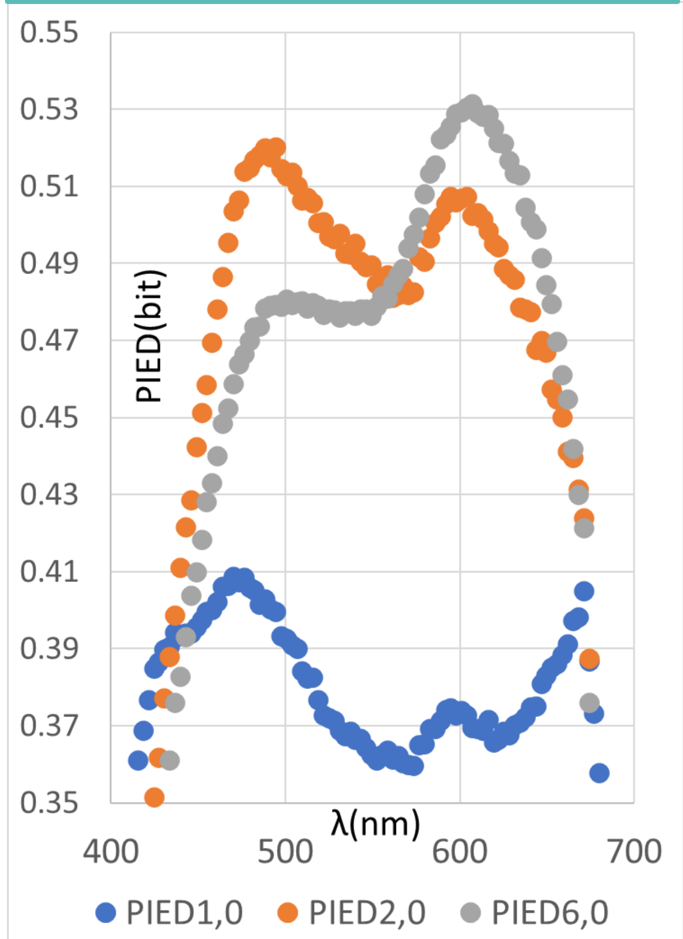


While $PIE_{1,0}$ (common sense entropy) does not provide any information about the change of the image structure upon focusing, the $PIE_{2,0}$ identifies clearly thickness of different colour layers.

No real objective may be constructed to project light with the same geometric precision at all wavelengths. A typical achromatic objective is geometrically and colour corrected to two wavelengths. By PIE calculation we may find images in which some structures are highlighted. The most informative is typically PIE/$PIED_{2.0}$.

Spectral dependency of image structure





Spectral dependency of image structure is a combination of image structure and objective properties. A metrological telecentric objective shows negligible distortion and we obtain sharp monochromatic images.

Rychtáriková, R. et al.: Point Divergence Gain and Multidimensional Data Sequences Analysis, Entropy 20(2), 106 (2018).
Rychtáriková, R. et al.: Super-Resolved 3-D Imaging of Live Cells' Organelles from Bright-Field Photon Transmission Micrographs. Ultramicroscopy 179, 1-14 (2017).
Rychtáriková, R. et al.: Point Information Gain and Multidimensional Data Analysis. Entropy 18(10), 372 (2016).
Lonhus, K. et al.: Quasi-Spectral Characterization of Intracellular Regions in Bright-Field Light Microscopy Images. Sci. Rep. 10, 18346 (2020).