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

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

\[ \Omega^{(L \rightarrow M)}_{\alpha} = \frac{1}{1 - \alpha} \log_2 \sum_{i=1}^{j} \left( p_i^{(L \rightarrow M)} \right)^{\alpha} - \frac{1}{1 - \alpha} \log_2 \sum_{i=1}^{j} (p_i)^{\alpha} \]

\( i \) – value of intensity
\( M \) – pixel intensity in the first image (\( I_l \))
\( L \) – pixel intensity in the following image (\( I_{l+1} \))
\( j \) – 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
\( \alpha \) – 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 (\( I_l \))

Point Information/Divergence Gain Entropy (PIE/PDG, \( I_\alpha \))

\[ I_\alpha (I_a; I_b) = \sum_{i=1}^{n} \left| \Omega^a_{\alpha \rightarrow b_i} \right| = \sum_{L=1}^{j} \sum_{M=1}^{j} n_{lm} \left| \Omega^{L \rightarrow M}_{\alpha} \right| \]

Point Information/Divergence Gain Entropy Density (PIED/PDGED, \( P_\alpha \))

\[ P_\alpha (I_a; I_b) = \sum_{L=1}^{j} \sum_{M=1}^{j} X_{lm} \left| \Omega^{L \rightarrow M}_{\alpha} \right| \]

\( X_{lm} = 1, n_{lm} \geq 1 \)
\( X_{lm} = 0, n_{lm} = 0 \)

\( I_a = \{a_1, ..., a_n\} \) and \( I_b = \{b, ..., b_n\} \) – 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 \( I_a \rightarrow I_b \)
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 is a combination of image structure and objective properties. A metrological telecentric objective shows negligible distortion and we obtain sharp monochromatic images.


