SUBJECT: Contrast enhancement with Adaptive Histogram Clip

The following information is provided as a service to our users and customers:

Contrast enhancement of portal images is usually based on histogram equalization techniques. To reduce the enhancement of noise and the distortion of field edges, a contrast limited histogram equalization (CLAHE) has been suggested by S. M. Pizer et al. (1987). However, a fixed clip level applied to the entire image may not be appropriate. In an attempt to improve the enhancement of portal images, the AHC algorithm has been developed, using an approach that recognizes the individual regions requiring different clipping values. It is based on the evaluation of the average value m_i and standard deviation σ_i of every contextual region R_i. Each R_i is assigned a particular clipping value c_i depending on the position of the point (m_i, σ_i) in the plane (m, σ). The regions outside the treatment field (background) have small values of m_i and σ_i and the corresponding points (m_i, σ_i) will be close to the origin of the coordinate system. They comprise the cluster **B**. The regions that cover the field edge will have average m_i and large σ_i, and comprise the cluster **E**, while the regions inside the field (cluster **F**) will be characterized by average or large m_i and average or relatively small σ_i. The corresponding areas are presented in the figure with open squares and black triangles, respectively.

To decrease the noise and to prevent significant blurring of the field edge, the contextual regions from the background and from the field edge have to have small c_i, while the regions inside the field are assigned larger values. The problem that has to be solved is to automatically segment the regions into the clusters **B**, **E** and **F**. The following clustering algorithm is used:

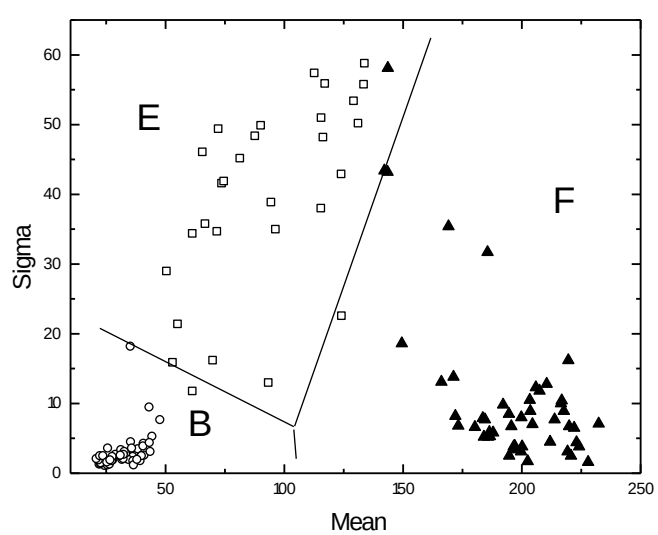
1. Select starting points B_1, E_1 and F_1 for **B**, **E** and **F**.
2. Create new clusters according to the rule: Point $M_i(m_i, \sigma_i)$ belongs to the cluster **B** if
   $r(B_1, M_i) \leq r(E_1, M_i) \wedge r(B_1, M_i) \leq r(F_1, M_i)$.
3. Evaluate center of gravity $\overline{B}_j$, $\overline{E}_j$ and $\overline{F}_j$ of every cluster for the current iteration j.

If the new centers of gravity are the same as the centers $\overline{B}_{j-1}$, $\overline{E}_{j-1}$ and $\overline{F}_{j-1}$ from the previous iteration, the separation of the clusters is completed, otherwise set $B_1 = \overline{B}_j$, $E_1 = \overline{E}_j$, $F_1 = \overline{F}_j$ and repeat step 2. This procedure usually

converges to a single distribution of the points between the three clusters. The boundaries between clusters do not depend on the starting points but the number of iterations may significantly depend on them. For the background cluster **B** an appropriate starting point will be B_1 with $m_{B1} = \min_i \{m_i\}$. For the field cluster **F** the point F_1 with $m_{F1} = \max_i \{m_i\}$ will be a good selection, while for the edge cluster **E** the starting point E_1 may be set at $\max_i \{\sigma_i\}$ with m_i close to average value of all m_i.

PIPS creates a plot of the (m, σ) plane and saves it to the file *chart.bmp* in the directory set in cfg! for temporary files. Regions belonging to cluster **B** are plotted in red, cluster **E** in blue, and cluster **F** in white. A sketch of such a plot is shown in the figure below. The three straight lines show the separation between the clusters. Boundaries between the clusters are defined by areas consisting of at least 10% of background pixels and at least 10% of pixels from the field simultaneously.

Once clusters have been delineated, clipping values c_i are assigned to the corresponding regions R_i. In PIPS, regions in cluster **B** are not enhanced, regions in cluster **E** are enhanced by AHE with a clip level of 1, and regions in cluster **F** are enhanced with the clipping level selected in the dialog box. The image with all regions identified by the appropriate color is saved to the file *cluster.bmp* in the directory set in config! for temporary files. Later applications of AHE will overwrite this file.



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1. S. M. Pizer, E. P. Amburn, J. D. Austin, R. Cromartie, A. Geselowitz, T. Greer, B. H. Romeny, J. B. Zimmerman, and K. Zuiderveld, "Adaptive histogram equalization and its variations," Comput. Vision. Graph. Image Process. **39**, 355-368 (1987)

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