Cross-entropy based image thresholding

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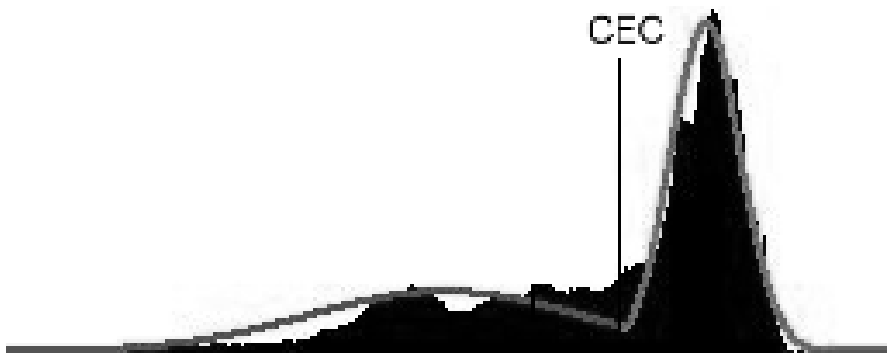
Introduction

- Segmentation of images into homogeneous regions is an important part of the ongoing research:
  - pattern recognition,
  - computer vision, etc.
- The image thresgonding methods divide in general into two groups:
  - global:
    - Otsu, ME;
  - local.

Cross-Entropy Clustering

- The image binarization is kind of clustering (for 2 clusters), so we can use a clustering algorithm. Here we use CEC.
- We want to classify each pixel as background or foreground.
  - We will try to fit two gaussians to match the overall image histogram.
  - One of those gaussians will represent background pixels distribution, and the other one - foreground.
- The crossing point of those two gaussians will be considered a threshold.



Cross-Entropy Clustering

- Cross-Entropy Clustering works similairily to EM.
  - It aims at finding a combination of $p_1 f_1, \ldots, p_k f_k$ such that $max(p_1 f_1, \ldots, p_k f_k)$ fits the data best according to maximum likelihood approach.
- We aim therefore at minimizing cost function:

$$CEC(f, X) = -\sum_{l=1}^{n} ln(max(p_1 f_1(x_l), \ldots, p_k f_k(x_l))),$$

  n - number of points in dataset X.
- We don't consider the density estimation though, but the clustering.

Cross-Entropy Clustering

- $X = 0, \ldots 255$ - possible colors
- $h : X \to \mathbb{R}$ - image histogram, $h(x)$ - number of occurances of color x.
- We consider only colors existing on image: $\bar{X} = \{x \in X : h(x) \neq 0\}$.
- We can define the mean and variance as usual:

$$\mathrm{mean}(\bar{X}; h) := \sum_{x \in \bar{X}} h(x) \cdot x, \quad \mathrm{var}(\bar{X}; h) := \sum_{x \in \bar{X}} h(x) \cdot (x - \mathrm{mean}(\bar{X}))^2$$

- The const function is then:

$$E(X_1, \ldots, X_k, h) = \sum_{i=1}^{k} p_i \cdot \left(-\ln(p_i) + \frac{1}{2} \ln(2\pi e) + \frac{1}{2} \ln(\sigma_i^2) \right),$$

where $\sigma_i^2 = \mathrm{var}(X_i; h)$, $p_i = \frac{|X_i|}{|\bar{X}|}$ and $\bar{X} = X_1 \cup \ldots \cup X_k$.

Cross-Entropy Clustering

- We can minimize the cost function in a greedy manner.
- This means we will check value of cost function for every possible color on image $(0, \ldots 255)$ and choose point with the lowest value as threshold.

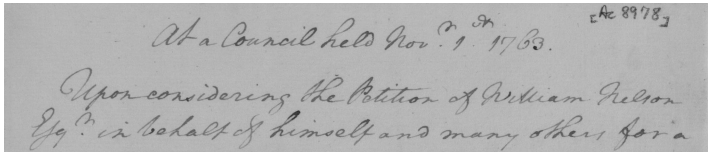
Experimental Results

- The CEC thresholding has been tested on real images from DIBCO2009 contest.
  - The images contain both printed text and handwriting.
- Below table present results comparison for selected algorithms.

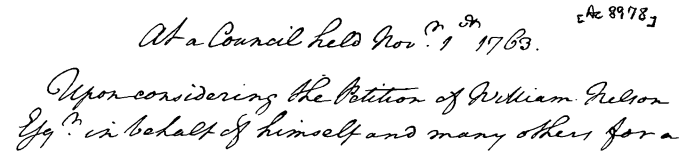
		CEC	Otsu	GMM	ME
H01	precission	0.7109	0.9263	0.6505	0.7880
	recall	0.9952	0.9006	0.9976	0.9868
	MCC	0.8286	0.9072	0.7898	0.8727
P05	precission	0.7212	0.8736	0.4822	0.9736
	recall	0.9824	0.9106	0.9990	0.9106
	MCC	0.8116	0.8729	0.6269	0.8729

Table: Comparison of the results according to precision, recall and MCC.

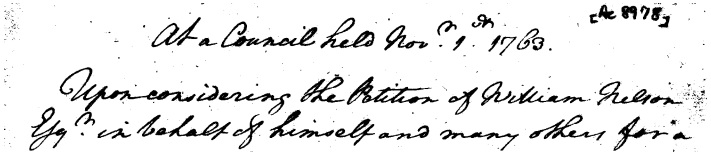
Experimental Results



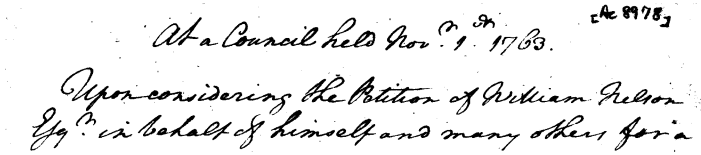
(a) Original



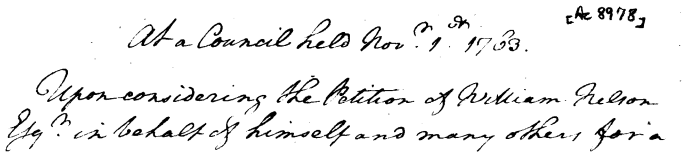
(b) Gold standard thresholding



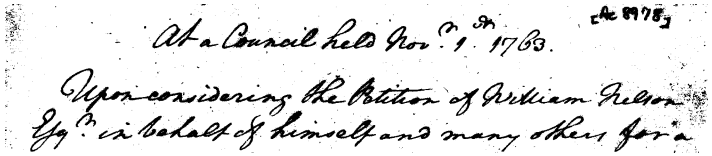
(c) CEC



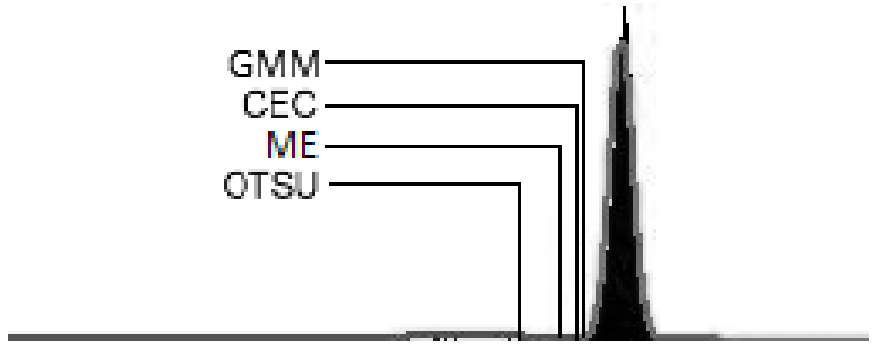
(d) Max Entropy



(e) Otsu

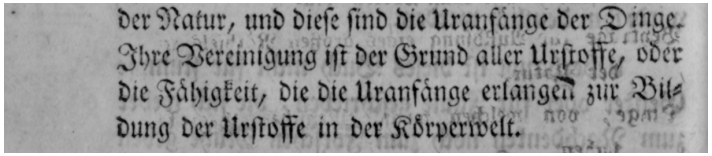


(f) GMM

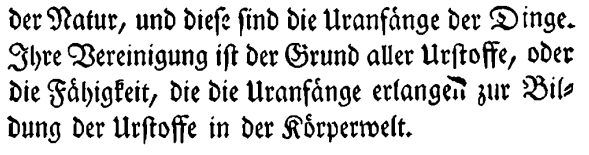


(g) Histogram

Experimental Results


der Natur, und dieſe ſind die Uranfänge der Dinge.
Ihre Vereinigung iſt der Grund aller Urſtoffe, oder
die Fähigkeit, die die Uranfänge erlangen zur Bil-
dung der Urſtoffe in der Körperwelt.

(a) Original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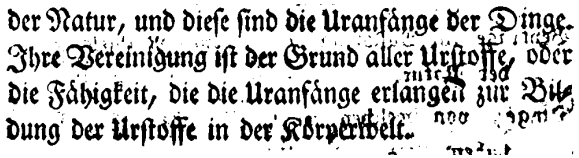
(b) Gold standard thresholding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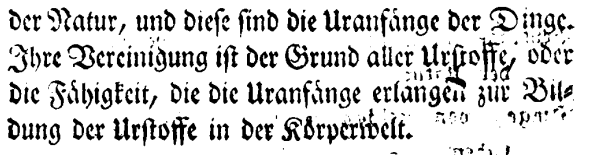
(c) CEC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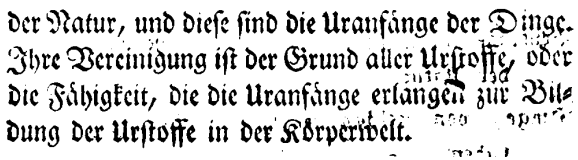
(d) Max entropy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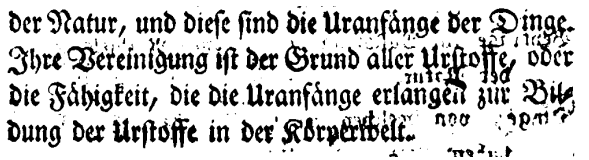
(e) Otsu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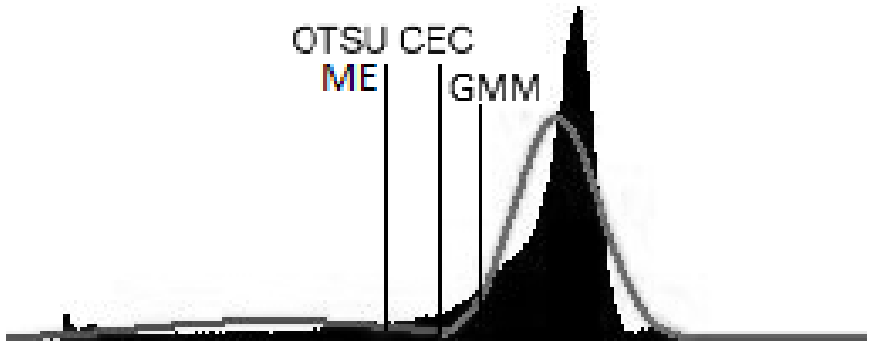
(f) GMM



(g) Histogram

Experimental Results

- The binary thresholding does not always fit well the image.

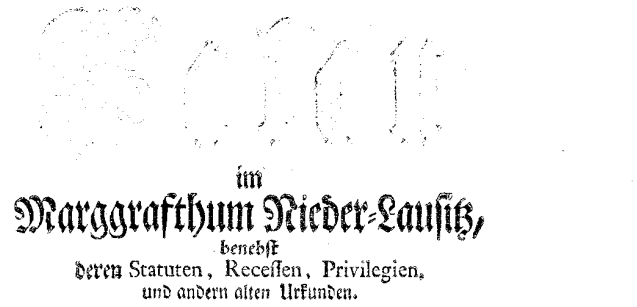
(a) original image

(b) histogram

Experimental Results

- The CEC thresholding allows for multi-level thresholding.
- This is a useful feature when the background-foreground relations are more complicated than just binary relation.

(a) original image



(b) lower section

(c) middle section

(d) upper section

Figure: Multilevel binarization of the H04 image.

ImageJ plugin

- A ImageJ plugin for CEC thresholding is available on page: `http://ww2.ii.uj.edu.pl/~spurek/imageJ/CECMultilevelThresholding/CECMultilevelThresholding.html`

Summary

- CEC thresholding attempts to match the results of GMM methods while preserving simplicity of algorithm, like Otsu.
- CEC chooses threshold more aggresively than Otsu, it is better option for images with many fine details.
- CEC is a good tool which can be used as preprocessing step in more complicated image processing procedures.

Questions?

Thank you.