Retaining Local Image Information in Gamut Mapping Algorithms

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Abstract

- Proposed method
  - Complement to global gamut mapping algorithm
    - Recovering the original local contrast between neighboring pixels
    - Avoiding artifacts introduced by the gamut mapping algorithm
      - Halo artifacts on sharp edges
  - Special attention
    - Running time and to avoid halo artifacts

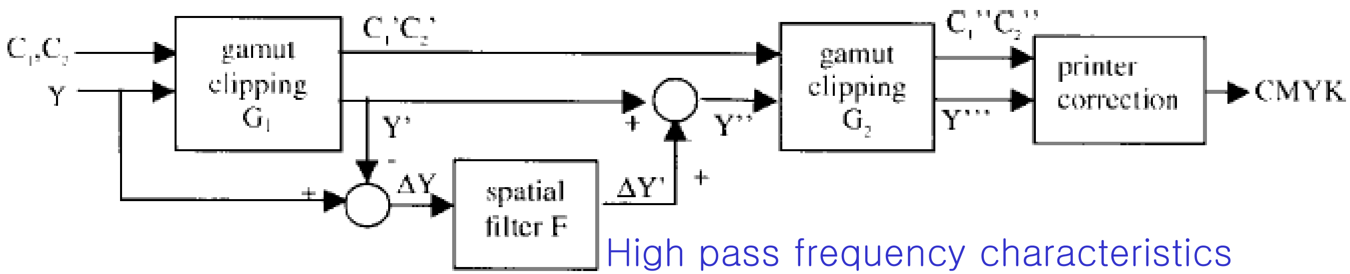
Introduction

- Gamut mapping
  - Adaptation of a specified color image to device limitations for digital color reproduction
- Global gamut mapping
  - Device to device and image to device
- Spatial gamut mapping
  - Color mapping depends on the spatial neighborhood of a pixel

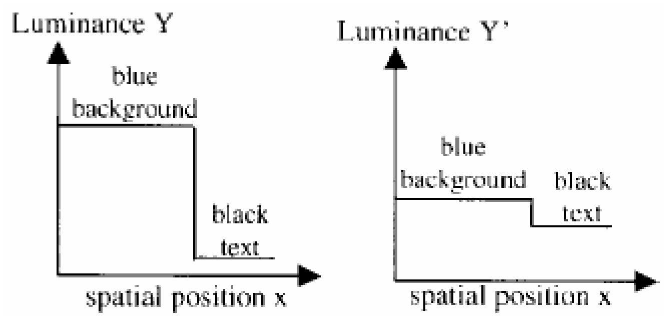
◆ Gamut mapping algorithm

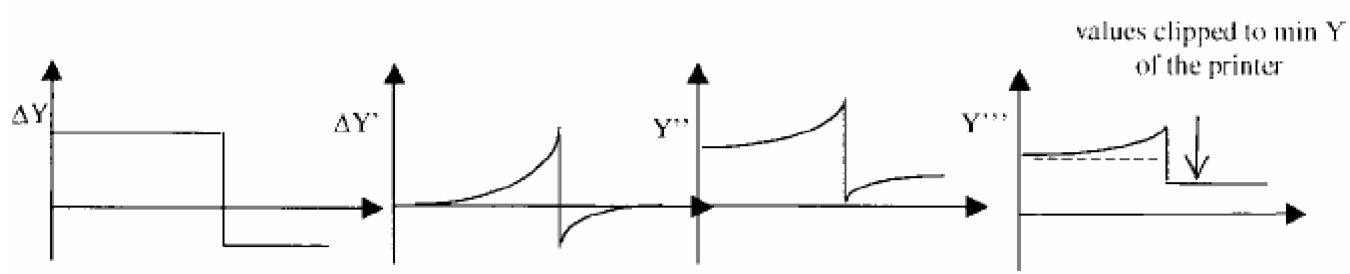
- Bala et al.
  - Processing the original image through a standard global mapping algorithm
  - Calculating the difference of the original and the mapped luminance channel
  - Extracting edge information by using an unsharp masking technique
  - Adding to the gamut mapped image
  - Processing result image by a gamut clipping algorithm

– Block diagram



High pass frequency characteristics





- A potential problem
  - Halo artifacts
- Preventions
  - Keeping the spatial parameters small enough
  - Applying the method with a reduced weight near strong edges
- Proposed method
  - Designed as a component among others within a gamut mapping concept

Methodology

- Basic model
  - A generalization of the method proposed by Bala et al.
  - Three steps
    - A Global gamut mapping step → initial gamut mapping
    - A unsharp masking operation → contrast recovery
    - A final remapping step
- Local operation
  - The form of filters with a kernel G

$$F(x,y) = \sum_{x',y'} I(x',y')G(x-x',y-y') \tag{1}$$

$$G_\sigma(x,y) = e^{-(x^2+y^2)/(2\sigma^2)} \tag{2}$$

◆ Mapping procedure

– Initial gamut mapping

$$I_M = GM_1(I_O) \tag{3}$$

– Smoothed difference image

$$I_S = I_D * G_{\sigma_S} \tag{4}$$

where I_D difference image $I_D = I_O - I_M$
σ_s reference spatial distance→width of the gaussian filter kernel

– Correction image

$$I_C = I_D - I_S \tag{5}$$

– Contrast recovered image

$$I_E = I_M + rI_C \qquad (6)$$

where r an arbitrary weight parameter

– Remapping image

$$I_{EM} = GM_2(I_E) \qquad (7)$$

◆ Effect of contrast recovery

– Halo effects on sharp edges

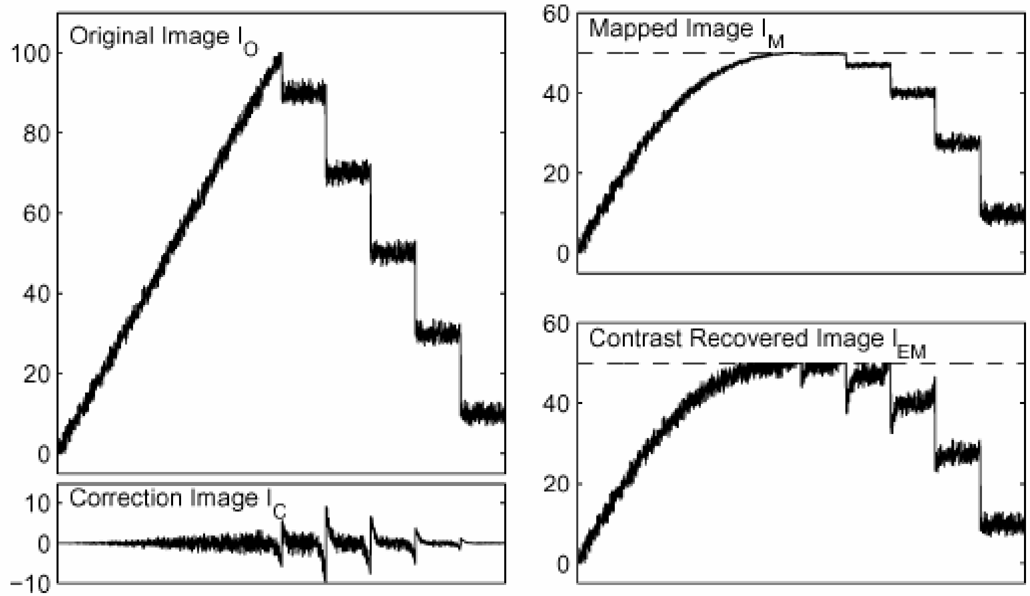


Fig. 1. Effect of contrast recovery for a 1-D monochrome image. (top left) original image, (top right) mapped image, (bottom left) correction image, and (bottom right) contrast recovery image.

◆ Extended model

– Combination of spatial and color distances

$$G_{\sigma_s,\sigma_c}(\vec{x},\vec{c}) = e^{-(((x^2+y^2)/\sigma_s)^2+((c_1^2+c_2^2+c_3^2)/\sigma_c)^2)/2} \quad (8)$$

where σ_c reference color distance

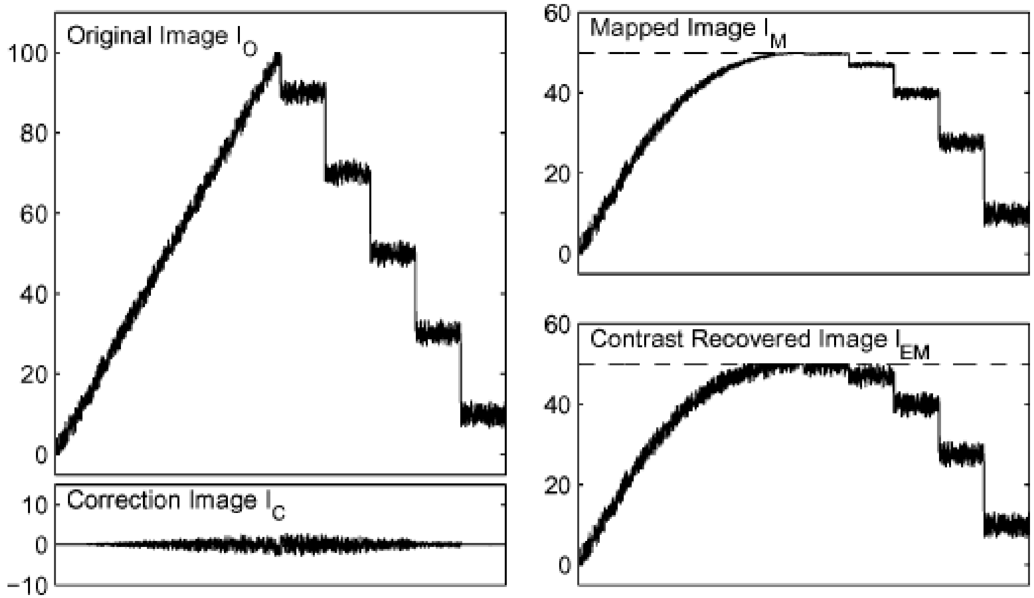


Fig. 2. Effect of contrast recovery for a 1-D monochrome image using an edge preserving smoothing. (top left) original image, (top right) mapped image, (bottom left) correction image, and (bottom right) contrast recovery image.

– Selection of σ_s and σ_c for the best results

- Determining σ_s in the range of 2% ~ 5% of the image diagonal
- The selection of σ_c is directly related to the definition of ΔE
  - The range of $\Delta E \rightarrow$ 10 ~ 25

◆ Halo effects on sharp edges

Fig. 3. Application of the basic and extended model to a mapped image: (left) mapped image I_M , (middle) image I_{EM} using basic image, (right) image I_{EM} using extended model.

◆ Computational issues

- Method of random sampling
  - Calculating by generating gaussian random numbers
- Instead of using all pixels of a filter, only a fixed number of randomly selected pixels are used

$$G_{\sigma_s,\sigma_c}(\vec{x},\vec{c}) = p(\vec{x})w(\vec{c}) \tag{9}$$

$$p(x,y) = e^{-((x^2+y^2)/\sigma_s)^2/2} \tag{10}$$

$$w(\vec{c}) = e^{-((c_1^2+c_2^2+c_3^2)/\sigma_c)^2/2} \tag{11}$$

- Replacing gaussian filter

$$F'(x,y) = \sum_{(x',y')\,in\,S} I(x',y')w(\vec{c}-\vec{c}\,') \tag{12}$$

Table 1. Computation time and mean pixel error as a function of image size and size n of random sampling.

	Gauss	$n = 4$	$n = 16$	$n = 64$	$n = 256$
computation time					
272*350	20 s	0.1 s	0.2 s	0.5 s	2 s
544*700	307 s	0.2 s	0.6 s	2 s	8 s
1088*1400	5000 s	1.2 s	4 s	10 s	35 s
2175*2800	79000 s	6 s	16 s	52 s	190 s
mean pixel error	-	6.1 ΔE	3.1 ΔE	1.7 ΔE	0.9 ΔE

Results and discussion

- Application to different gamut mapping algorithms
  - Linear compression → Lcomp
  - Hue-preserving minimum distance clipping → HPMinDE
  - Smooth gamut deformation algorithm → SGDA
  - SGCK → the second CIE-recommendation
- Parameters
  - σ_s =4%, σ_c =20, r =1

◆ Sample images

Fig. 4. Effect of contrast recovery for three GMAs: (left) LComp, (middle) SGDA, and (right) HPMinDE on the example of the MUSICIAN image. The top row shows the mapped image I_M and the bottom row the contrast recovered image I_{EM} .

◆ Two types of evaluation of the presented gamut mapping approach

- Psycho-visual test
  - Following the CIE-guidelines

without contrast recovery | original | with contrast recovery

LCD screen(EIZO cg220)

- Analysis of the contrast mapping
  - Using local mapping histograms

◆ Psycho-visual tests

– Following the CIE-guidelines

- Set1 → a traditional set of eight test images
- Set2 → 64 images from a newspaper agency

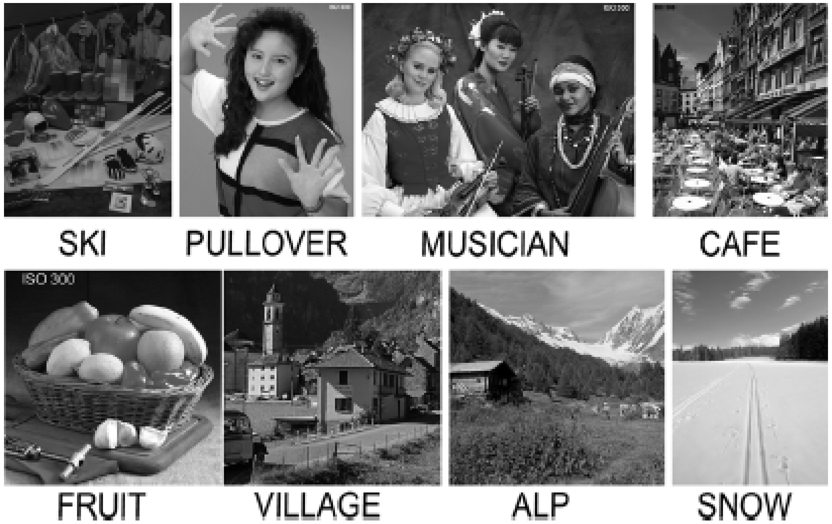


Fig. 5. Psycho-visual tests: images of Set1 containing eight images, with identification used in this paper.

– The results

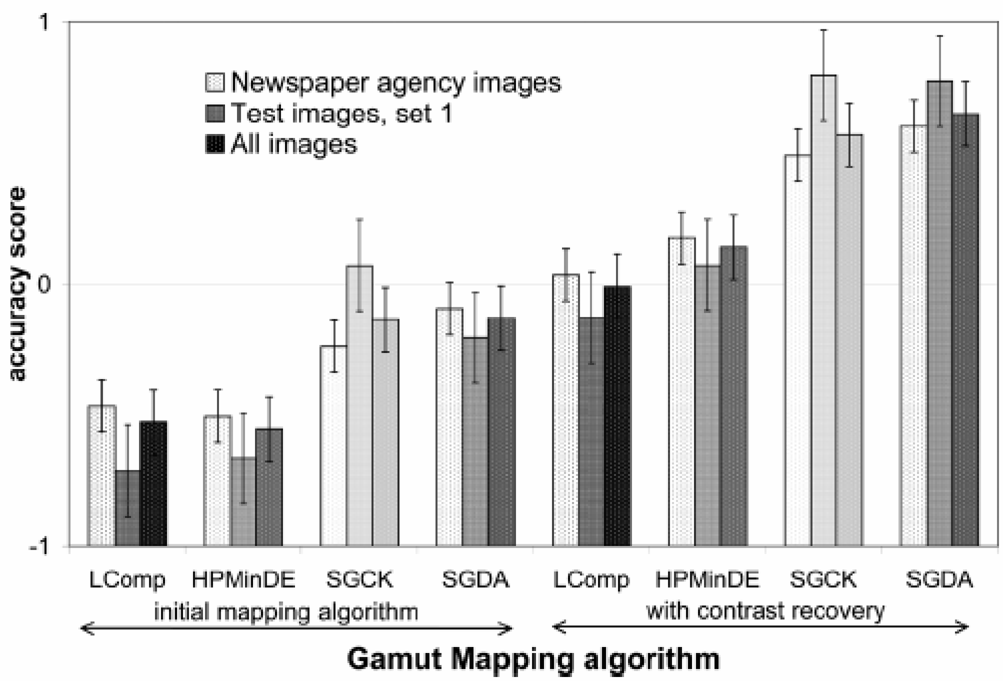


Fig. 6. Psycho-visual tests: results of (left light bars) Set1, (middle bars) Set2, and (right dark bars) all images. On the left, the results for initial mapping algorithm; on the right, the results using contrast recovery are shown.

– Raw percentage matrix

Table 2. Raw percentage matrix for the combined test set.

	SGCK-1	SGDA-1	LComp-1	HPMinDE-1	SGCK-0	SGDA-0	LComp-0	HPMinDE-0
SGCK-1	-	0.52	0.26	0.45	0.21	0.27	0.15	0.24
SGDA-1	0.48	-	0.22	0.37	0.23	0.21	0.13	0.27
LComp-1	0.74	0.78	-	0.53	0.46	0.43	0.27	0.30
HPMinDE-1	0.55	0.63	0.47	-	0.45	0.43	0.40	0.22
SGCK-0	**0.79**	0.77	0.54	0.55	-	0.52	0.34	0.32
SGDA-0	0.73	**0.79**	0.57	0.57	0.48	-	0.33	0.33
LComp-0	0.85	0.87	**0.73**	0.60	0.66	0.67	-	0.39
HPMinDE-0	0.76	0.73	0.70	**0.78**	0.68	0.67	0.61	-

◆ Contrast mapping evaluations

– Local contrast histograms

- Quality judgment of a gamut mapping algorithm
- Demonstrating the effect of contrast recovery

$$r = \left| (\vec{c}_i^{\,m} - \vec{c}_j^{\,m}) \right| / \left| (\vec{c}_i^{\,o} - \vec{c}_j^{\,o}) \right| \qquad (13)$$

where i, j two pixels of a pair with a defined spatial distance d_s in the image

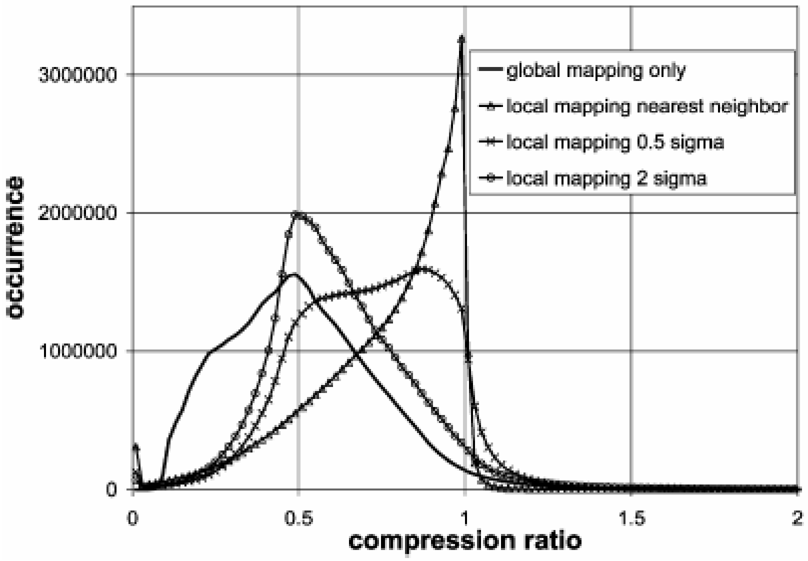


Fig. 7. Local contrast histogram for SGDA as(solid line) initial GMA and after local mapping for three different pair distances.

- Artifacts suppression of the original GMA
  - Reducing discontinuities in mapping color gradients by the initial GMA

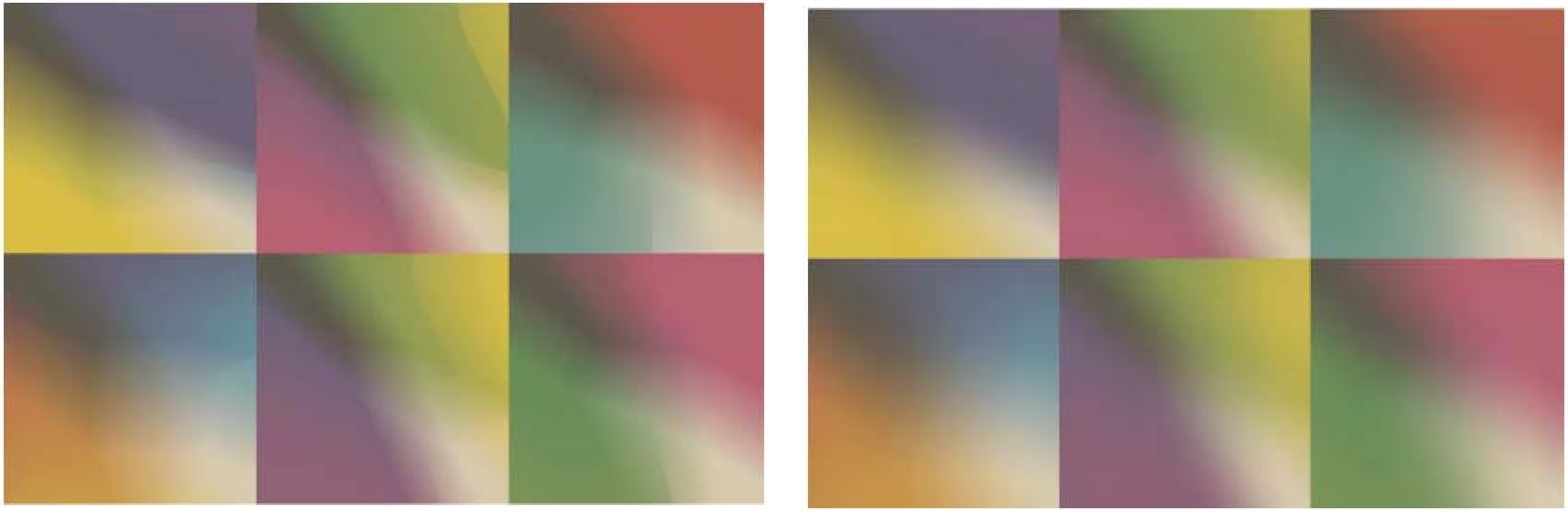


Fig. 8. Artifacts produced by (left) global mapping algorithms are removed by (right) local filtering method.

- Reducing the occurrence of unwanted compression ratio

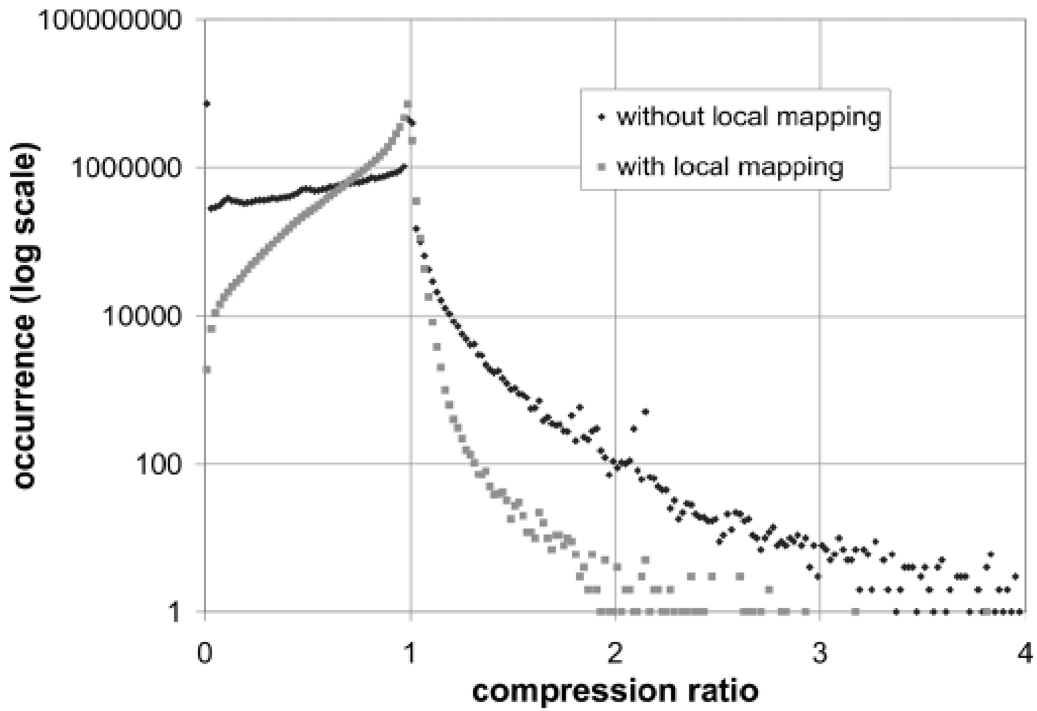


Fig. 9. Local contrast histogram for initial minimum distance clipping algorithm (squares) before masking and (diamonds) after masking. Note the logarithmic scale of the occurrence axis.

Conclusion

- Proposed method
  - Spatial methods adding to existing gamut mapping algorithms
    - A substantial gain in perceived image quality
    - The contrast recovery and the suppression of artifacts
- Future work
  - Universal gamut mapping algorithm
    - Combination of nonlinear compression, spatial methods, and image-to-device methods