Improvement of Digital Print in Preference by Adding Noise

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Introduction

Development of the digital imaging technology is remarkable. Combination of high-resolution digital camera with high performance ink-jet printer results in noiseless prints. On the other hand, with disappearance of noise, we lost impression of space and texture which we get from complicated 3D structure of silver grains or dye clouds. In the preceding paper, we showed that adding white noise to some type of picture like wood, cloud, etc. results in improvement increase of scores of preference.[1] *In the present paper, it was attempted to improve digital prints in preference by adding white, blue, or 1/f noise.*

Analysis of Noise

Noise image was put on a scanner (EPSON GT-9700F) together with a gray scale and digital values were converted to densities. Type of noise was judged according to frequency distribution obtained by Fourier transformation.

Generation of Noise

In Fig. 1 types of noise which were applied in this paper were shown. Their generation method is described below.

White Noise

Two-dimensional white noise was generated using normal random variate. Level of noise was controlled by changing of amplitude.

High-Frequency Noise (HF)

By cutting low-frequency component of power spectrum of white noise and by its inverse Fourier transform, high-frequency noise was obtained.

1/f Noise

After the addition of white noise gray image of digital value of 128 was Fourier-transformed to obtain power spectrum. It was multiplied by 1/f (f: frequency). The inverse Fourier transformed image was printed by an ink-jet printer. Curve showing logarithm of power spectrum against logarithm of frequency was obtained from the power spectrum. Images of its slope between -1.2 and -0.8 were employed as 1/f noise.

Level of Noise Applied

RMS granularity of noise applied was kept constant in each noise type. Figure 2 shows noise levels to obtain the same level RMS granularity for each noise type.

Noise level is here standard deviation of histogram of noise. With 1/f noise higher noise level was required to fulfill this purpose.

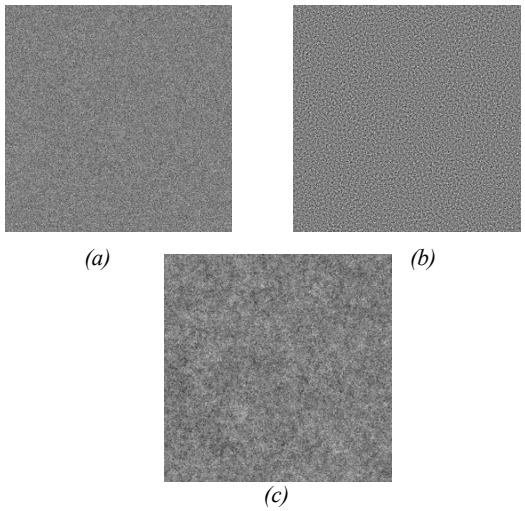

Figure 1. Type of noise: (a) White noise; (b) high-frequency noise; (c) 1/f noise

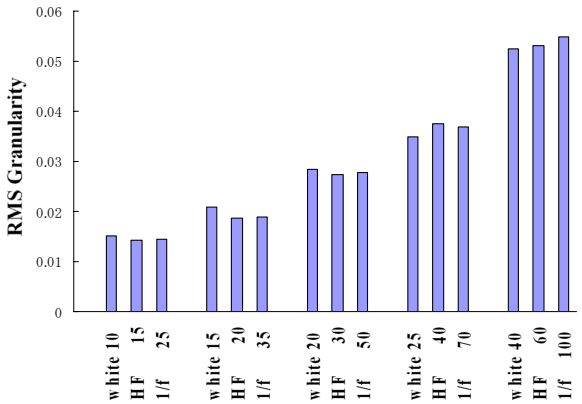

Figure 2. Noise levels to obtain a same level of RMS granularity of noise image for each noise type. Noise level is standard deviation of histogram of noise.

Application of Noise to Pictures

Two noise application methods were tested:

1. A certain level of noise was added on a certain object by masking out of the other parts.
2. Noise level was changed with image density. Noise was put showing a plateau of its level in the middle densities.

Samples for Evaluation

The original pictures used for evaluation were shown in Fig. 3. Their objects were plants, wood, cars, cloud, natural landscape, scene on the corner, and portrait. Their resolving power was so high that it did not influence upon the granularity of the sample. The samples of A4 size were printed out by EPSON PM4000PX at 200 dpi.

Figure 3. Pictures used for evaluation

Evaluation

Subjective evaluation was performed by selecting the most preferred one and one for the best expression of texture in the following groups of pictures.

- Samples No.1, 2, 3, and 4
- Samples No.1, 5, 6, and 7
- Samples No.1, 8, 9, and 10
- All samples

Table 1: Type and Level of Noise Applied of the Samples

Sample No.	1	2	3	4
Type of noise	Original	White	White	White
Level of noise	–	Low	Middle	High

5	6	7	8	9	10
1/f	1/f	1/f	HF	HF	HF
Low	Middle	High	Low	Middle	High

The observation conditions were as follows: Toshiba natural color evaluation lamp, 5000 K, 700 lx; observation distance: 50 cm; panel: 20 students who are studying image technology.

Results

Subjective evaluation suggested that addition of noise resulted in increase of score of preference under some conditions. 1/f noise was generally higher score than other types of noise. HF noise brought about moire-like pattern, and HF noise samples were almost always worst. The samples obtaining especially high score were pictures of leaf, cloud, and wood (Fig. 4(a)), on which 1/f noise was applied. In the case of portrait, low level 1/f obtained high score. But the number of the person who does not accept texture of skin is not small. With samples of glossy objects like metal, application of every noise results in lowering of score (Fig. 4(b)). Noise application method 2 resulted in higher or same level of score as method 1. With method 2 realization of an automatic selection of the area, where noise will be applied, would be easier.

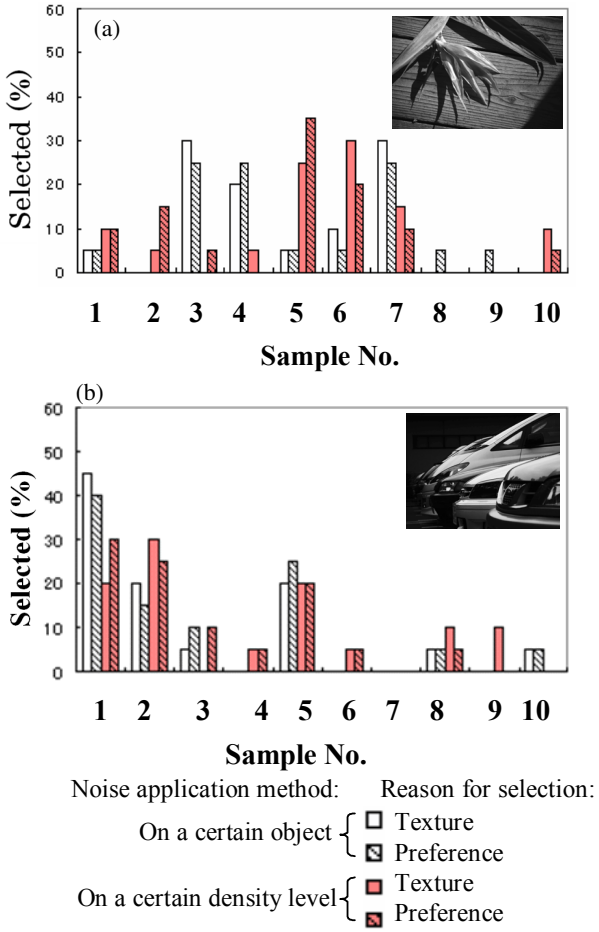

Figure 4. Selected ratio (%) of the samples (see Table 1)

Reference

1. Y. Kashibuchi, N. Aoki, M. Inui, and H. Kobayashi, "Improvement of Description in Digital Print by Adding Noise", J. Soc. Photogr. Sci. Tech.Japan, 66(5),471-480(2003).

Author Biography

Hiroyuki Kobayashi received his M.Eng. in Photographic Engineering from Chiba University, Japan, in 1974. He received Dr.rer.nat. in Chemistry from University of Erlangen, Germany, in 1979. He joined Chiba University in 1980 and from 1995 he is professor. His recent works focus on image properties stimulating our sensibility.