Pixel Structure for Jaggy Reduction in Line Representation using Pseudorandom Pixel Placement

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Abstract The pixels in the conventional image systems are placed at lattice positions, that cause the jaggy edge perceived in the slant lines and curve lines. We have proposed the pseudorandom pixel placement for reducing the jaggy effect, which is implemented the random arrangement of four types of pixels with variety of active area positions. In this paper, we describe the appearance of jaggies by spatial frequency of jaggies and describe pixel structure by showing the relation between the spatial frequency and aperture ratio.

Key words Pseudorandom Pixel Placement, jaggy, spatial frequency

1. Introduction

The conventional image systems have been developed for enhancing the image resolution. However, since the pixels are placed at lattice positions, steps of pixels (jaggies) at the edge of the slant line are strongly perceived by human eyes [1], it is difficult to eliminate the jaggies effect by pixel size reduction.

We have been proposing the method of reducing the jaggies effect by arranging the effective area (photo receptor) at pseudorandom positions, with keeping the lattice arrangement of pixel boundaries [2]. In this paper, we discuss the structure and type of pixels with pseudorandom pixel placement in terms of the spatial frequency of jaggies.

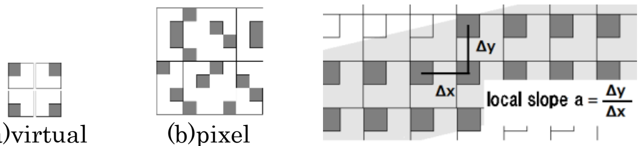
2. Expression of line with pseudorandom pixel placement

The concept and the example of pseudorandom pixel placement for jaggies effect reduction are show in Fig.1. Although we have high sensitivity on perceiving the jaggies or the isolated step [3], we have low sensitivity on perceiving the continuous random step generated by pseudorandom arrangement.

Since the area in the pixel which practically composing an image (effective area) occupies a part of pixel, we can generate pseudorandom arrangement of the effective areas by placing various types of pixels whose effective area positions are different.

We used the pseudorandom pixel placement with 300 × 300 virtual pixels (composed of 72×72 [pixel]) to generate the simulation image, where the types of virtual pixels are randomly selected to form the virtual pixel plain. We generated the slant line with various slopes on the virtual pixel plain, where the binary value of each virtual pixel is determined whether its effective area is included in the slant line or not, as shown in Fig.1.(c).

The measure how we strongly perceive the jaggies at the edge of the line are relational to the cycle of jaggies, or the spatial frequency. We assume that we watch the presented image composed of the virtual pixels whose pitch is 0.3 [mm] at the distance of 60 [cm]. Here, we define the local slope of edge, "a" for the jaggies at the edge of lines as shown in Fig.1.(c). We calculate "a" along with the horizontal axis at each (virtual) pixel, as well as its spatial spectrum. Then, we calculate the product of the spatial spectrum and the spatial characteristics of the human eye's perceiving sensitivity, P(f) [4]. The existence of the distinguished factor in the spatial spectrum in the range we strong perceive is corresponding to the perceived jaggies. Here, we define the ratio of the strongest factor to the average of the other factors in the calculated spectrum, Top/Other, as the measure to indicate how we strongly perceive the jaggies. The small value of Top/Other corresponds to the situation we weakly perceive the jaggies.



(a)virtual pixel (b)pixel placement (c)local slope

Figure 1 Pixel structure and local slope

3. Evaluation of jaggies

3.1. Type of effective area placement

We calculated Top/Other for pseudorandom pixel placement with 4, 9, and 16 types of pixels, as shown in Fig.2, whose active area's position are different, respectively for the lines of 1 [deg] to 45 [deg] with the step of 1 [deg].

Fig.3. shows the average of Top/Other for all lines with 10 trials, with pixel types of 4, 9, and 16, respectively. We obtain the smallest Top/Other with pixel types of 4 in case pf the aperture ratio (the ratio of the active area size to the pixel size) of larger than 0.3.

3.2. Change the appearance frequency of specific pixel placement

We also carried out the simulation of Top/Other in case of pixel types of 16, with different existence probability for the groups of C and D, p_c and p_d, respectively, as shown Fig.2.(d). The image composed of only C groups, or $p_d=0$, is identical to the case of pixel types of 4.

Fig.4. shows the calculated Top/Other for carious value of p_c/p_d. In most case, we obtain the smallest value of Top/Other for pixel types of 4 (only C groups pixels).

(a)types of 4 (b)types of 9 (c)types of 16 (d)two groups

Figure 2 Pixel placement type

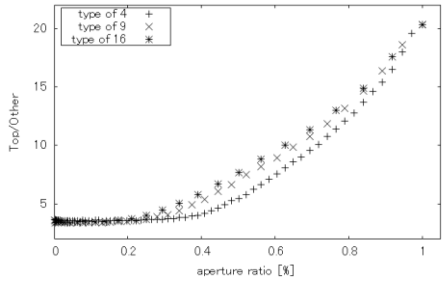


Figure 3 Top/Other for 4, 9, and 16 types

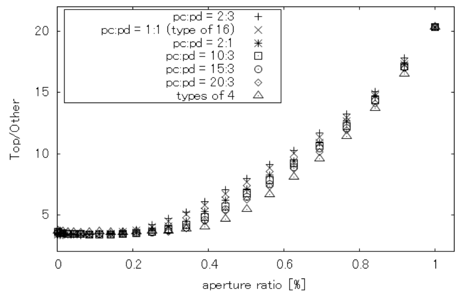


Figure 4 Top/Other for pc/pd

4. Conclusion

The smaller the aperture ratio is, the lower Top/Other is and it's considered difficult to appear the effect of jaggies. But if aperture ratio is low, it is not practical because the brightness is low and so on. So we consider that 4 type pixel placement is better to reduce the effect of the jaggies.

5. References

1) M.Kanazawa, et.al. : "Study on Synergism of Resolution and Gray Scale Characteristics in Image Recognition in Relation to Vernier Acuity", Japanese Journal of ITE , 57 , 11 , pp.1491-1500 (2003)

2) J.Akita, et.al. : "Image-acquisition-and-display device architecture without directional singularity using pseudorandom pixel placement", Japanese Journal of ITE, 60, 7, pp.1-4 (2006)

3) M.F.Deering, : "A Photon Accurate Model of the Human Eye",ACM Transactions on Graphics, 24, 3, pp.649–658 (2005)

4) C.Izak, J.Akita, : "Pixel Structure for Jaggy Reduction in Line Representation using Pseudorandom Pixel Placement", Japanese Journal of ITE, 68, 11, pp.J522-J524 (2014.