Contour perception of half-toned density step image

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Abstract

Contour is important elements of image and is usually expressed by the density jump between two areas of image. Recognition of object is usually carried out from the contour. In some cases, emerging of false contour is problem in image coding and de-cording process. Half-toning is essential processing for digital printing of continuous tone. Contour perception conditions are studied experimentally on various half-toning conditions, observation distances, and illumination conditions. It is found that the contour perception become easy as the stimulus of the halftone dot decreases in human visual system.

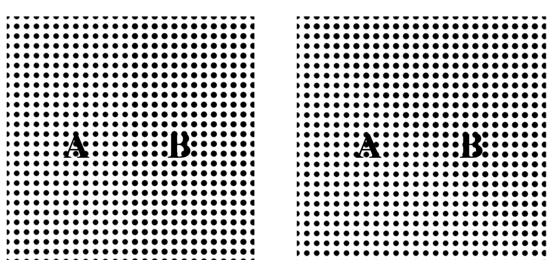
Introduction

In the image processing, contour in the image is important factor, because our perception of object and its recognition is carried out from the contour. In a sense, it can be said that our eyes are searching the contour in the image. Contour is the boundary of two different density, color or texture areas. For obtaining good quality image printing, it is considered that the contour expression characteristics in the image are important.

Digital half-toning is essential processing in digital printing. There are various methods in the digital half-toning. Conventional halftone is fundamental method and is used in the wide area of printing. Estimation of digital half-toning has been carried out from the various viewpoints, but the relation between the easiness of perceiving the contour, which is one of simplest elements of image, and the half-toning methods, has not sufficiently understood yet.

In this study, contour perception dependences on density difference between two areas, halftone cycle, halftone angle, illumination condition, and observation distance are studied experimentally.

Experimental

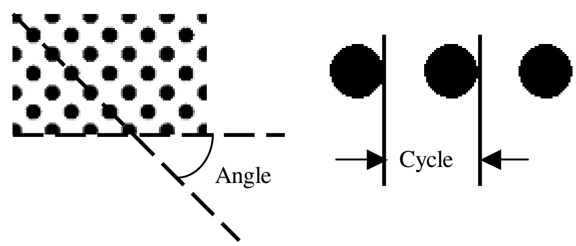


(a) (b)

Figure 1. *Example of density jump pattern,(a) Perpendicular contour pattern, (b) Diagonal contour pattern.*

Table 1: Observation sample preparation,
(a) Density jump and density values, (b) Angle of halftone dots, (c) Cycle of halftone dots.

(a)			(b)	(c)
Density jump	Density values of A and B area		Angle of halftone dots	Cycle of halftone dots (mm)
	(A)-(B)	(A)-(B)		
1	64-63	192-191	0°	1
2	64-62	192-190		
3	64-61	192-189		
4	64-60	192-188		2
5	64-59	192-187		
6	64-58	192-186		
7	64-57	192-185	45°	3
8	64-56	192-184		
9	64-55	192-183		
10	64-54	192-182		4
11	64-53	192-181		
12	64-52	192-180		



(a) (b)

Figure 2. *Explanation of halftone dot arrangement: (a) Angle of halftone dots, (b) Cycle of halftone dots.*

Figure 1 shows the two images used in this experiment; (a) image with perpendicular contour line and (b) image with diagonal contour line. The images were printed at size 10 cm x 10 cm with the resolution of 300 dpi. The image printing conditions are shown in Table 1. In Table 1, area A was fixed density level of 64 and 192, the density level of area B was changed from 191 to 180, and from 63 to 52, respectively. Figure 2 shows the explanations of halftone dot arrangement; screen dot shape and screen angle. The dot shape of halftone is circular and Table 1 (b) and (c) shows the screen angle of halftone dots.

The Experimental Methodology

The observation experiments are carried out as shown in Fig.3. The observers are 10 students of Nippon Institute of Technology. Their perceptibility of the contour in halftoned images are examined. The experimental conditions of illumination and observation distance are shown in Table 2.

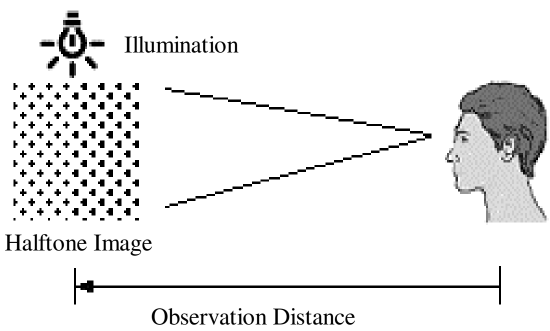


Figure 3. *Schematics of experiment.*

Table 2: Experimental condition, (a) Illumination, (b) Observation distance.

(a)

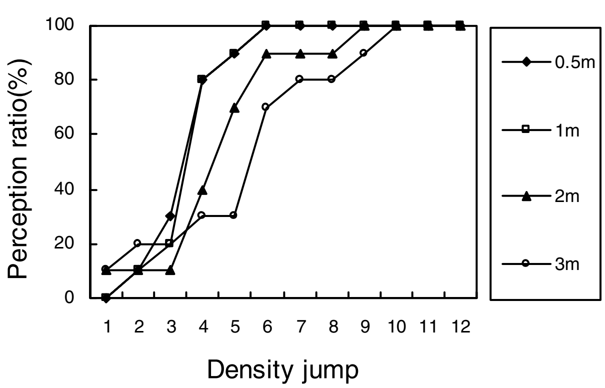
Illumination (Lux)
1.0 x 10
1.0 x 10^2
1.0 x 10^3

(b)

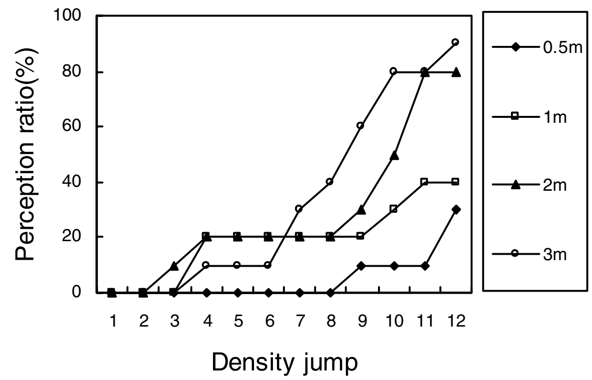
Observation distance
0.5 m
1.0 m
1.5 m
2.0 m
2.5 m
3.0 m

Results and Discussions

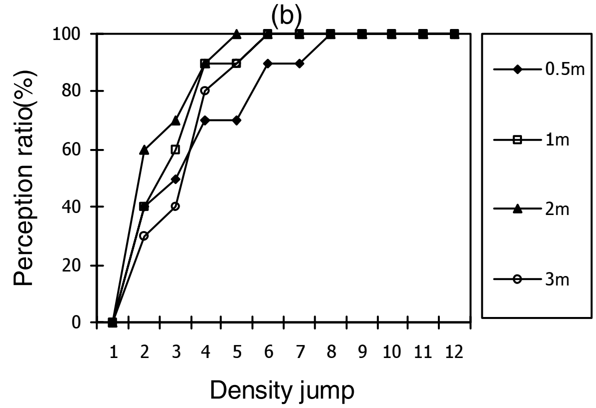
The perception ratio that means the ratio of the persons of perceiving contour is plotted against the density jump between area A and B. The ratio means the easiness of contour perception. The ratios are obtained on changing three factors: cycle of halftone dot, screen angle, and illumination.



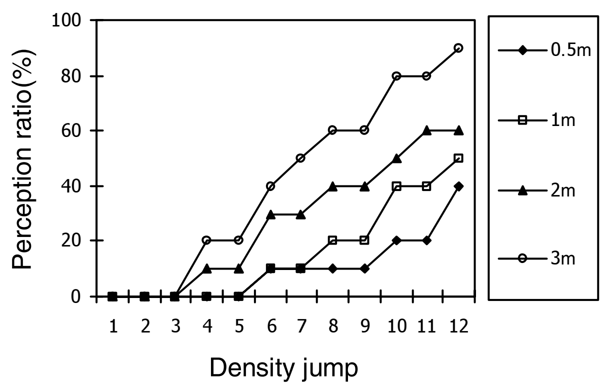
(a)



(b)



(c)

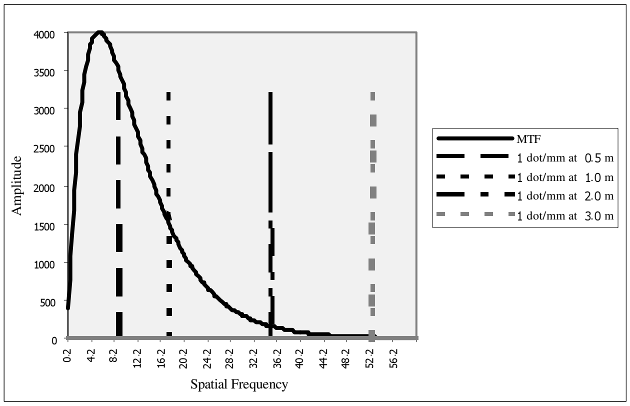


(d)

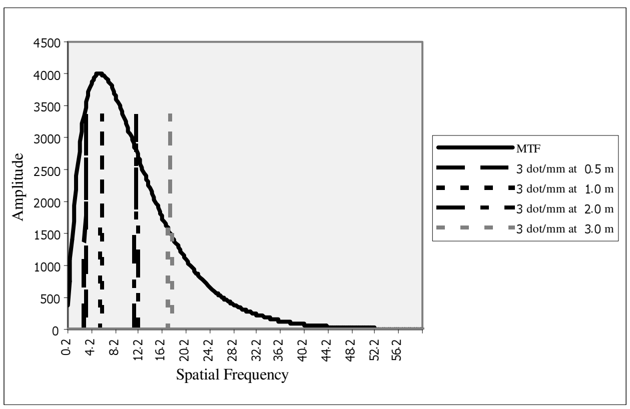
Figure 4. *Perception ratio dependence on density jump between 192-180 when the angle 45 degree, (a) condition of illumination 1.0x10Lux, cycle 1mm, (b) condition of illumination 1.0x10Lux, cycle 3mm, (c) condition of illumination 1.0x10^{3}Lux, cycle 1mm,(d) condition of illumination 1.0x10^{3}Lux, cycle 3mm.*

1) Cycle of halftone dot

Figure 4 shows the perception ratio dependence on density jump, when the screen angle is 45 degrees. In all cases in Fig.4, the perception ratio increases according to the increase of density jump. It is found that when the dot cycle is 3 mm, the increase of the ratio is slow compared with the case of dot cycle 1mm, and the ratio increases as the observation distance increase.



(a)

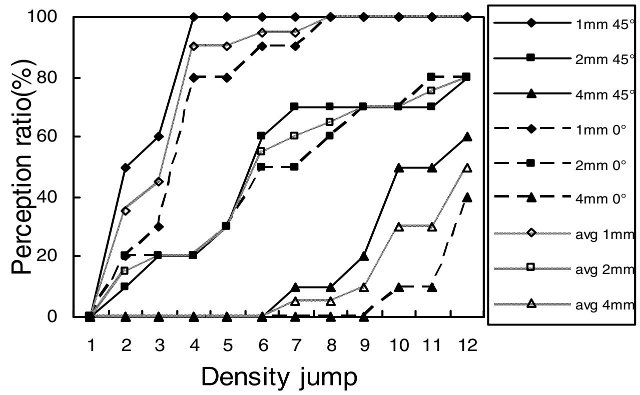


(b)

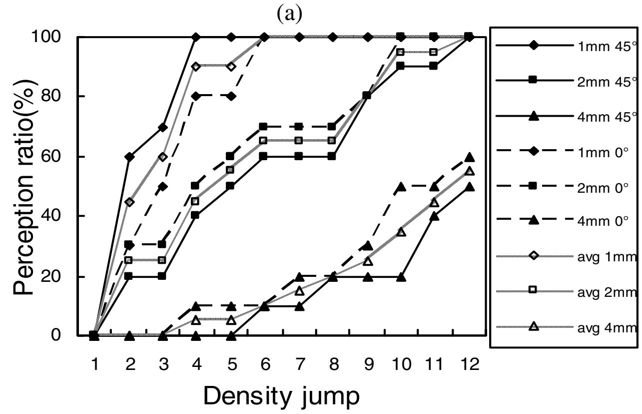
Figure 5. *Relationship between Discrete Fourier Transform of halftone frequency and Modulation transfer function of HVS, (a) Halftone frequency 1 dot/mm. (b) Halftone frequency 3 dot/mm.*

Figure 5 shows the peaks of the respective half-tone frequencies and MTF curve of HVS (human visual system) on the horizontal axis of the scale of cycle/degree from the eye. MTF curve is for understanding the stimulus strength of half-tone dots. When the half-tone frequency is 1 dot/mm, it is forecasted that half-tone dots have certain stimulus strength in the observation distance of less than 1 m, and in more than 2 m the dot stimulus strength become week. When 0.33 dot/mm (the dot cycle: 3mm) in the less than 2 m of observation length, the stimulus of the dot is certain and at the observation distance 3 m dot stimulus strength decreases to a halt of the value of less than 1 m.

Above results agree to our subjective estimation. Figure 4 (d) shows that the perception ratio increases as the observation distance increases. It is considered due to the half-tone stimulus decreases as the observation distance increases. On the other hand, Figure 4 (c) shows high perception ratio compare with Figure 4(d). This is also considered due to the difference of the strength of stimulus. In Fig. 4 (c), the perception ratio of the observation distance 0.5 m is a little bit less than in the cases of other distance. This is also considered the difference of half tone stimulus strength.



(a)

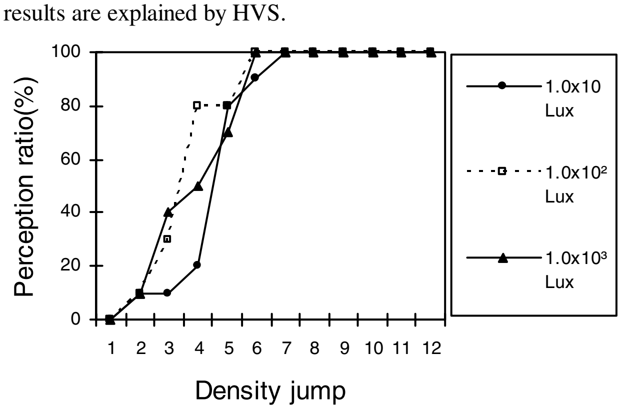


(b)

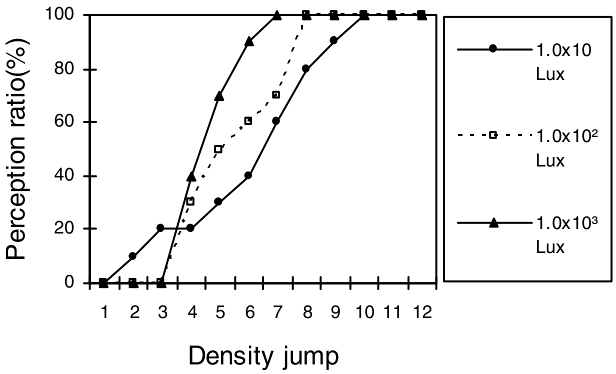
Figure 6. *Perception ratio dependence on density jumps Density values between 192-180, observation distance 1 m and illumination 1.0x10^{2}Lux. (a) Perpendicular pattern, (b) Diagonal pattern.*

2) Halftone screen angle

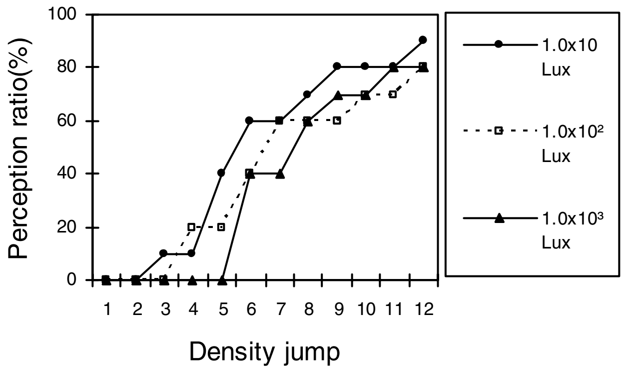
Figure 6 shows the perception ratio dependence on density jump at the observation distance 1.0 m and illumination 1.0x10^{2}Lux of halftone angle 0 and 45. It is found from Figure 6 that the halftone image with the screen of angle 45 degree can be detected easier than the screen of angle 0 degree at perpendicular pattern. From the comparison between Figure 6(a) and (b), it is found that perception ratio of halftone image with diagonal pattern is higher than the one with perpendicular pattern. It is proposed that above results are explained by HVS.



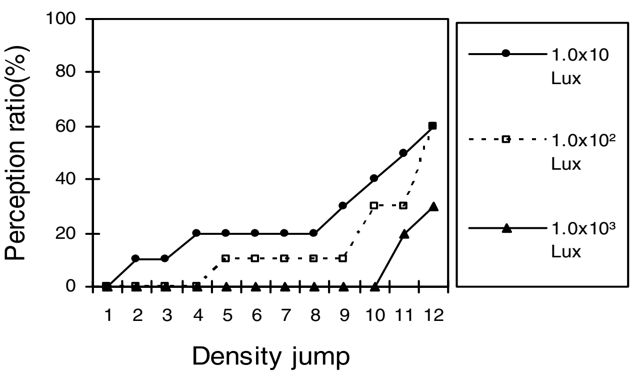
(a)



(b)



(c)



(d)

Figure 7. *Perception ratio dependence on density jump between 64-52 and the angle 45 degree, (a) Condition of cycle 1 mm, observation distance 1 m, (b) Condition of cycle 4 mm, observation distance 1 m, (c) Condition of cycle 1mm,observation distance 3 m, (d) Condition of cycle 4 mm, observation distance 3 m.*

3) Illumination

Figure 7 shows the perception ratio dependence on density jump of the angle 45 degree when the illumination is at 1.0x10, $1.0x10^2$, $1.0x10^3$ Lux. The illumination has little effect when dot size is 1 mm at observation distance 1 m. On the other hand, illumination has influence the contour perception when the observation distance increases at the dot cycle 4 mm. At the observation distances 3 m, perception ratio increase as the illumination decreases.

Conclusions

Contour perception conditions are investigated on various halftone and observation conditions. At the large halftone dot cycles of 3 mm, the contour becomes easy to perceive when the observing distance increases. It is explained due to the decrease of dot stimulus compared with contour signal in human visual system. When the halftone angle is 45 degree, it is found that the perception is better than when the angle is 0 degree. Concerning the effect of illumination, it is found that the contour perception is better when illumination strength decreases at the large halftone dot cycles 3 mm.

References

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[2] M. Ikeda Image Processing in Human Vision (In Japanese), pp 137-181 (1999).

Author Biography

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