HALFTONE DOT GENERATION IN COLOR AND MONOCHROME SCANNERS

Yoshio Ono*

Abstract: This paper describes dot generation in Dainippon Screen's color and monochrome scanners. The optical systems for halftone dot exposure, particularly the recording head with built-in laser, in the various Direct Scanagraph color scanners are described, and the halftone dot formation, composed of approximately 23 x 23 minute dots, and its advantages in halftone dot quality and tone reproduction are discussed. The importance of the advantages in reproducing tones through certain types of halftone dots and in simultaneously outputting images and linework through a page make-up system is also explained. The optical system for dot exposure in the Scanica monochrome scanner and the relation between CCD input scanning and laser output recording are also described, and the halftone dot formation, composed of fewer minute dots than those of the color scanners, and tone reproduction are discussed in comparison to those of the color scanners.

Introduction

In the reproduction process used to reproduce continuous tone originals by lithographic and letterpress printing, it is necessary to convert continuous tone originals into halftones. For many years, a traditional photographic process using a simple optical system and glass or film contact screens has been used for this conversion. Recently, however, color scanners with direct screening function, more particularly those equipped with dot generators that electronically generate halftone dots, have come into widespread use, and most continuous tone/halftone conversions in color reproduction today are performed in a photographic process using electronic/optoelectronic equipment. In monochrome reproduction as well, monochrome scanners, i.e., electronic process cameras, have become fairly employed, and photographic typesetting systems with integrated halftone screening function have increased in popularity, gradually replacing traditional methods with electronic/optoelectronic dot generation.

In color scanners, Dainippon Screen manufactures and markets several models of Direct Scanagraphs; in monochrome scanners, the Scanica. All of these scanners employ an electronic dot generator. The Direct Scanagraphs form

*Dainippon Screen Mfg. Co,. Ltd.

halftone dots through multibeam parallel exposure using the rotating cylinder scanning method. The Scanica, on the other hand, forms halftone dots through single-beam exposure using the flatbed scanning method. Following is a description of the halftone dot generators and dot formation in the Scanagraphs and the Scanica.

Direct Scanagraph Color Scanners

Recording optical system

Dainippon Screen first announced the Direct Scanagraph, equipped with its halftone dot generator, in 1981. From the beginning, the Direct Scanagraph with halftone dot generator employed a system, described in detail later, in which a matrix of approximately 23 x 23 minute dots for each halftone dot unit area is exposed by ten light beams arranged in parallel straight lines. Main portion of the recording optical system which consists of an argon laser, beam splitters which split the laser beam into ten beams, and ten light modulators was housed separately from the main scanner unit, and the ten light beams were transmitted by optical fibers to the recording head that faces the film cylinder. This type of optical system is still used in the present Scanagraph models SG-818, SG-888, and SG-777.

In 1984, the SG-608, a Scanagraph that eliminated a separately housed optical system and employed a new recording optical system in the main scanner unit, was announced. This optical system, which is shown in Figure 1, had the laser and all other optical elements built into the recording head. Other features of this system included its simple construction and the first application of a helium-neon laser in a dot generator for color scanners. All of these characteristics contributed to cutting the cost of the entire optical system.

As shown in the figure, the amount of the light beam output from the helium-neon laser is adjusted and the beam is split into ten beams by the light adjustment unit. The ten beams are turned on and off individually by a single acousto-optical light modulator (AOM) according to dot signals produced by the image signals and the screen signals. The light beams are directed by two mirrors, and only first-order diffraction light beams are allowed to pass by the slit for separating zero-order and first-order light beams, thus blocking out the zero-order light beams that passed directly through the AOM. The beams that pass through the

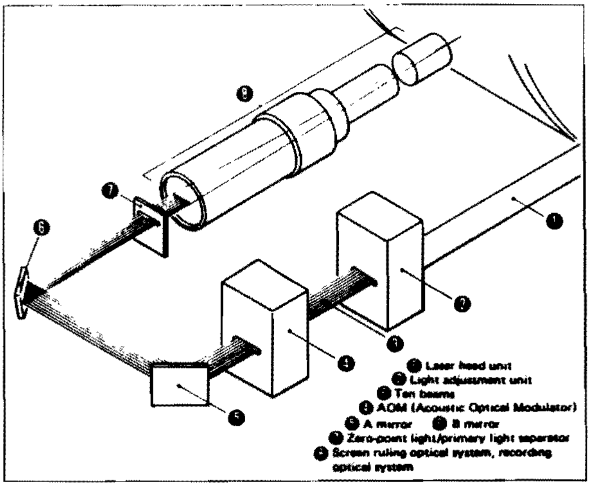

Figure 1. Recording optical system for SG-608 halftone dot generation.

slit are finally focused by a zoom lens into light spots on the film mounted on the cylinder.

Although this optical system is used unchanged in the SG-688 Scanagraph, the helium-neon laser shown in Figure 1 is replaced with an argon laser in the system used in the SG-757 Scanagraph.

In addition to these systems, an extremely simple optical system consisting of a light source constructed of a staggered array of ten LEDs is used for exposure in the SG-101 and SG-111 Scanagraphs. This LED-array recording head is also employed in the IP-1000 and IP-700 Image Processing Systems for Japanese-language text and graphics, where it is used for recording characters and other linework.

Halftone Dot Formation

The formation of halftone dots recorded with any of the above three optical systems is the same with some exceptions. Figure 2 illustrates the basic dot formation at a screen angle of 90 degree. As shown in the figure, individual halftone dots are recorded in about 2.3 passes of the ten light beams. In other words, each halftone dot is recorded as a collection of the on/off condition of approximately 23 x 23 light spots produced by the light beams. Changes in screen ruling are controlled by the zoom lens shown in Figure 1, with the same dot formation being stan-

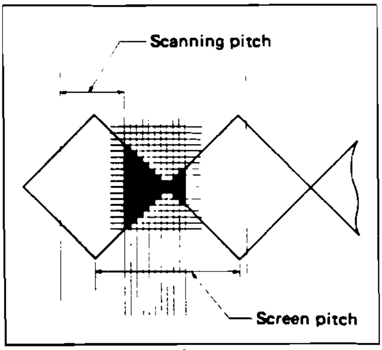

Figure 2. Relation between screen pitch and scanning pitch or minute dot array.

dardly used in the range of 85 to 200 lines per inch. Different dot formations, however, are used in some Scanagraph models (e.g., the SG-111 and SG-708), where a fixed or semi-fixed feeding speed of the recording head is used in the secondary scanning direction.

The original development goal of obtaining high-quality halftone dots was the main reason that a matrix of so many minute dots, i.e., 23 x 23, was used to form halftone dots. Table 1 lists, by screen ruling N, size A of the minute dots that compose the halftone dots, i.e., the length of the side of a minute dot when it is regarded as a square. Although these values vary from 13 microns for an 85-line-per-inch screen ruling to 5.5 microns for a 200-line-per-inch screen ruling, their exceptional minuteness ensures that high-quality halftone dots with little edge jaggedness will be obtained, as can be imagined by examining Figure 2. The

Table 1. Relation between screen ruling N and minute dot size A

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N (1/inch)	A (μm)
85	13.0
100	11.0
110	10.0
120	9.2
133	8.3
150	7.4
175	6.3
200	5.5

extremely high resolution of scanning exposure is also clear from an examination of scanning densities: about 4,600 lines per inch for a 200-line-per-inch screen, about 4,000 lines per inch for a 175-line-per-inch screen, and a bit less than 2,000 lines per inch even for the coarsest screen, an 85-line-per-inch screen.

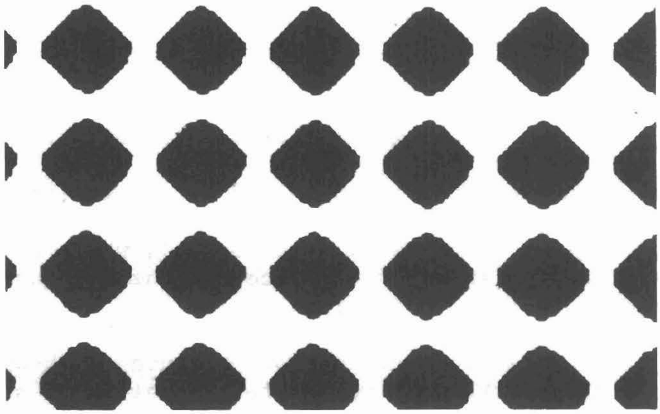

Figure 3. Photomicrograph of 175 line halftone dots produced by Direct Scanagraph: screen angle 90 degree, dot area about 40 percent.

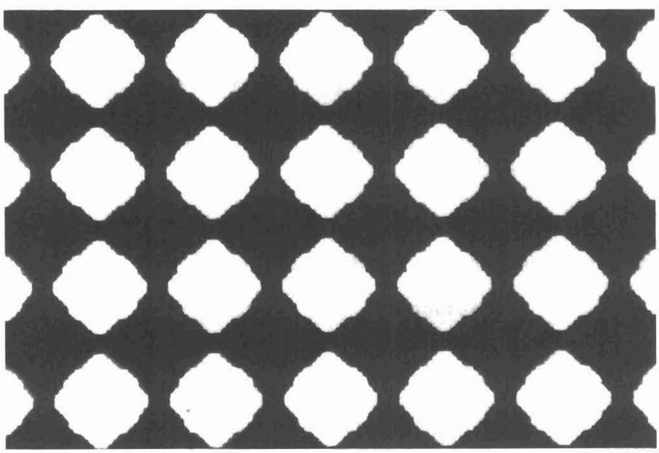

Figure 4. Photomicrograph of 175 line halftone dots produced by Direct Scanagraph: screen angle 90 degree, dot area about 60 percent.

Figure 3 through Figure 6 show photomicrographs of halftone dots actually exposed on an Direct Scanagraph at 175 lines per inch. The halftones in Figure 3 and Figure 4 are for screens set at 90 degree with about 40 percent and 60 percent dot area ratios, respectively. The halftone dots in Figure 5 and Figure 6 are for screens set at 15 degree with about 30 percent and 70 percent dot area ratios, respectively.

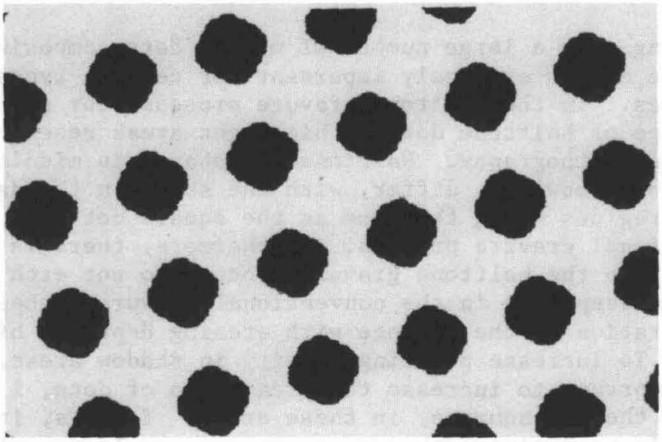

Figure 5. Photomicrograph of 175 line halftone dots produced by Direct Scanagraph: screen angle 15 degree, dot area about 30 percent.

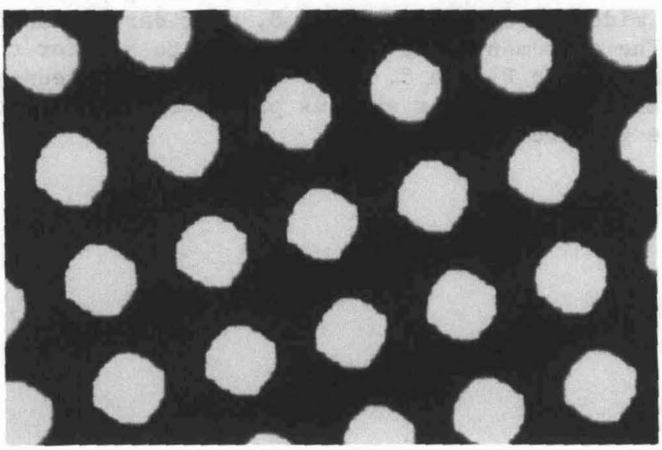

Figure 6. Photomicrograph of 175 line halftone dots produced by Direct Scanagraph: screen angle 15 degree, dot area about 70 percent.

Another immediate effect of having individual halftone dots composed of 23 x 23, or 529, minute dots is a large range of freedom in tone reproduction in halftones. Generally, color scanners digitally express each separation in 8-bit tones, making it possible to produce a maximum of 256 tones. Because each halftone dot consists of 529 minute dots, there is a great deal of latitude in halftone dot size variations corresponding to these tones, allowing smoother tone reproduction.

Having such a large number of minute dots composing each halftone dot is extremely important for certain types of halftones. In the halftone gravure process, for example, the shape of halftone dots in highlight areas resembles that in offset lithography. Halftone dot shapes in middle tones to shadows, however, differ, with the shape in the darkest shadow regions being the same as the square dot used in the conventional gravure process. Furthermore, there is a tendency in the halftone gravure process to not etch shadow cells as deeply as in the conventional gravure process, in consideration of the balance with etching depth in highlight cells. To increase printing density in shadow areas, it is thus important to increase the area ratio of dots, i.e., the size of the dot squares, in these areas. That is, it is desirable to maximize the ratio between the length of a side of shadow dot squares and the space (i.e., the clear or white lines) between adjacent squares. Figure 7 and Figure 8 show photomicrographs of samples of halftone dots produced on a Direct Scanagraph for use in halftone gravure. Figure 7 shows middle tone dots; Figure 8, near darkest shadow dots. The aforementioned ratio was set to 5:1 for the halftone dots in Figure 8. The very little jaggedness on the edges of white lines enables production of high-quality halftone gravure cylinders.

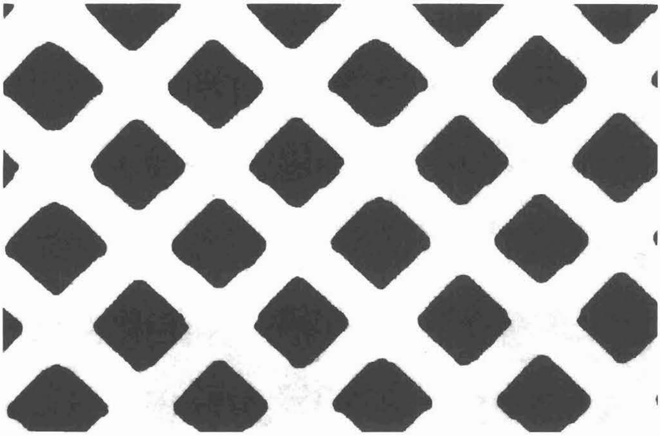

Figure 7. Photomicrograph of 175 line halftone gravure dots produced by Direct Scanagraph: middle tone.

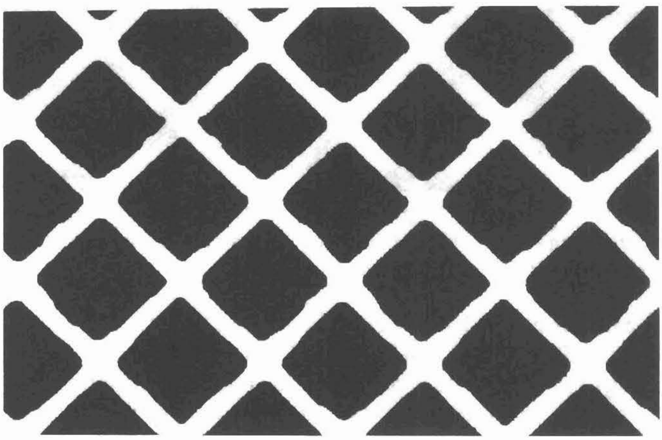

Figure 8. Photomicrograph of 175 line haltone gravure dots produced by Direct Scanagraph: near deepest shadow.

Another example of the advantages of using a 23 x 23-minute dot formation for halftone dots is that it allows linework resolution to be set to a higher level when combining images and linework (including text) for simultaneous output recording. When recording from a Dainippon Screen Sigmagraph color page make-up system, all ten beams of the recording head expose halftone images as normal, while the ten beams are divided into five pairs of adjacent beams for linework areas for independent control and modulation via linework signals that multiply the specific resolution by five. This process permits linework to be recorded at an extremely high resolution. When recording halftone images at a 150-line-per-inch screen ruling, for example, linework would be recorded at a resolution that is 23/2 times higher, or about 1,700 lines-per-inch. The photomicrograph in Figure 9 shows an example of halftone image and linework simultaneously output from a Sigmagraph System.

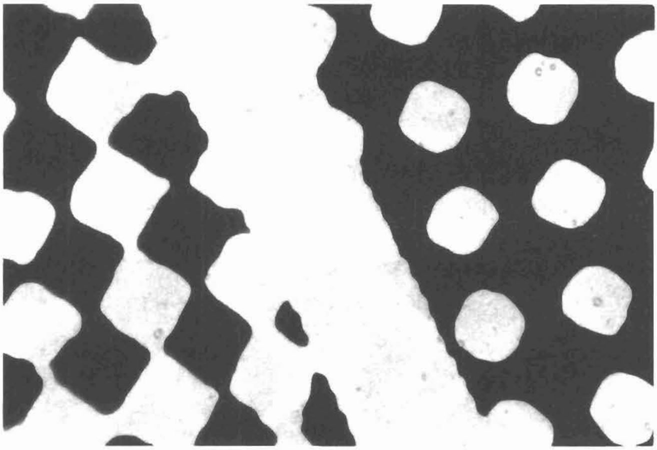

Figure 9. Photomicrograph of a portion of integrated negative image of halftone (175 lines per inch) and line work produced by Sigmagraph System.

Since the end of 1985 and autamn 1986, Dainippon Screen has also had favorable response from marketing, in Japan, the Rastergraph 2500 and Rastergraph 5000, both rotating cylinder-type, high precision laser plotters that modify the dot generator recording optical system shown in Figure 1 to enable speedy production of artwork for printed circuit boards (PCB) from CAD data. Although both of these systems rapidly and accurately produce high-density artwork through a 10-beam, parallel scanning exposure system that utilizes an argon laser, the Rastergraph 5000 adds the ability to change individual light spot size between 5 and 10 microns, making it the highest resolution PCB laser plotter in the world.

Scanica Monochrome Scanner
Relation between Input and Output Scanning and Recording Optical Systems

Dainippon Screen successfully developed the Scanica SF-222 as a monochrome flatbed scanner, and has marketed it since the beginning of 1986. As shown in Figure 10, both the original and film are mounted flat for scanning on this scanner. CCD line image sensors are used to input originals, and a helium-neon laser is used to output reproduced images onto film.

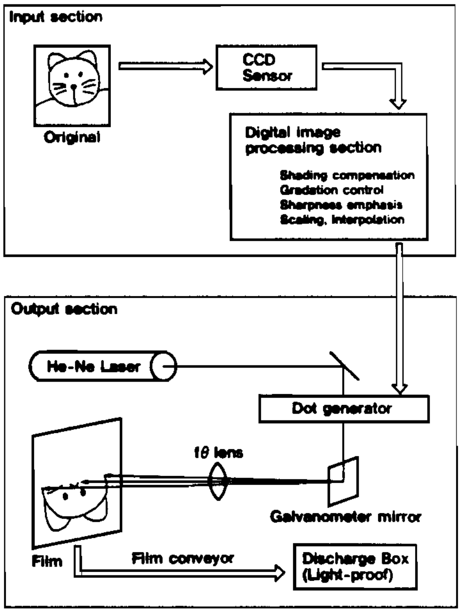

Figure 10. Overall Scanica construction.

Development goals for this scanner included the achievement of maximum speed without loss in quality. Also, in consideration of balancing these with cost factors, the laser output recording density was set to 1500 lines per inch for fine screen rulings and 750 lines per inch for coarse screen rulings. Although an input scanning resolution that is twice the output screen ruling is generally thought to be sufficient for halftone reproduction, CCD input scanning resolution in the principal direction was set to 750 lines per inch in the SCANICA to ensure maximum resolution in halftone reproduction and to allow for quality in linework reproduction. However, the scanning density, that is, the resolution in the secondary scanning direction, is 750 lines per inch for fine screens; 375 lines per inch for coarse screens. The resolution in the principal scanning direction given above is for same-size exposure. The corresponding resolution in the primary scanning direction on output images in the case of enlargements or reductions will change because the magnification of the image-formation optical system from the original to the CCD is fixed. These considerations mean that with the Scanica, two lines are always exposed for each input scanning line.

For example, when using a screen ruling of 150 lines per inch with the recording optical system set for a 90 degree screen angle, each halftone dot is exposed through ten scanning movements of the laser beam. During this interval, the CCD sensors on the input side scan five lines. For each line scanned from the original, the image signals are output twice to the recording side, first the values of the scanned line then followed by the average values (interpolated values) between the scanned line and the following line. A comparison is made each time with the screen signal, and on/off signals are generated for dot generator exposure control. Because an image signal with five or more times the resolution of the screen ruling is employed in this case, halftone images of exceptional quality are recorded. The same type of interpolation processing is performed for changes in resolution corresponding to magnification ratio in the primary scanning direction.

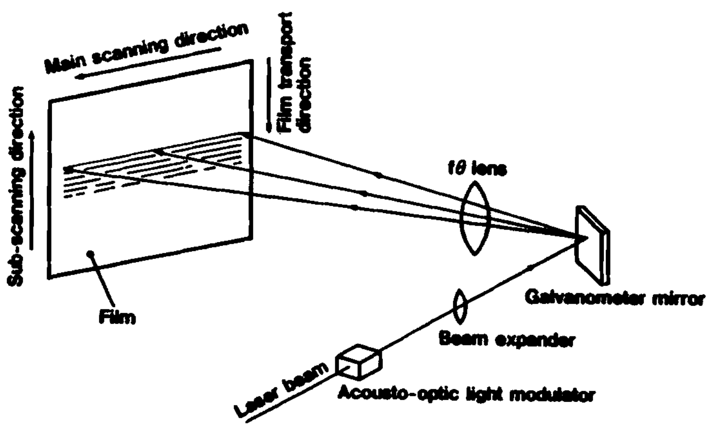

Figure 11. Scanica output recording optical system.

The structure of the recording optical system is illustrated in Figure 11. On/off modulation is performed for the helium-neon laser beam according to the image signals and the screen signals. A galvanometer mirror that vibrates 200 times per second deflects the modulated light beam, and an fθ lens focuses a light spot on the film while scanning laterally (across the feed direction). When scanning at 1500 lines per inch, the individual minute dots which compose halftone dots measure 17 x 17 microns. At 750 lines per inch, these dots measure 34 x 34 microns. Corresponding changes in the size of the light spot are accomplished by changing the optical path.

Halftone Dot Formation

The Scanica, as opposed to the Direct Scanagraphs, using a single light beam, emphasizes exposure speed and thus has relatively large size minute dots, as given above, composing halftone dots. The number of minute dots composing individual halftone dots for 150-line screens is thus 100. Because the size of the light spot is determined by the scanning density, the number of minute dots composing individual halftone dots varies with changes in the screen ruling, whereas it does not with color scanners. For each scanning density, the higher (finer) the screen ruling, the smaller the number of minute dots, and the lower (coarser) the screen ruling, the greater the number of minute dots.

Even for the coarsest rulings in the fine or coarse screen groups, that is, 133 and 65 lines per inch, the number of minute dots per halftone dot is approximately 120, and for the finest rulings, that is, 175 and 100 lines per inch, it is approximately 70 or 80. Thus, because all of the tones for 8-bit image data cannot be reproduced within one halftone dot, multiple adjacent dots are used as a unit for tone reproduction.

Conclusion

The above report has described halftone dot generation in Dainippon Screen color and monochrome scanners. To summarize, I think the following points were clearly understood: that the extremely high resolution of halftone dots produced by the Direct Scanagraph provides the advantages in halftone dot quality, tone reproduction, and quality of text and linework; that these have recently been achieved through a relatively simple optical system; that the Scanica on the other hand achieves high resolution as a monochrome scanner through exposure at a relatively fine scanning density in spite of its high scanning speed; and that the Scanica also provides sufficient quality in tone reproduction.