CHAPTER II
THEORETICAL AND LITERATURE REVIEW

Printing Industry today classifies image data as continuous tone image and bi-level image. Usually, continuous tone image is found on digital process by computer while bi-level image is found on conventional printing. The continuous tone image, which an element of the image is able to generate the richness of color or shade, supports photograph. In contrast, bi-level image, which an element can generate only two tone levels supports, only line Art and pain-text.

However, continuous tone image can be mimic from bi-level tone image though halftone process. Halftone is a process that translates images from continuous tone to bi-level tone in order to be able to print though output devices. The principle of halftone is that each element of image would be gathered for demonstrating various tone levels observed by human eyes. As the human visual system has low-pass filter characteristics, the eyes, thus, tends to average tone of a region, which depicts various tone level.[1,2]

2.1 Theoretical Background

2.1.1 Halftone Model Based

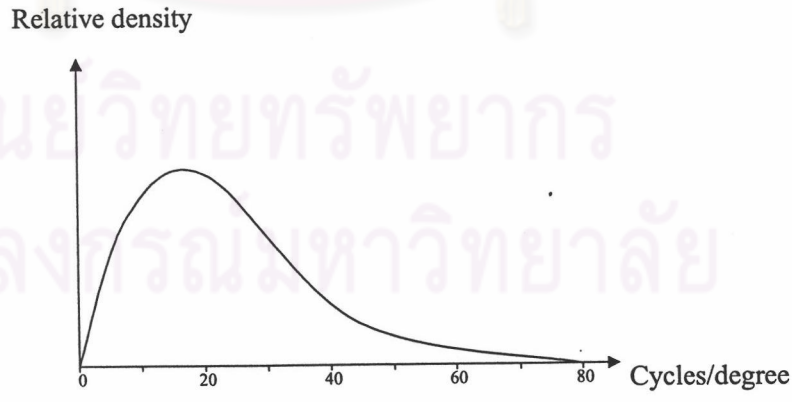

Figure 2-1 Eyes MTF of human characteristic as low-pass filter

Human eyes will be characterized as a low pass filter, which is limited in the high frequency perception. This makes human eyes cannot separate the resolution over 8-10 cycle/degree, as shown in the Figure 2-1. The observers will see the small disperse black dots as the gray. As result, halftone image will adjust the limitation by creating the variety tone reproduction from bi-level processing (see Figure 2-2). [3,4]

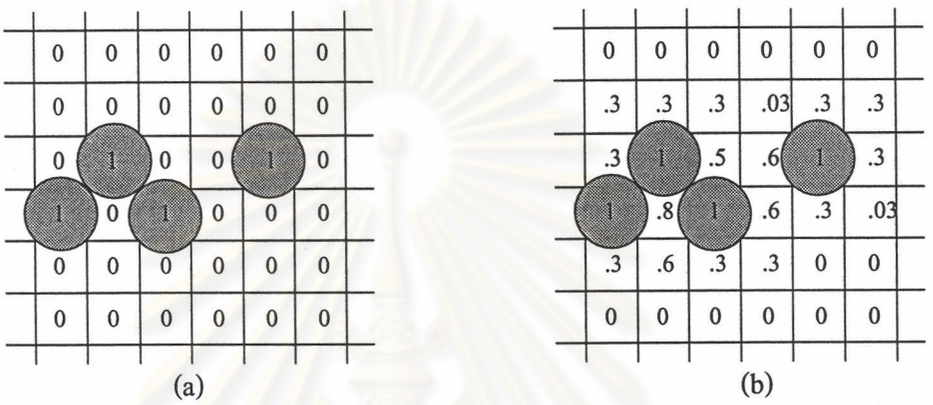

Figure 2-2 The model base of image elements (a) from the printout (b) perceived by human eyes

2.1.2 Conventional Halftoning

In 1893, Louis and Max Levy found conventional bi-level technique, called screening, for photomechanical printing. They used two glass plates that were etched with parallel lines. An Opaque black material was rubbed into the lines of the plates. The two plates were then bonded together so that the grooves of one plate were situated at right angles to those of the other, forming a crosshatched screen. The grids form transparent squares precisely spaced and specified in terms of lines per inch (lpi). The glass cross-line screen is considered to be the origin of the classical halftoning that provided sharp-edged dots. [5]

2.1.3 Digital Halftone

Digital halftone started around the 1920s and was used to display images on digital bi-level devices and to reduce the transmitting bandwidth. The printing industry adopted digital halftone much later, gaining momentum after the introduction of the electronic proofing and desktop publication. [6,7]

Tones gradation generated from digital halftone processing is resulted by the arrangement of halftone dot, which is separated in 2 types, cluster dot and disperse dot. [8]

2.1.3.1 Cluster dot or AM screen generates screen dots on the grid line by linking each element, or pixel, to vary dot size. Highlight would be represented by the tiny dot; while midtone and shadow would be replaced by larger dots.

2.1.3.2 Dispersed Dot or FM screen generates tone by the distribution of each pixel on grid pattern in different arrangement. Highlight has a sparse dispersion, while the shadow has a higher dense dispersion.

2.1.4 Tone Equation

The variation of tone reproduction can be created by 2 methods. One is changing the size of screen dot, which is the principle of AM screen. Another one is changing the area covered by screen dot and fixing dot size which is the principle of FM screen. Dot area percentage can be calculated by Equation 2-1. The characteristic of two types is explained as follow. [9]

$$\% \text{ Dot Area} = \frac{\text{Area covered by ink}}{\text{Total area}} \qquad (2\text{-}1)$$

2.1.5 AM Screen

AM screen is a technique in halftone processing by changing the size of dot screen to represent different tone reproduction. The size of dot can be enlarged their size by plotting the image element together. In addition, the screen dot will be set on the grid line as the pattern.

The terminology involving halftone method has their relation as shown in Figure 2-3. One of the vital parameters is the size of cell, which is related to dpi value of input image and lpi value of output image. The cell size is related to the numerical tone reproduction, which is created by halftone algorithm shown in Equation 2-2. If the tone reproduction of screen is inadequate in creating output image, the result is

called Posterize, which is the major cause of discontinuous tone reproduction perceived by human eyes. Normally, the visibility of human eyes cannot distinguish the tone reproduction more than 100 shade.

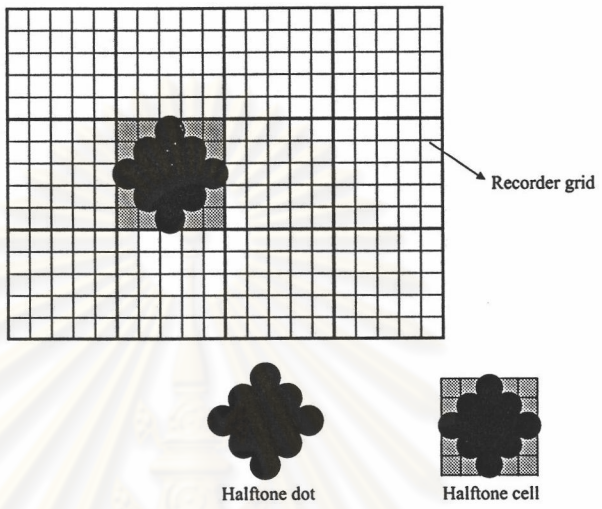

Figure 2-3 Halftone component

$$\text{Cell size} = \frac{\text{dpi}}{\text{lpi}} \qquad (2\text{-}2)$$

The lpi is the image quality parameter notifying that the limitation of screen can support the frequency input image or fine image. If the high frequency input image is processed by the low lpi, the quality of image is dropped. Usually the lpi parameter is set to the maximum as it possible. However, the means to changing lpi parameter and the created tone reproduction will be based on the limitation of dpi parameter of input image. Due to this limitation, the recommended dpi/lpi values can be defined from Equation 2-3.

$$\text{Number of shades} = \left[\frac{\text{dpi}}{\text{lpi}}\right]^2 + 1 \qquad (2\text{-}3)$$

The arrangement of the dots creates image pattern, when 4-colors printing is employed. However it should be note that the pattern may brings to occur moiré, To reduce this effect, it can be done by rotation, each color plane as different angle. [10]

2.1.6 FM Screen

FM screen is the technique of processing halftone image through the arrangement of dispersed pixels or fix sized small dots. The dense dots populations represent shadow reproduction; while the sparse dots population represent highlight. Tone reproduction, thus relates with the distribution technique and dot size as shown in Figure 2-4

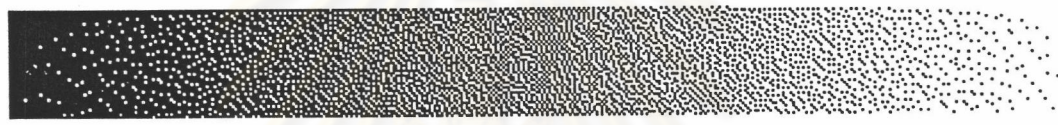

Figure 2-4 The arrangement of the same dot size of FM screen

The principal parameter of FM screen is the size of dot, which directly influences the ability in supporting the high frequency of original image. The system can support the high-frequency image when the screen size is very small. However, if the screen size is too small, it will affect the capability of conventional printing process; which in some cases, isolated dots of FM screen in highlight area disappears from the printout.

The characteristic of FM screen will generate a plenty of tiny dots in the image. This makes a serious problem when dot gain occurs, by which the tone reproduction becomes more serious compared with that of AM screen. Accordingly, it is restricted in only some printing systems, which can control the size of dot such as ink-jet which have high performance with uniformity of dot size.

Through using the dot dispersing of FM screen representing color reproduction, the dot randomness is effective because the screen don't have moiré when composition color component. [11]

2.1.7 Halftone Processing

2.1.7.1 Basic Algorithm

Sub-Image processing is a technique, which processes an image divided into sections, and processes each section as non-overlapping. The essential parameter used in sub-image processing is the size of sub-image of which the unit is pixel. The dimension of sub-image is square, sometimes, called this sub-image as " cell ".

Line-scan is the processing route which processes the whole image as pixel-by-pixel following from side to side and top to bottom.

2.1.7.2 Algorithm used in creating AM screen

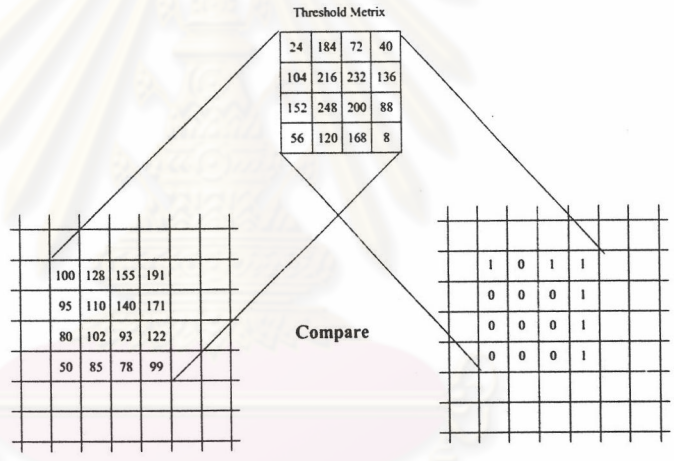

Figure 2-5 Threshold comparison with AM algorithm

Threshold matrix is the square matrix, which has equal size as halftone cell. It is a place, for storing the code value, which results in tone reproduction. Since, the code value in threshold matrix would be compared with sub-image data. If the code value from the center extending to the edge of the matrix decline, the possibility of cluster dot is high, the shape and size of comparative result are also characterized by threshold matrix. [12]

Based on sub-image processing, AM screen processes each part in the cell which has the same size. The sub-image will be compared with threshold matrix one by one as shown in Figure 2-5.

2.1.7.3 FM Algorithm

The code value of each pixel is converted to binary by comparing with 50 % threshold, usually setting at 128. If the pixel has the value less than the threshold value, the data would be clear to be 0. On the other hand, if the pixel has value more than 128, the data would be set to be 1. Then, the error from binary coding would be computed, and dispersed to adjacent pixels, as shown in Figure 2-6. [14,15,16]

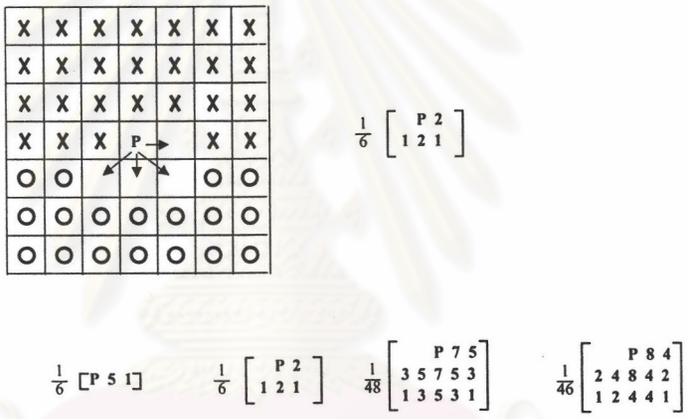

Figure 2-6 Error diffusion and their weighing windows

2.2 Literature Review

Floyd and Steinberg created FM algorithm by using negative feedback of an error, which received from the representation of continuous tone data by bi-level image. The error is propagated to the next neighboring pixel through the weighty window. The nearer of processing dot is the higher the error fraction becomes. So, the image composed of many isolated dots. The result shows that the screen responds to fine detail.[17,18]

Masaki and Hiroaki modified error diffusion method, regarding the weight of ED filter, like Floyd and Steinberg's algorithm. The periodic noise then is applied

to get uniformly dispersed dots at highlight and shadow. The result shows that wormy pattern disappears in highlight and shadow area.[19]

Hoshino and Yanaka created algorithm that reproduces continuous tone image on bi-level output device by using the optimum screen pattern. Based on sub-image processing, the optimum binary pattern which gives the reproduced image most similar to original image is selected. The low pass filter, simulating human visual system, is a criterion for choosing optimum pattern. The result shows that the appearance of artifact effects are substantially reduced. However, it is found that such possibly algorithm generate the halftone image with peculiar texture pattern especially in flat area.[20]

Zhigang applied negative feed back of Floyd and Steinberg's technique over the group of dots used in AM algorithm. The errors, which get from the representation of dot group will be dispersed to the next pixel. For that reason, the screen can generate more shades than original AM algorithm. On the other hand, a dot in Floyd and Steinberg's technique is substituted by a grouped dot. Furthermore, abundant of shade can be created in limited resolution of an out put device. [21]

Kitakubo et al. provided the method to improve the image quality from a device with a relative low spatial resolution, based on the number of microdot in halftone cell that were driven in binary mode. The algorithm uses error diffusion method, based on cluster dots, which consist of 1,4,9,16 and 25 pixels respectively. The original image is represented by intermediate level by using look up table method. Then, the total sum of an error in one group of pixel was distributed to the neighboring group. The result shows that false contours are diminished.[22]

Samworth used hybrid screening to compensate dot gain effect in conventional printing. Smoothly shade reproduction can be created using FM screen in highlight area and AM screen in mid-tone and shadows area. The result shows that highlight give better tone but the boundary between both screens is detectable by naked eyes. [23,24]