

ขั้นตอนวิธีการสร้างมุมสกรีนลูกผสมใช้เทคนิคแบบ IRRATIONAL TANGENT



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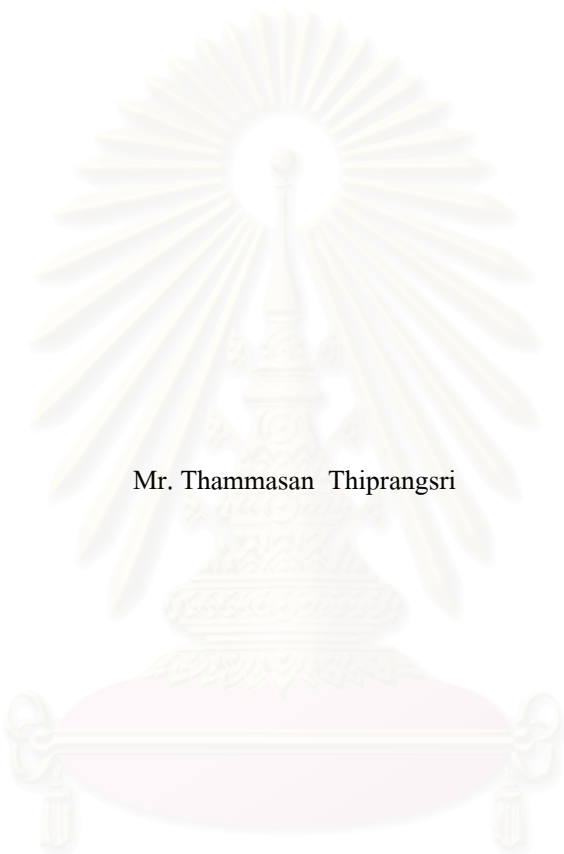
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ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

ALGORITHM FOR GENERATING HYBRID SCREEN ANGLES USING  
IRRATIONAL TANGENT TECHNIQUE



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สภามหาวิทยาลัย  
จุฬาลงกรณ์มหาวิทยาลัย

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งานวิจัยนี้นำเสนอขั้นตอนวิธีการสร้างมุมสกรีนลูกผสมด้วยเทคนิค Irrational Tangent โดย  
ใช้หลักการเคลื่อนย้ายข้อมูลภาพให้หมุนไปตามมุมสกรีนที่ต้องการ พบว่าวิธีการดังกล่าวสามารถทำ  
การชดเชยข้อมูลที่สูญหายไปได้ในระหว่างการหมุนข้อมูลภาพเพื่อให้ได้ผลที่ถูกต้อง และตำแหน่ง  
เชื่อมต่อที่เหมาะสมระหว่าง FM กับ AM ควรกำหนดที่ค่า Code Value 180-200 ช่วงระยะเวลาผสม  
อยู่ที่ Code Value 20-30 นอกจากนี้มุมสกรีนระหว่าง CMY จะแตกต่างกันตามปกติที่ใช้ในการพิมพ์  
สกรีนแบบ AM ทั่วไปคือ 30 องศา ผลจากการทดลอง แสดงว่าภาพพิมพ์ที่ได้จากสกรีนแบบลูกผสมจะ  
แสดงรายละเอียดของภาพในบริเวณสว่างได้ดีกว่าภาพพิมพ์ที่ใช้สกรีนแบบ AM และ สามารถผลิตน้ำ  
หนักสีภาพได้ดีกว่าภาพพิมพ์ที่ใช้สกรีนแบบ FM

## สถาบันวิทยบริการ จุฬาลงกรณ์มหาวิทยาลัย

ภาควิชา ...วิทยาศาสตร์ทางภาพถ่ายและเทคโนโลยีทางการพิมพ์...

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ลายมือชื่อนิสิต

ลายมือชื่ออาจารย์ที่ปรึกษา

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THAMMASAN THIPRANGSRI: ALGORITHM FOR GENERATING  
HYBRID SCREEN ANGLES USING IRRATIONAL TANGENT

TECHNIQUE. THESIS ADVISOR: ASSOC. PROF. ARAN HANSUEBSAI,

Ph.D., THESIS CO-ADVISOR: ASSOC. PROF. PONTAWEE

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This research proposes an algorithm of generating screen angle by irrational tangent technique. It is based on rotating data in an image to the required angle. It is found that the algorithm can compensate the lost data in rotated images for accurate results. The code value for proper linkage positions between FM and AM screens should be at 180-200 and the distance for mixing screen at the value of 20-30. In addition, the CMY screen angles in the hybrid zone should be maintained at a difference of 30 degrees as normally used in AM screen. The result shows that the print image obtained from hybrid screen technique is better than that of AM screen in highlight area; and better than that of FM screen based on tone reproduction consideration.

Department ....Imaging and printing technology... Student's signature .....

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Thammasan Thiprangsri  
จุฬาลงกรณ์มหาวิทยาลัย

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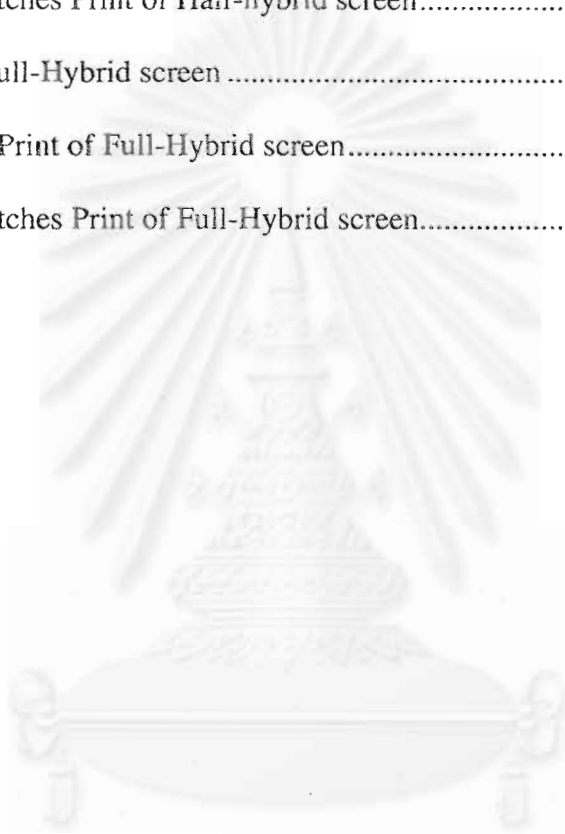
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# CHAPTER I

## INTRODUCTION

### 1.1 Scientific Rational

In high quality printing, hybrid screen is a technique that uses the mixture of AM and FM screen. As we know, each screen has its own characteristic based on tone reproduction. FM screen gives better tonal range in highlight, whereas AM screen is suitable for mid-tone and shadow. Thus, hybrid screen can be used to control better tone reproduction. In addition, finer detail of the image can be preserved. The appearance of Moire patterns, which are caused by the low-frequency components of the interference of different ink planes, will be not a problem. Particularly, using FM screen, the rotation angles of CMYK color separation is not necessary. For AM screen, proper screen is assigned. In this case, irrational tangent technique is employed to rotate the angle of CMYK separation, by which the difference in size and shape is obtained. This research proposes the algorithm of irrational tangent for rotating angle in hybrid screen.

## 1.2 Objective

To establish proper algorithm for rotating angles of hybrid screen in process color printing.

## 1.3 Scope of the research

This research is aimed at establishing an effective algorithm in order to generate an image with rotating screen angles for hybrid screen under following conditions:

1. Rotating screen angles would cover all printing process.
2. The selective mixing screen can be done any position. The range of mixing area is dependent on an original image. Therefore, in the algorithm, the ratio should not be restrained.
3. The process will be done after separating color images.
4. The algorithm will not include other image manipulation, such as re-sampling data, extending size of image, color separation of image, controlling output data for printing and so on.

## 1.4 Content of the Thesis

Chapter 2 gives the overview of the theoretical considerations and literature reviews. Chapter 3 describes the algorithm for rotate screen angles, materials under study, experimental work, including the process in prepress, and printing. Chapter 4 contains the results the discussion. Finally conclusion will be given in Chapter5, together with some suggestions.



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## CHAPTER II

### THEORETICAL AND LITERATURE REVIEW

Printing process today classify halftone image as clustered dot screen (AM) and dispersed dot screen (FM). Usually, AM screen gives tone reproduction preferable when dot gain occurred, but some fine detail in highlight is easily lost. FM screen has its own characteristic to keep fine details of the image, but there are deflection happened when dot gain is occurred particularly in mid-tone and shadow areas. The advantages of each screen pattern lead to link them together for high quality printing.

However, it should be noted that some problem in the part of AM screen may be appeared. AM screen will produce line pattern in an image, as we know Moire effect in process color printing. Thus, rotating screen angles should be proper defined to reduce this effect.

#### 2.1 Theoretical Background

##### 2.1.1 Digital Halftone

Digital halftone processing is transformed from the characteristic of arrangement of halftone dot which is categorized into 2 types: cluster dot (AM screen) and disperse dot (FM screen). In addition, other vital parameters include 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 Eq.2.1. Tone reproduction of output image can be perceived by human eye to detect its discontinuity. Note that the visibility of human eyes cannot distinguish the gray levels more than 100 shade.

$$\% \text{ Dot Area} = \frac{\text{Area covered by ink}}{\text{Total area}} \dots\dots\dots(2.1)$$

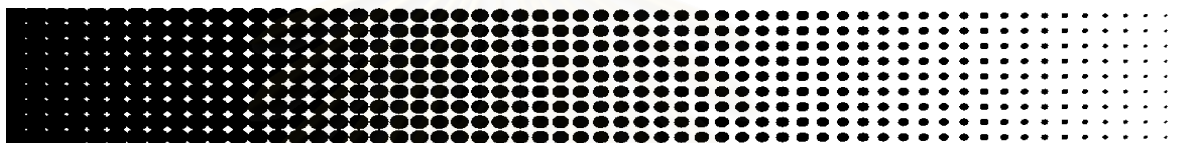
Lpi is the image quality parameter notifying that the limitation of screen can support the frequency input image or fine image. If the high frequency input image is processed by the low lpi, the quality of image is dropped. Usually the lpi parameter is set to the maximum as it could be. However, the limitation of lpi parameter to create gray levels or shades will be based on dpi parameter of input image. The suitable of lpi/dpi values can be calculated and from the Equation 2.2.

$$\text{Number of shades} = \frac{\text{dpi}^2}{\text{lpi}} + 1 \dots\dots\dots(2.2)$$

To reproduce halftoning, the arrangement of the dots can create image pattern, when there are 4 image color planes together. The pattern brings to creation of moiré which this effect can be reduced by rotation each color plane in different angles. [1]

### 2.1.1.1 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 as the pattern.



**Figure 2-1 AM screen dots**

The algorithm used in creating AM screen, will be based on threshold matrix, it is linear built-in matrix whose size is equal to a halftone cell. At this stage the code value of each pixel will be compared with those values in threshold matrix. If the code values within a matrix size, from the center to the edge respectively decline, the possibility of cluster dot is high. Note that the shape and size of obtained dots are also characterized by threshold matrix. [2-4]

### 2.1.1.2 FM Screen

FM screen is a technique of processing halftone image, with an arrangement of dispersed dots. The more dense dots population, the darker shadow tonal range becomes. It is found that tone reproduction of FM screen relates with enumerate dot. Consequently, All screen dots have the same size as shown in Figure 2-2



**Figure 2-2 FM screen dots**

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.

From the characteristic of FM screen using dot dispersing in creating tone will generate a plenty of tiny dots in the image. The serious problem when the dot gain occur greatly influence to the tone reproduction comparing AM screen. Accordingly, dot gain conjugate all perimeter of plentiful dots. Since the FM screen is rapidly effected from dot gain, 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.

The algorithm converting to halftone image by FM screen is the process of each pixel following line scan route. The code value of each pixel is converted to binary by comparing with 50 % threshold; usually it was set to be 128. If the pixel has

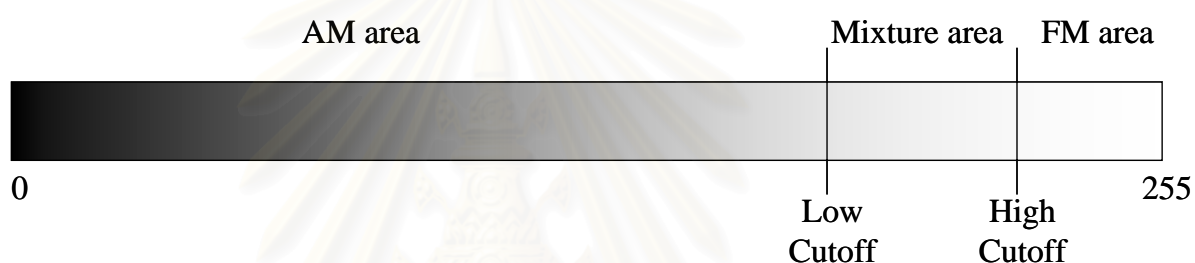
the value less than threshold, the data would be clear to be 0. On the other hand, if the pixel has value more than 128, the data would be set to be 1. Then, the error from binary coding would be computed, and it would be dispersed to adjacent pixels which is never coding. [5-6]

### **2.1.2 Hybrid Screen**

Hybrid screen is characterized as the mixture of dispersed dots (FM Screen) and clustered dots (AM Screen) halftoning. Dispersed dots (FM Screen) halftoning is the algorithm using spatial frequency patterns to create binary image such as Floyd and Steinberg's Error Diffusion . Tone reproduction is represented by the dispersion of tiny dots. While clustered dot (AM Screen) halftoning is constructed from many tiny dots that are built on a printed grid of an output device. Within this grid, the distance from the center of one halftone dot to the next is constant, while the size of halftone dot illustrates tone reproduction generated by halftone. The algorithm is created by using Threshold Matrix. Threshold array is an algorithm that uses array to specify dot shape of each halftone cell. The sub-image is processed by comparing with threshold value kept in the array, which its dimension is equal to halftone cell. Each tone value of the image data is compared with the subscriber of the threshold array dot by dot. Most of sub-image data is compared with threshold value, and then the next is processed later.

In order to avoid non-smooth area at the boundary of the different screen types, The algorithm needs to generate some band called Mixture Area between AM screen and FM screen. The Mixture Area gradually changing from AM screen to FM

screen. Therefore, it needs proper band to enable smoothly changing. At the boundary, the technique in screening is different from the ordinary screen techniques. It is consist of both AM and FM characteristics that have especial arrangement. In other word, it is a combination of AM and FM screen technique. As a result, each pixel at the mixture area has cluster dots at the center, and the cluster dot is surrounded by dispersed dots. [7-8]



**Figure 2-3 Three areas of different screen techniques**

### 2.1.3 Irrational Tangent

Irrational tangent screen is developed to overcome the screen angle limitation. An irrational screen has a non-integer tangent ratio. This means that one or more of the corners are not located at the intersection point. Without confining itself to the digital grid, the dot pattern and the number of tone levels vary from cell to cell. This is accomplished by selecting a screen of the desired frequency and rotating it to the desired angle (shown in Figure.1), then evaluating the screen function for every pixel and every cell. The dot rotation is computed on the fly, the computation speed and cost are very high. Moreover, a pixel in the digital grid may fall between several points of the threshold array. In this case, a bilinear interpolation is required to

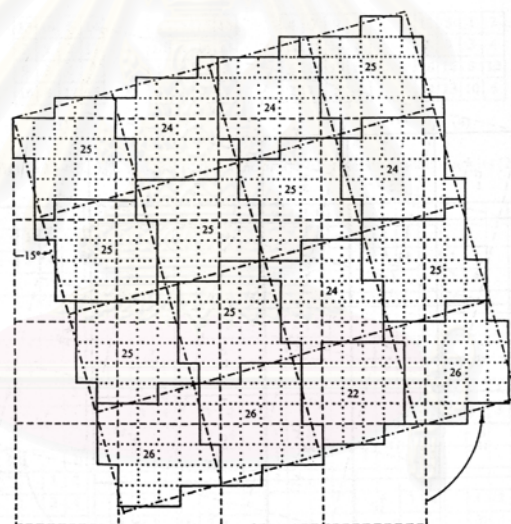
calculate the pixel value from elements of the threshold array that intersect the pixel.

[9-10]

A simple approach is to rotate a pre-constructed  $0^\circ$  threshold array any desired angle using irrational tangent screen (trigonometric relationship). After rotating an angle  $\alpha$  with respect to the origin, the position  $(x', y')$  is related to the initial position  $(x, y)$  in equations 2.3 and 2.4.

$$x' = x \cos \alpha - y \sin \alpha \dots\dots\dots(2.3)$$

$$y' = y \cos \alpha + x \sin \alpha \dots\dots\dots(2.4)$$



**Figure 2-4 Irrational tangent screen mapping 5x5 array by 15° rotation**

## **2.2 Algorithm for Hybrid Screen**

Hybrid screen algorithm is aimed to generate screen angle in the range of AM screen area. It composes of two vital concepts that have different functions in processing image. Having proper screen angle is an important factor for hybrid screen technique. The process is to rotate data by using irrational tangent technique, therefore, as mentioned before.

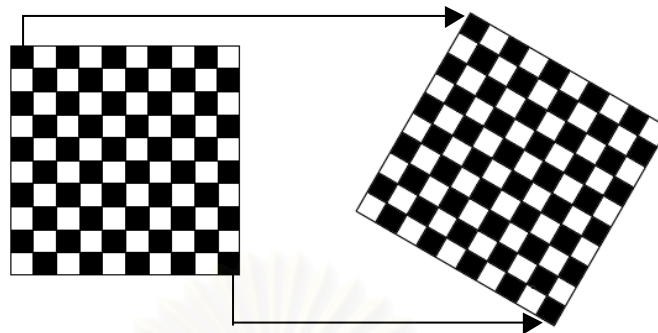
### **2.2.1 Generating Screen Angles Algorithm**

Generating screen angles can directly affect image quality in 4-color printing, for example moire problem. In order to avoid this effect, The algorithm has to be able to rotate image from 0 degree to other degree screen angle. The technique generating difference screen angle, consists of rotating image algorithm and repairing incorrect data image algorithm.

#### **2.2.1.1 Rotating Image Algorithm**

Thus, rotate image algorithm is a part of generating screen angles algorithm. This algorithm must compose of an angle of screen printing and pixel positions of each pixel in an image. The new pixel position is calculated from pixel position of original image. All pixel in the original image must rotate to the new position. Shown in Figure 2-5.





**Figure 2-5 Rotating Image Angle**

### **2.2.1.2 Repairing Incorrect Data Image Algorithm**

Repairing incorrect data image algorithm is one procedure of generating screen angle algorithm, that directly affect to corrective data of image after rotate. It operates checking and repairing incorrect data in rotated image. Both procedures should reference the rotated image data from original image at the same position before rotating. The position of data in image before rotating is  $(x,y)$  and after rotate is  $(x',y')$ , that calculate from equation (2.3) and (2.4). This procedure needs to know all pixel position after rotate and screen angle  $(\alpha)$  for checking and repairing data form this equation.

$$y' \sin \alpha + x' \cos \alpha = x((\sin \alpha)(\sin \alpha)) + x((\cos \alpha)(\cos \alpha)) \dots\dots\dots(2.5)$$

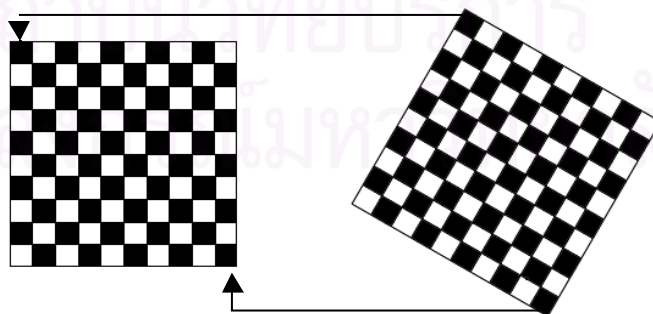
Thus, based on this equation, we knew screen angles  $(\alpha)$  and pixel position after rotating  $(x',y')$  from equation (2.3,2.4). If it has incorrect data image in some position  $(x',y')$  after rotation, This position  $(x',y')$  can be calculated the original pixel position from equation (2.5). Before calculating, the result is original pixel position

(x,y). The incorrect data image at position (x',y') was replaced by original data image from position (x,y).

### 2.2.1.3 Reverse Screen Angles

Reverse screen angle algorithm is a final process of generating screen angles algorithm, which operated after hybrid halftone process. This process must received the data image from hybrid halftone algorithm for reversing image, the reversing image will rotate data image from screen angles to original angle.

This mentioned algorithm uses a procedure like the rotating image algorithm, The pixel position (x,y) is calculated in equation (2.3, 2.4). The result pixel position (x',y') is coordinate for select the data image, which copied from rotated pixel position to original pixel position. In this research the result of image angle after process all algorithm is 0 degree. Shown in Figure 2-6.



**Figure 2-6 Reverse Screen Angles Algorithm**

### **2.2.2 Hybrid Halftone Algorithm**

Hybrid Halftone Algorithm is aimed to generating mixing screen. The algorithm composes of three vital concepts that have different functions in processing image. Area Selection algorithm plays the important role in matching the suitable area of image with the effective screen technique, AM screen or FM screen. After choosing the screen techniques, the process has to convert data by AM screen or FM screen; therefore, the second major is AM Screen algorithm which is used in generating AM screen, and the final one is FM Screen algorithm which explains in establishing FM screen. Following topic, there are abbreviated concepts of the three algorithms.

#### **2.2.2.1 Area Selection**

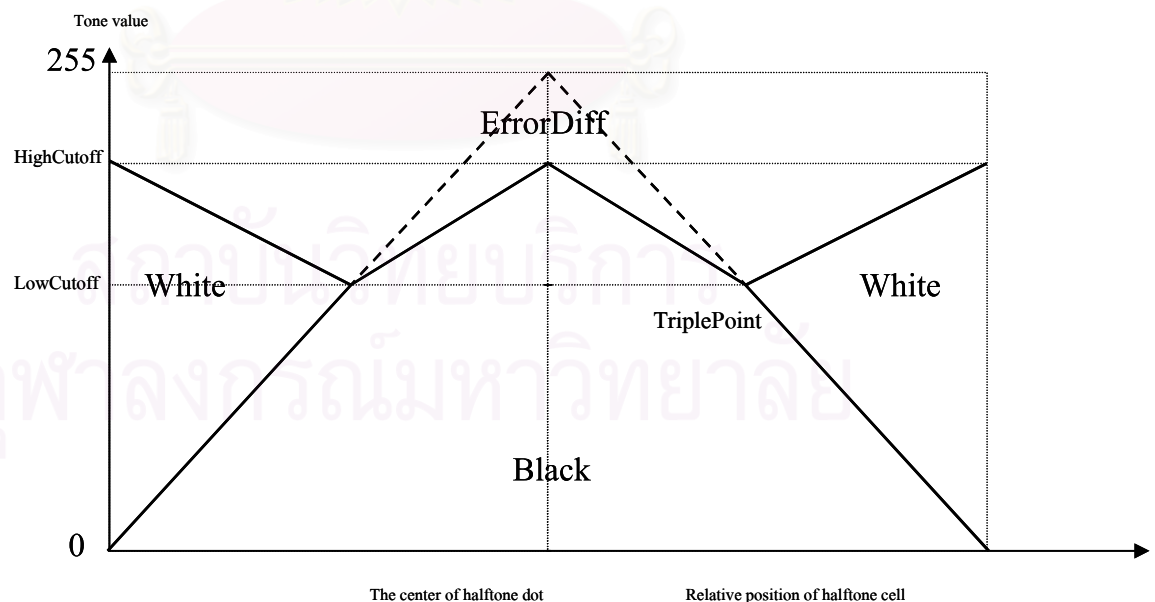
Area Selection is a separation module that smartly determines suitable area between AM or FM screen for hybrid screening. It affects the appearance of image tone reproduction. To process entire image area effectively and efficiently, there are two aspects to be considered.

First, algorithm has to generate some band called Mixture Area between low cutoff point and high cutoff point. The Mixture Area is provided for gradually changing from AM screen to FM screen. Therefore, it need proper band to enable smoothly changing. At the boundary, the technique in screening is different from the ordinary screen techniques. It is consist of both AM and FM characteristics that have especial arrangement. In other word, it is a combination of AM and FM screen

technique. As a result, each pixel at the mixture area has cluster dots at the center, and the cluster dot is surrounded by dispersed dots.

Second, hybrid threshold is a matrix that keeps the code value of pixel relating to its location in a cell. In this research, the threshold matrix is set to have two functions. The former function is to be used in the area selection algorithm for classifying the pixel to the proper screen modules. The later function is working at the AM screen module. The detail of using threshold matrix will be described on the following subject.

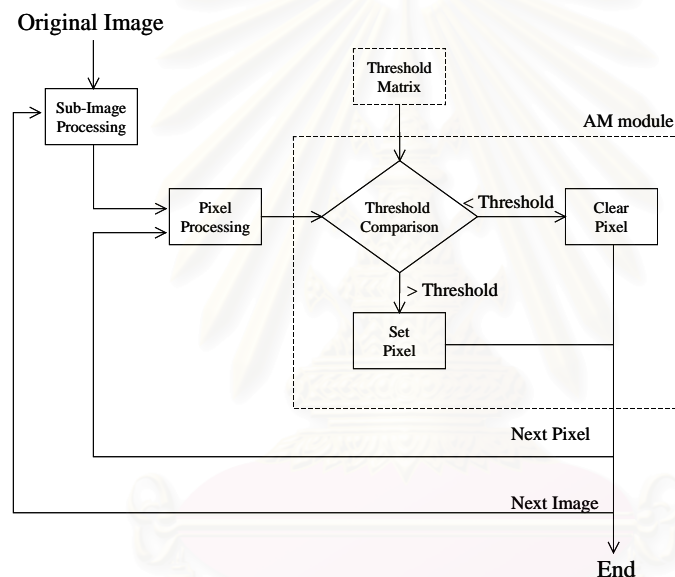
In Figure 2-7 shows the cross section of hybrid threshold of the halftone cell. Horizontal axis shows the distance from the center of halftone dot to the edge of the cell. Vertical axis shows the code value of each pixel. Black and White areas are chosen for AM technique, while the dotted area for FM technique. [11]



**Figure 2-7 Threshold of hybrid algorithm using for area selection**

### 2.2.2.2 AM Screen Algorithm

To generate AM screen, the threshold matrix plays the vital role by comparing the matrix member with the code value of the image. The flowchart shown in Figure 2-8 is proposed steps of creating AM screen.



**Figure 2-8 Flowchart of AM Algorithm**

AM screen algorithm starts with Sub-image processing. In this step, the original image is analyzed and processed by being cut into small parts that have the same size as cell. Next, a cell is applied to Pixel Processing, which is working by concentrating each pixel in the cell following processing route. Then pixel would be sent to Threshold Comparison, taking the pixel directly comparing with the member of threshold matrix. If the pixel has more value than the threshold matrix member, it

would be set to be one, In contrast, if the pixel has value fewer than the threshold matrix member, the pixel would be clear to be 0. This process will be following this routine until finishing all pixels in a cell and all cells in an image.

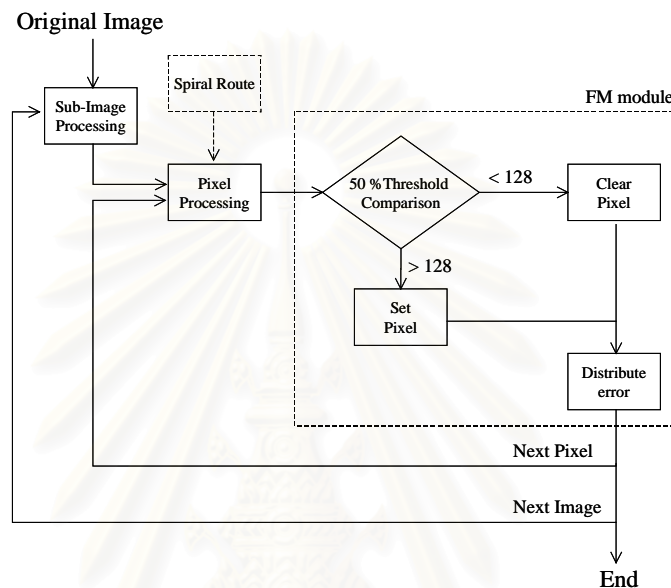
### **2.2.2.3 FM Screen Algorithm**

FM algorithm uses Spiral Error Diffusion technique developed from Floyd and Steinberg Error Diffusion. As a result, the algorithm is compatible with AM algorithm using in the mixture area. Following topic describes two major concept of FM algorithm, spiral processing based on sub-image processing, and the sequence process from the center of cell and spiral to the edge of cell.

Error diffusion is a method that tries to disperse error to the neighbor pixel. The pixel, which analyzed is found out errors by representing the pixel data with binary pattern value. The errors are propagated to the adjacent pixel with different weight. The weight depends on distance between the analyzing pixel and the adjacent pixels; the closer pixels will obtain more effect. The algorithm is described in flowchart shown in Figure 2-9.

The FM algorithm analyzes an original image through Sub-image and Pixel processing. Pixel process would analyze each pixel in a cell though Spiral Processing technique by using Spiral Route. Next, the pixel data would be sent to compare with 50% threshold, which is value of 128, the output pixel data would be set to maximum or clear to minimum of the code value. After setting new data, it has to compute errors from the setting in order to disperse errors to adjacent pixels called Distribution error. The errors will be used to compute to subtract the output pixel with the input pixel.

The result is the error value, which is dispersed to the next pixel. The process will continue this routine until finishing all pixels in cell and all cell in the image.

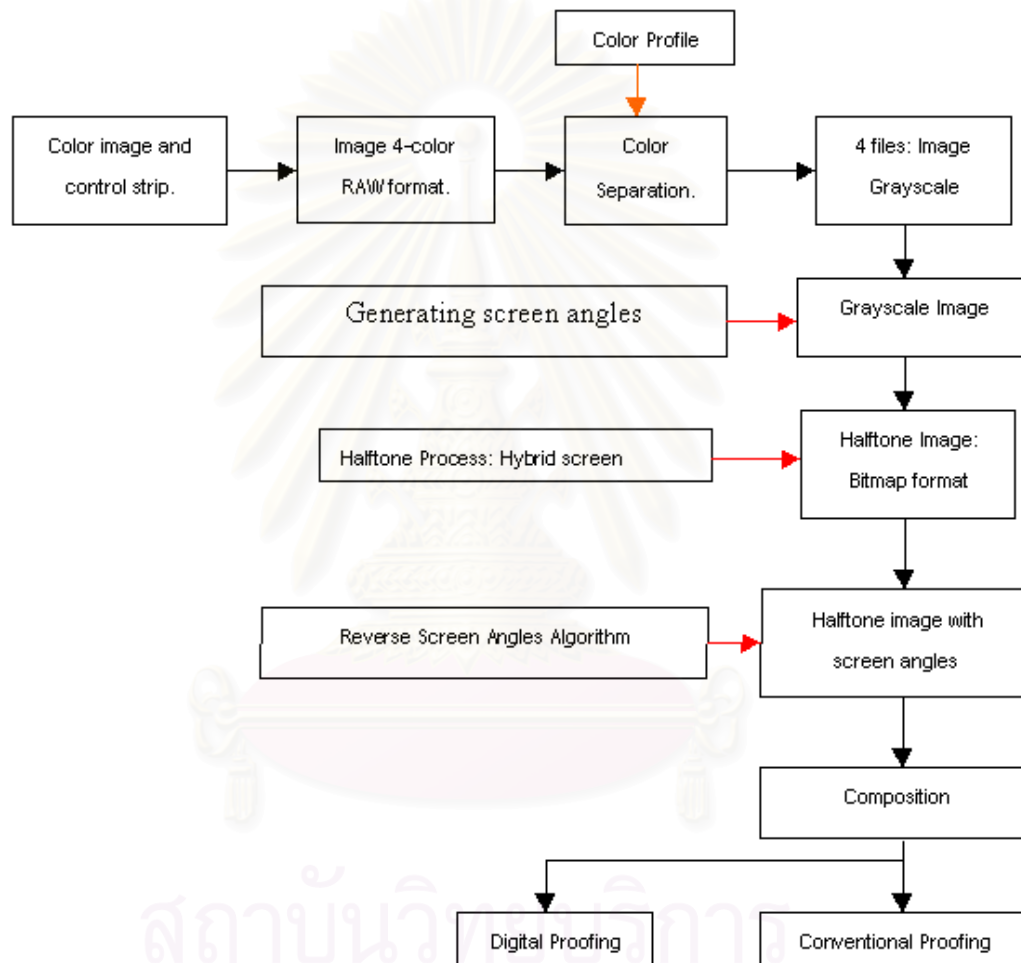


**Figure 2-9 Flowchart of FM algorithm**

### 2.3 Digital Workflow

To generate screen angles, the algorithm was changed to C programming on personal computer. Note that this algorithm does not include such manipulation process as resolution adjusting, printing, and so on as they can be done though other image-processing software. The related software and entire process are shown in Figure 2-10.

The original color image will be separated to gray-image with suitable resolution for output devices. The image from the process would be kept in .RAW file format, as it is convenient in access to the data.



**Figure 2-10 Digital Workflow for Generating Screen Angles**



Using C language, the algorithm processes the image. It composes of many parts such as opening and saving module of .RAW file format. The obtained output is kept as bi-level image.

The image is transformed to bi-level as bitmap image by cutting at 50% threshold. To save the halftone image, TIF file format will be used with dimension suitable for the next step.

The image generated from each part will then be composed for printing on output device. The data will be sent to output device by using some application software, which the bitmap image would be suitable mapped to the grid line of output device or high quality output device.

### **2.3.1 Printing Testform**

To evaluate printing quality, test form image is employed. It consists of RGB standard image, gray continuous tone wedge and color patches, as shown in Figure 2-11 and 2-12.

In this work, we use offset printing technique CMYK. The evaluations done by naked eyes, based on the criteria of moire appearance. While densitometric measurement of color patches determines tone reproduction.



Figure 2-11 Test form for printing

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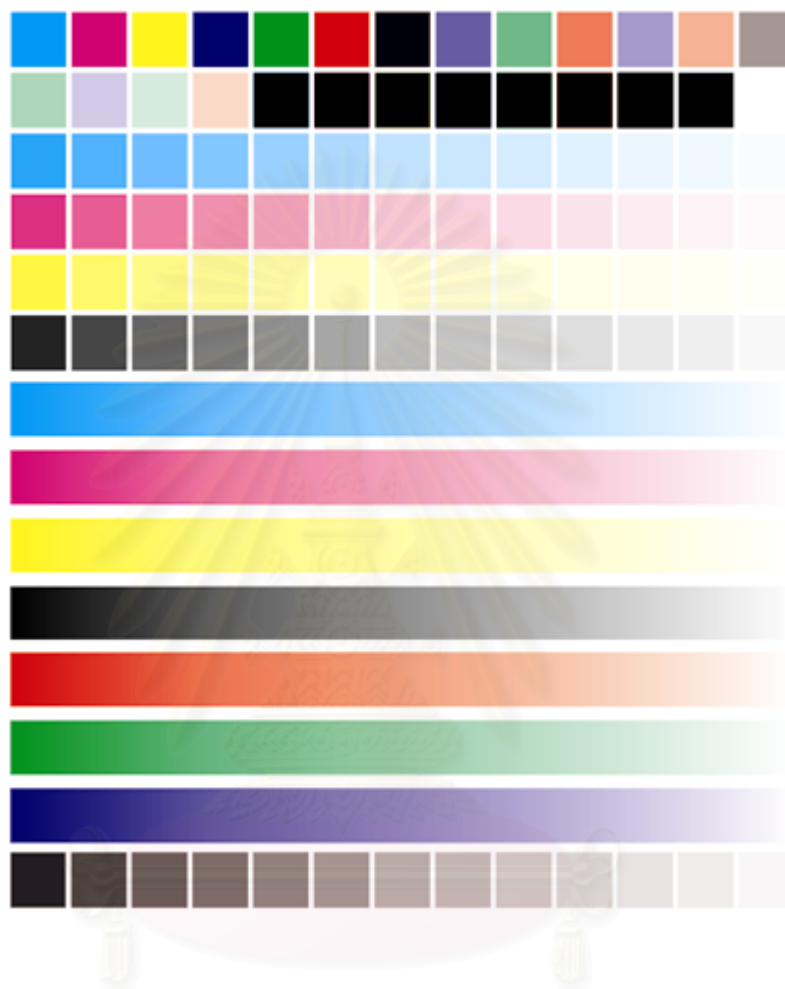


Figure 2-12 Color control patches in test form

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## 2.4 Literature Review

Floyd and Steinberg [1] created the FM algorithm by using negative feedback of error getting from the representative of continuous tone data by bi-level image. The errors are propagated to the next neighbor pixel through the weighty window. By this technique, the nearer of processing dot is the higher error fraction become. So, the image consist of so many isolated dots. The result shows that the FM screen gives better fine detail

Anderson. [2] applied negative feed back of Floyd and steinberg technique over the grouped dot used in AM algorithm. The error which get from the representative of dot group is disperses 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 the abundant shade can be created in limited resolution of an out put device.

Levien [3] investigated the halftone screen pattern generation system for computing halftone screened images with rotated screens including multiple angle and ruling combinations, including irrational tangent angles. The screen pattern is generating by storing a plurality of strips from an ideal angled screen pattern and then concatenated a sequence comprising a selected order of the plurality of strips in a sequence.

Levien [4] discussed about error diffusion, or adaptive dither method of producing halftone images includes an injected periodic screen pattern. The frequency of error diffusion dot formation is tuned to roughly match the frequency of the periodic screen pattern by adjustment of a hysteresis constant so that dot formation is

phase and frequency locked to the phase and frequency of the periodic screen pattern. The obtained halftone, consisting of an orderly array of dots placed on a grid pattern. At substantially the same angle and screen ruling as the periodic screen pattern, combines the advantages of both traditional screening such as precisely angled screens, and the advantages of error diffusion screening, such as better rejection of both internal and external moire artifacts. Any type of screen generation technique such as rational tangent, irrational tangent and rational supercell techniques can be used as a source of the periodic screen pattern.

Sexton [6] explained method for applying FM screening to a digital image in a computer. The method allowed the "on-screen" editing of each of the four color separations (cyan, magenta, yellow, and black) of the CMYK FM screened image while viewed as a single composite image. The "on-screen" editing of the CMYK image performed and viewed before the image is directed to an imaging device.

Suksawad [11] investigated the appropriate algorithm of hybrid screen using spiral error diffusion and threshold matrix. Smoothly tone reproduction can be created using dispersed dot in highlight area and clustered dot in midtone and shadows area.

## CHAPTER III

### EXPERIMENTAL

#### 3.1 Materials

1. Imagesetter Film : Fuji No.4LDW (HRD)
2. Bromide paper : Fuji No.4LDW (PD-100WP)
3. Developer : Fuji HR Developer HR-D1
4. Fixer : Fuji Grandex Fixer GR-F1
5. Plain paper : 80 gram A4
6. OHP Film : A4 (Inkjet printable)

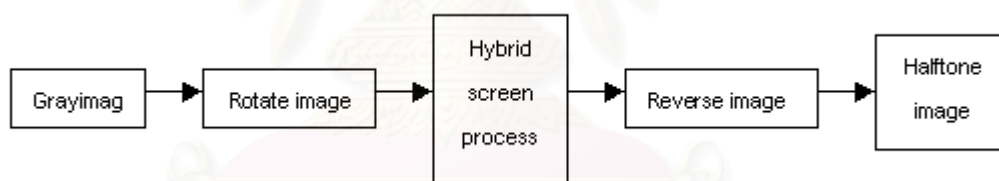
#### 3.2 Apparatus

1. Personal Computer : Pentium celeton 533 MHz.
2. Image setter : Linotronic 260, Linotype-Hell
3. Laser printer : Apple LaserPro630
4. Inkjet printer : Canon BJC8500
5. Densitometer : Macbeth R917
6. Software PhotoShop v.6 : Adobe California, USA
7. Software Illustrator v.8 : Adobe California, USA.
8. Software Visual C++ v.6 : Microsoft Washington, USA.

### 3.3 Experiment

#### 3.3.1 Skeleton Step

This step is intended to test the possibility of algorithm processing as rotating image, repairing incorrect data image, reversing screen angles and Hybrid halftoning. It also focuses on searching an effective digital and conventional workflow for experiments. Base on printing process, the screen angles are defined as 15, 45 and 75 degree for C, K and M respectively. The workflow related to halftone process is shown in Fig. 3-1.

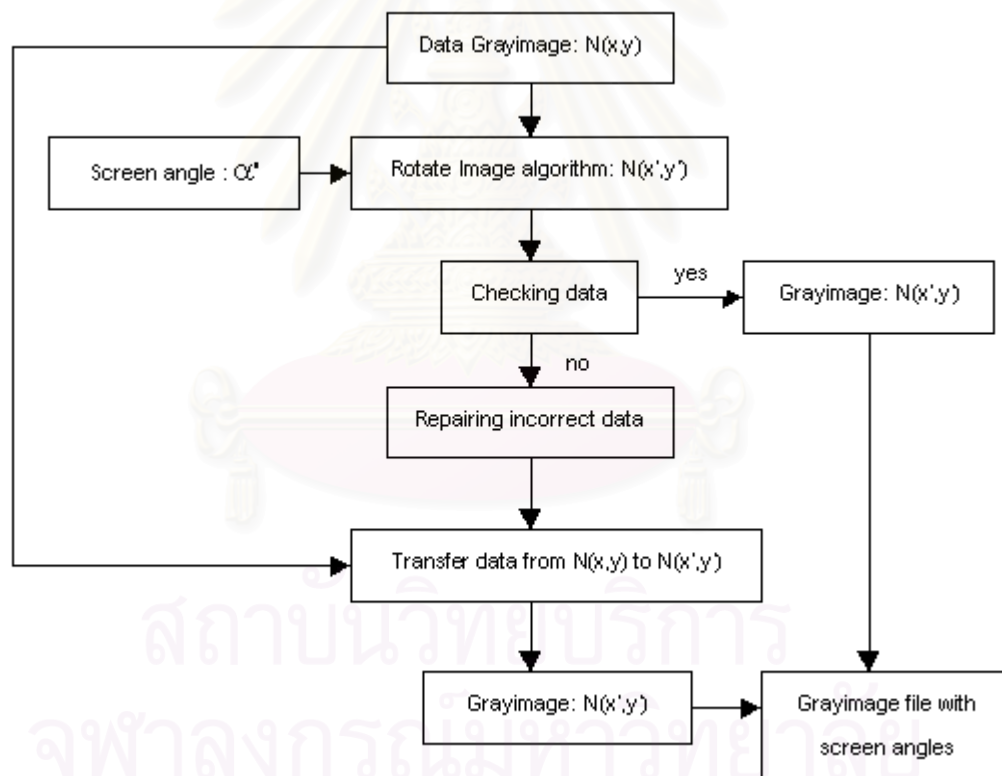


**Figure 3-1 Workflow of Skeleton step**

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### 3.3.1.1 Rotating image and repairing incorrect data image algorithm

The starting stage of algorithm at input data gray-image. The pixel position  $(x,y)$  is sent to compute in rotate image processing module which has duty to calculate the new pixel position for generating screen angles. Then, the pixel data is sent to check data and to repair data module described in topic 2.2.1.2. The process repeats again and again until completing all pixels in an image. The skeleton step programming details are shown in appendix A. flowchart shown in Figure 3-2.

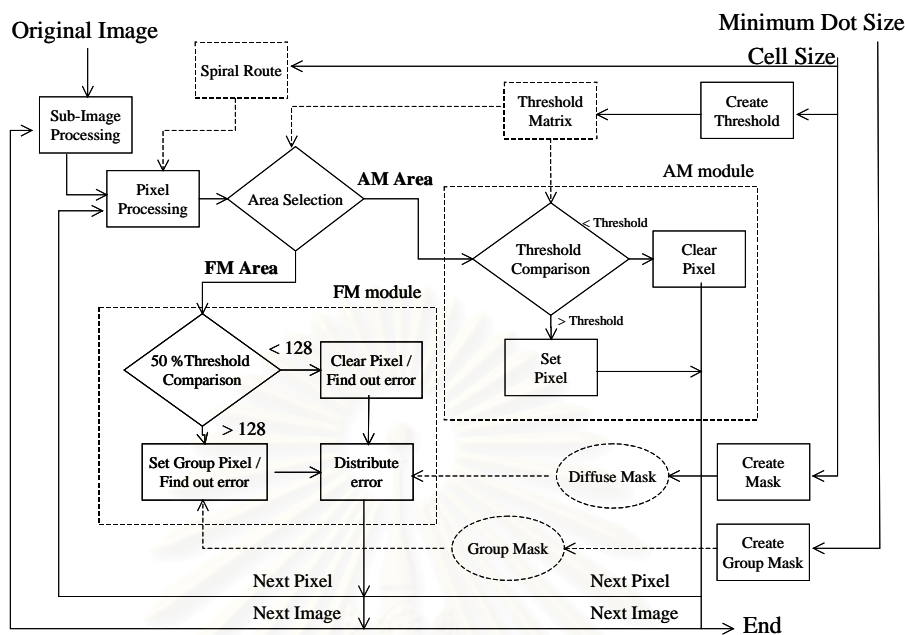


**Figure 3-2 Flowchart of rotating image and repairing incorrect data image algorithm**



### 3.3.1.2 Hybrid halftone algorithm

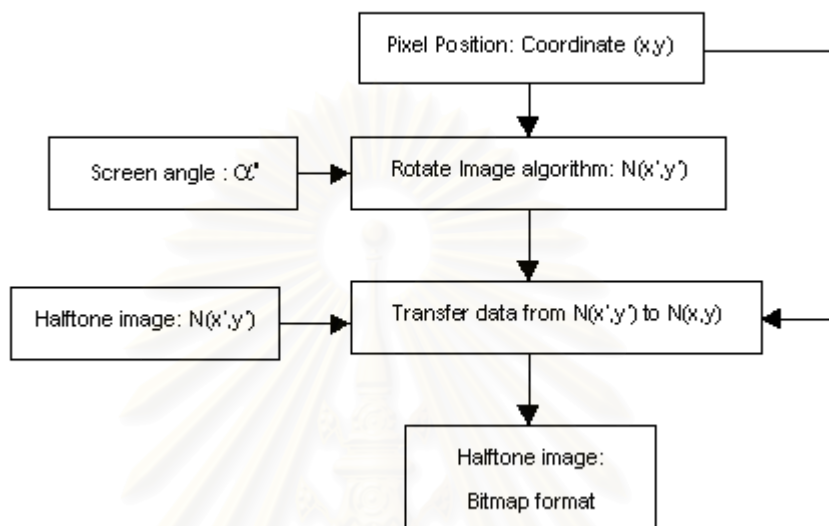
The algorithm begins at Sub-Image Processing and Pixel Processing modules. The pixel data is sent to compute in Area Selection module which calculates and chooses the most suitable screen technique for processing pixel. Note that the output of this process is still digital output data. The analyzes then is started in each part of image, by spiral processing method. The obtained results determine the choice of suitable screen technique in Area Selection. If the pixel chosen is for AM screen, its code value will be compared with threshold value to generate bi-level image. While FM screen technique, the code value of pixel data will be compared with 50 % threshold. As a result, a group of pixel is obtained. This is useful to calculate the screen size. The location of adjacent element is set as a group by algorithm, following by, the error diffusion process as shown in Figure 3-3. The process continues until completing all pixel in the image.



**Figure 3-3 Flowchart of hybrid halftone algorithm**

The experiment composes hybrid halftoning techniques into 5 styles, AM Screen (Clustered dot in Highlight to Shadow area), FM Screen (Dispersed dot in Highlight to Shadow area), HB(Hybrid Screen: FM Screen in Highlight area and AM Screen in Midtone to Shadow area), HHB(Half-Hybrid Screen: FM Screen in Highlight to Midtone area and AM Screen in Midtone to Shadow area) and FHB(Full-Hybrid Screen: FM Screen in Highlight and Shadow area and AM Screen in Midtone area).

### 3.3.1.3 Reversing image algorithm



**Figure 3-4 Flowchart of Reverse image algorithm**

The pixel position  $(x,y)$  is sent to compute in rotating image processing module which calculates the new pixel position for generating screen angles, that described in topic 2.1.1.1. The result of rotating image processing module is pixel position  $(x',y')$ . The pixel position  $(x',y')$  is used to access the data of halftone image, which transfers data from position  $(x',y')$  to  $(x,y)$ , that described in topic 2.2.1.3. The process follows these steps until completing all pixels in an image. The result of all process is halftone image (Bitmap format). The skeleton step programming details are shown in appendix A and Figure 3-7.

### **3.3.2 Processing Step**

Processing step is the functional control of halftone screen for experimental under condition of printing process. In experiment, it can separate the halftone screen into 5 styles of conventional printing process.

Note that it is necessary to control the resolution for printing process. This research uses 120 lpi with cell-size 21 pixels.

#### **3.3.2.1 AM Screen (Clustered dot)**

- Minimum dot size: 1 pixel
- Minimum hole size: 1 pixel
- Dot compensation: 0
- Hole compensation: 0

#### **3.3.2.2 FM Screen (Dispersed dot)**

- Dot size: 5 pixel
- Dot compensation: 0

#### **3.3.2.3 Hybrid Screen (FM Screen in Highlight area and AM Screen in Midtone to Shadow area)**

- Minimum dot size: 1 pixel
- Dot size: 5 pixel
- Dot compensation: 0
- Highlight cutoff: 210
- Highlight span 20

**3.3.2.4 Half-Hybrid Screen (FM Screen in Highlight to Midtone area and AM Screen in Midtone to Shadow area) process under condition.**

- Minimum dot size: 1 pixel
- Dot size: 5 pixel
- Dot compensation: 0
- Highlight cutoff: 140
- Highlight span 20

**3.3.2.5 Full-Hybrid Screen (FM Screen in Highlight and Shadow area and AM Screen in Midtone area) process under condition.**

- Minimum dot size: 1 pixel
- Minimum hole: 1 pixel
- Dot size: 5 pixel
- Hole size: 5 pixel
- Dot compensation: 3
- Hole compensation: 3
- Highlight cutoff: 210
- Highlight span 20
- Shadow cutoff: 40
- Shadow Span 20

All condition prepared for halftone process, which produce halftone image by hybrid screen program.

## CHAPTER IV

### RESULTS AND DISCUSSION

From the experiment in chapter 3, we pay attention on the result of algorithm processing in the part of detail in image and tone reproduction. As methods in evaluating the result, the printout are highlighted. The evaluation is classified into 3 parts, reduce moire pattern, tone reproduction and detail of image.

The image data is converted from tested image in topic 3.1.1. It would be qualified by human visual system as naked eyes, which have no standard in measure of quality. Overall result is detected such the detail image, screen angle, tone reproduction and so on.

An arrangement in order of the density of color patches,. It is the principal level in analyzing tone reproduction. The image will be measured by densitometer. Then, the data is used to plot graph for analysis of the slope.

#### 4.1 Generating screen angles

The result from using the rotate image algorithm enables the output image which has the screen angles in the creation for hybrid halftone image. In each screen angle the image size does not have the same value. The result of image size in each screen angle can be shown in the Table 4-1 to Table 4-4.

**Table 4-1 Results of rotating image algorithm (Test Image)**

Image Color	Screen Angles(Degree)	Resolution (DPI)	Size image(Pixel)	Size Rotated image (Pixel)
Cyan	15	2540	12000x10300	14256x13054
Magenta	75	2540	12000x10300	13054x14256
Yellow	90	2540	12000x10300	12000x10300
Black	45	2540	12000x10300	15768x15768

**Table 4-2 Results of rotating image algorithm (Color patches)**

Control Strip Color	Screen Angles(Degree)	Resolution (DPI)	Size image(Pixel)	Size Rotated image (Pixel)
Cyan	15	2540	12000x13762	15152x16398
Magenta	75	2540	12000x13762	16398x15152
Yellow	90	2540	12000x13762	12000x13762
Black	45	2540	12000x13762	18216x18216

**Table 4-3 Results of reversing image algorithm (Test Image)**

Image Color	Screen Angles(Degree)	Resolution (DPI)	Size Halftone image Before Reverse (Pixel)	Halftone image after Reverse(Pixel)
Cyan	15	2540	14256x13054	12000x10300
Magenta	75	2540	13054x14256	12000x10300
Yellow	90	2540	12000x10300	12000x10300
Black	45	2540	15768x15768	12000x10300

**Table 4-4 Results of reversing Image algorithm (Color patches)**

Control Strip Color	Screen Angles(Degree)	Resolution (DPI)	Size Halftone image Before Reverse (Pixel)	Halftone image after Reverse(Pixel)
Cyan	15	2540	15152x16398	12000x13762
Magenta	75	2540	16398x15152	12000x13762
Yellow	90	2540	12000x13762	12000x13762
Black	45	2540	18216x18216	12000x13762



## 4.2 Image quality determination

### 4.2.1 Tone reproduction

It is found that using the rotating image algorithm and hybrid halftone algorithm enables the output hybrid image to have screen angles with 3 separated areas. AM, FM and Hybrid screens. In as tone reproduction of each area does not have the same behavior, this technique help connecting the linkage between AM screen and FM screen, by which smoothly tone reproduction can be obtained. The results of printed experiment shown in Figure 4-1 to 4-10. Regarding tone reproduction curves, we found that hybrid screen can produce tone reproduction like the mixture of tone from AM screen and FM screen.

We note that the length of mixing area of AM screen and FM screen in hybrid screen can be varied, depending on printing process. If the length of mixing area is short (less than 10 Code-value) it causes discontinuous tone reproduction, as the differential behavior of each screen. In addition, the number of code values is not enough to produce smooth connection area between AM screen and FM screen.

If the length of mixing area is too long (more than 30 Code-value), decreases image quality, as the mixing area covers the different tone reproduction, this reduces the tone gradation and sharpen of image.

We also found some awareness in choosing mixing area as followings: if FM screen is defined from highlight to midtone area, the mixing area will process in midtone area. This give unawareness of tone gradation. If FM screen is defined in

shadow area, the tone continuity in area connection between AM screen and FM screen is reduced, as higher dot gain effect.

We recommend that the highlight is suitable area for mixing area. It is because the tone reproduction of AM screen and FM screen has less effect to link such different screen type. The length of mixing area is suitable at 10-30 code-value.



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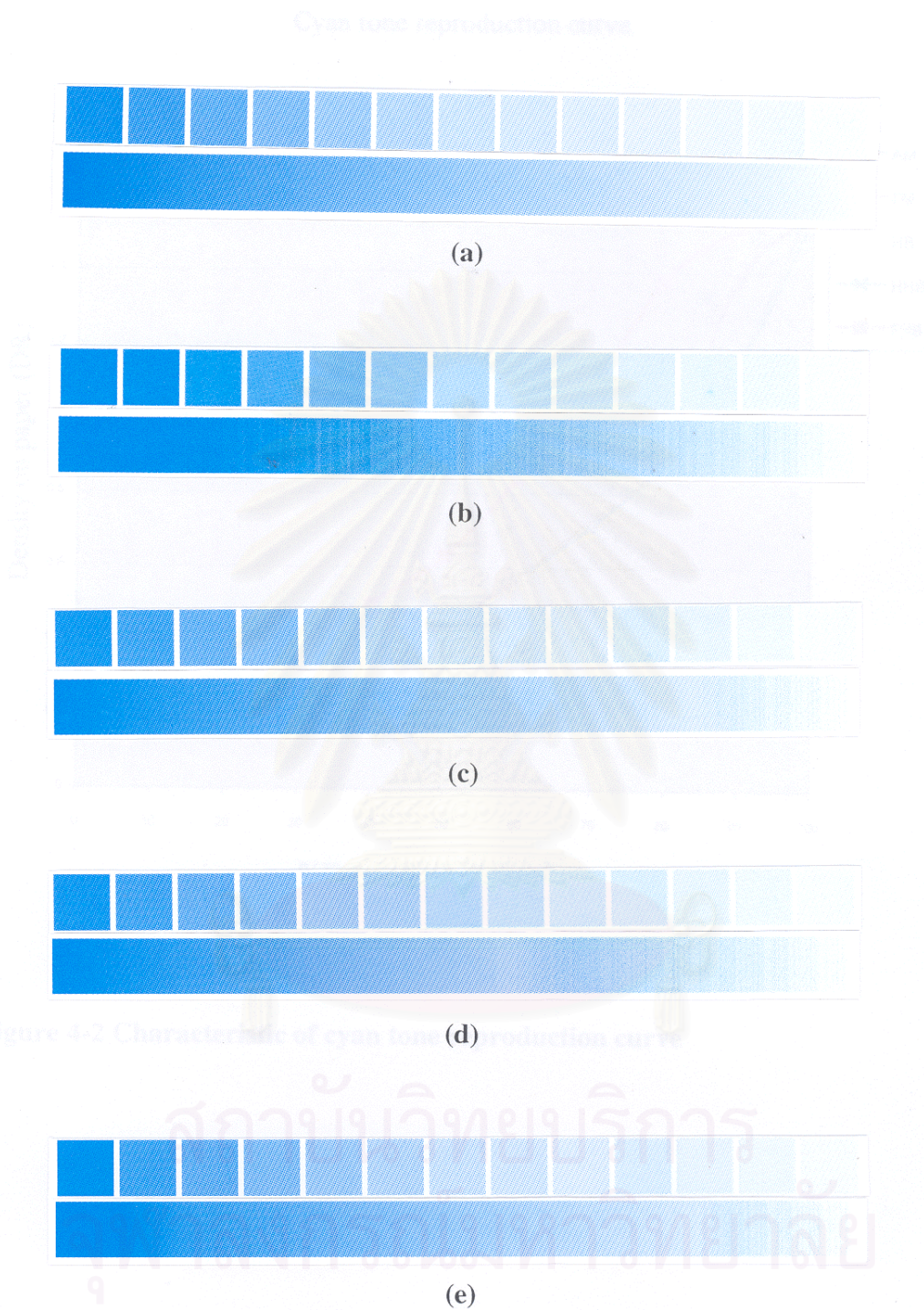


Figure 4-2 Characteristic of cyan tone reproduction curve

**Figure 4-1 Tone reproduction of print(cyan) (a) AM Screen (b) FM Screen (c) Hybrid Screen (d) Half-hybrid Screen (e) Full-hybrid Screen**

Cyan tone reproduction curve.

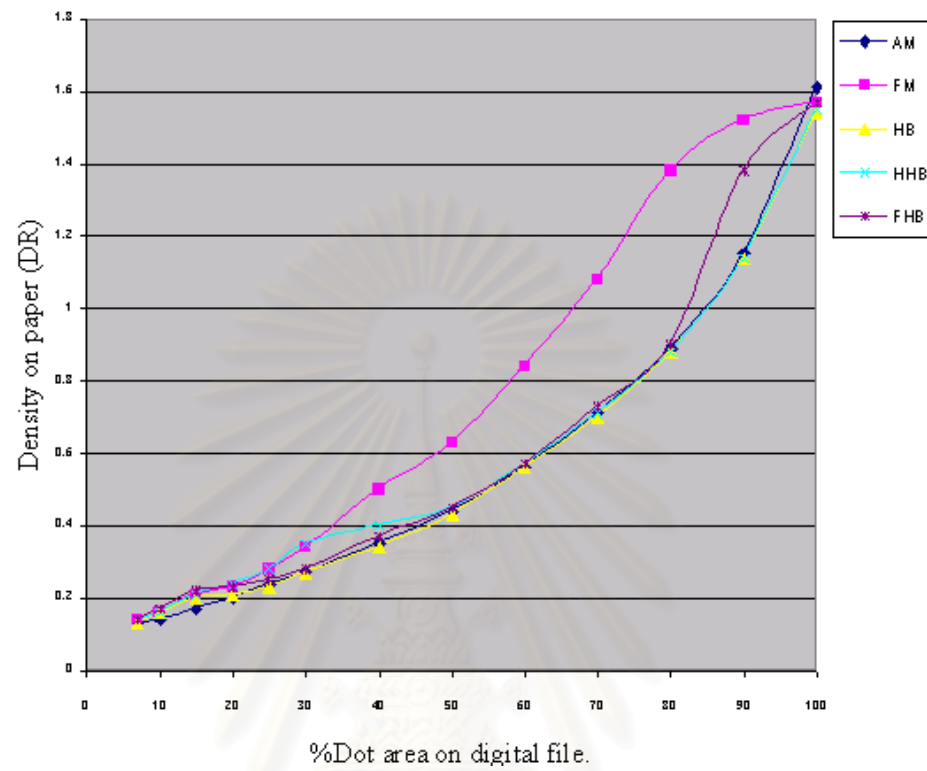
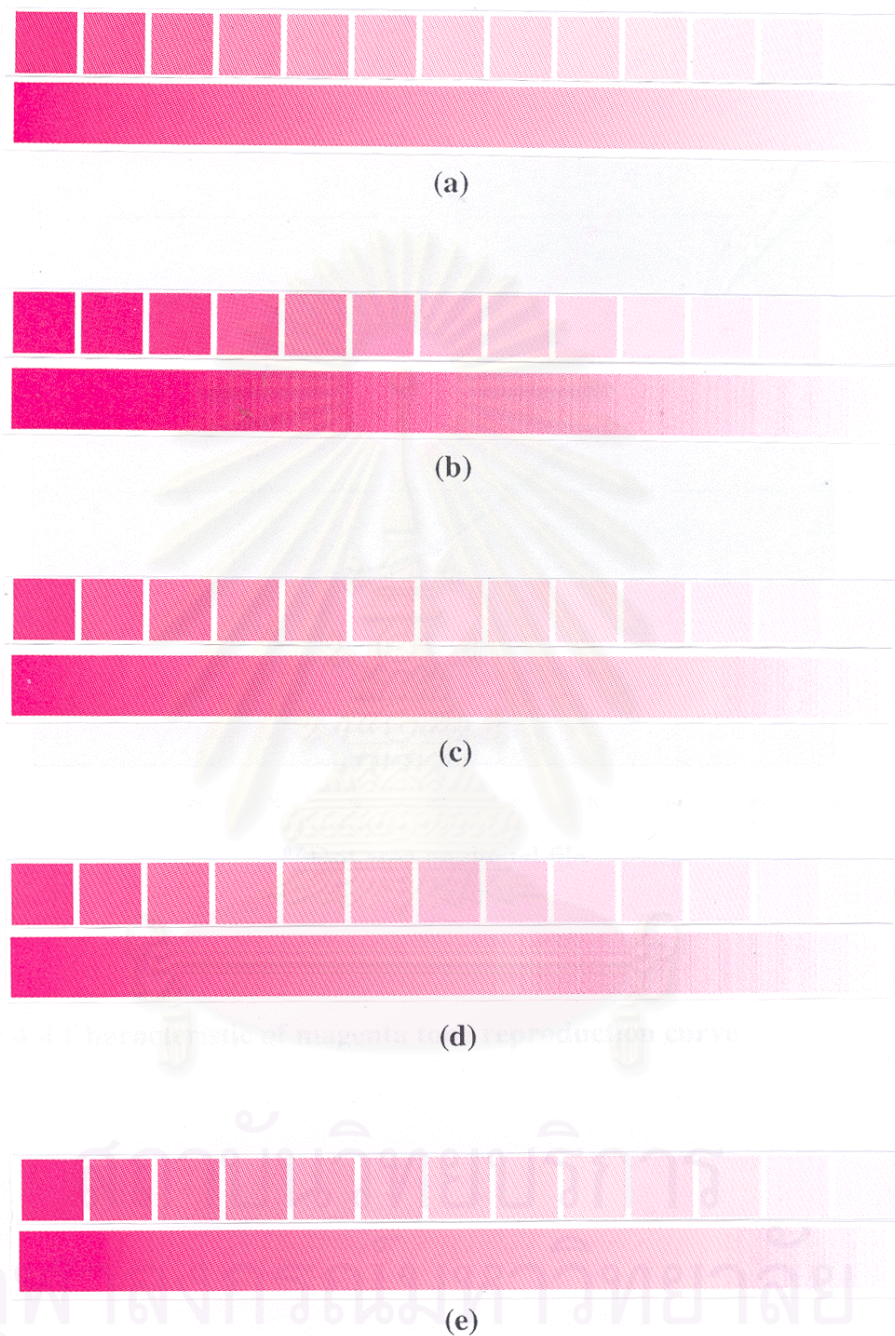


Figure 4-2 Characteristic of cyan tone reproduction curve

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**Figure 4-3 Tone reproduction of print(magenta) (a) AM Screen (b) FM Screen (c) Hybrid Screen (d) Half-hybrid Screen (e) Full-hybrid Screen**

Magenta tone reproduction curve

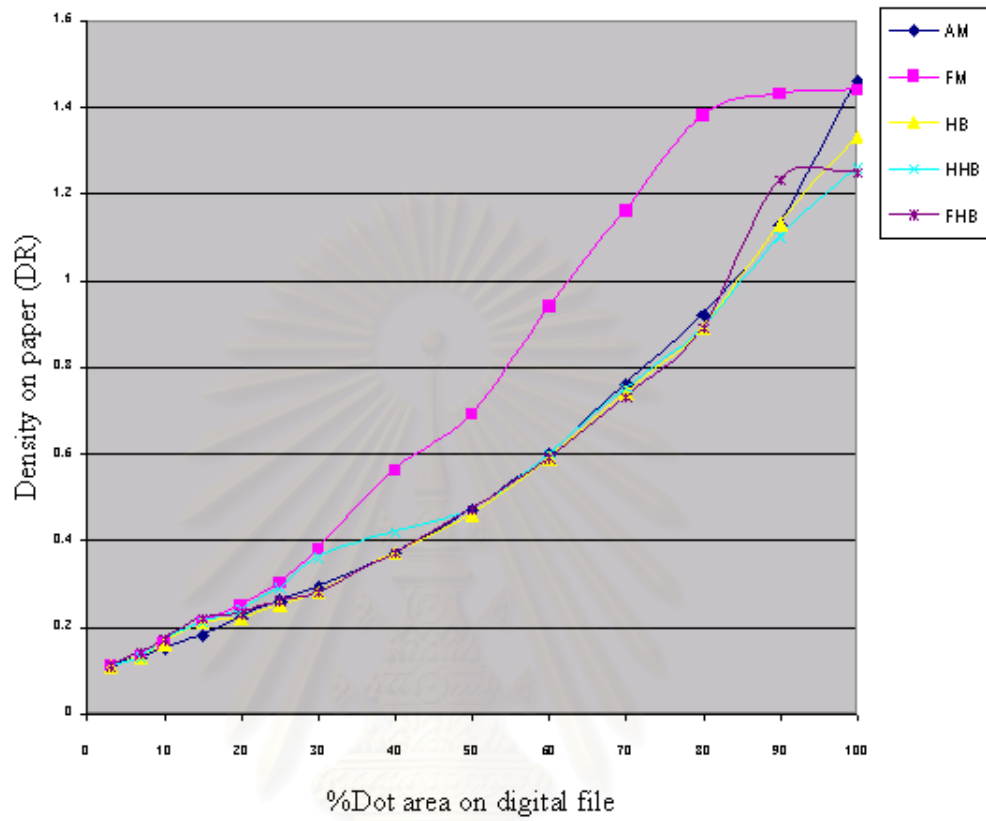
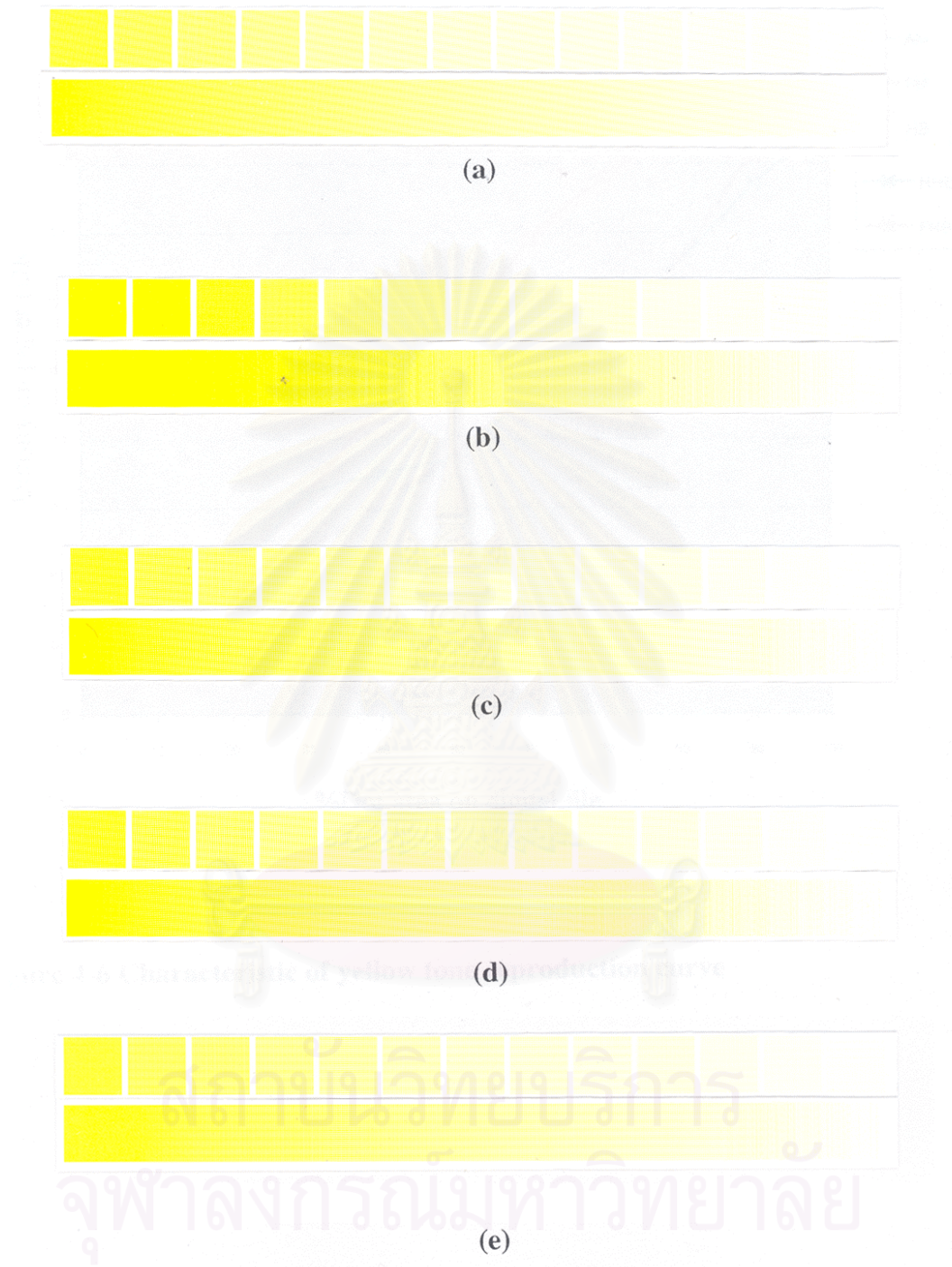


Figure 4-4 Characteristic of magenta tone reproduction curve

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**Figure 4-5 Tone reproduction of print(yellow) (a) AM Screen (b) FM Screen (c) Hybrid Screen (d) Half-hybrid Screen (e) Full-hybrid Screen**

Yellow tone reproduction curve

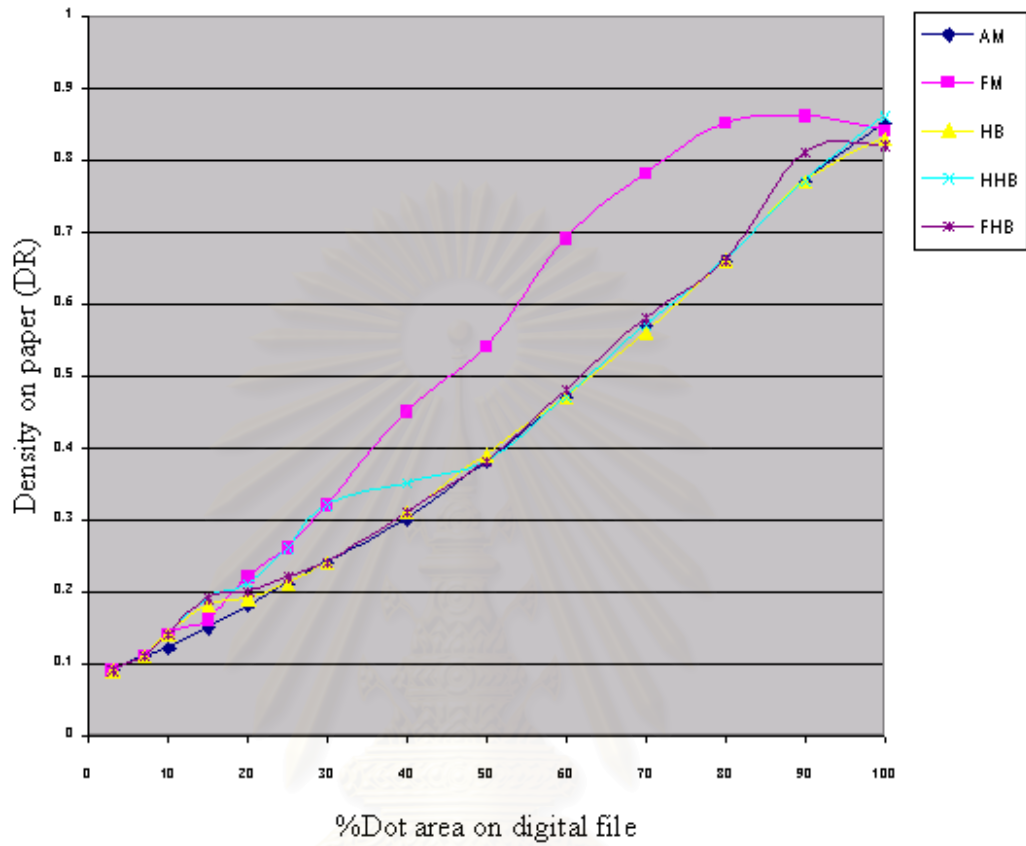
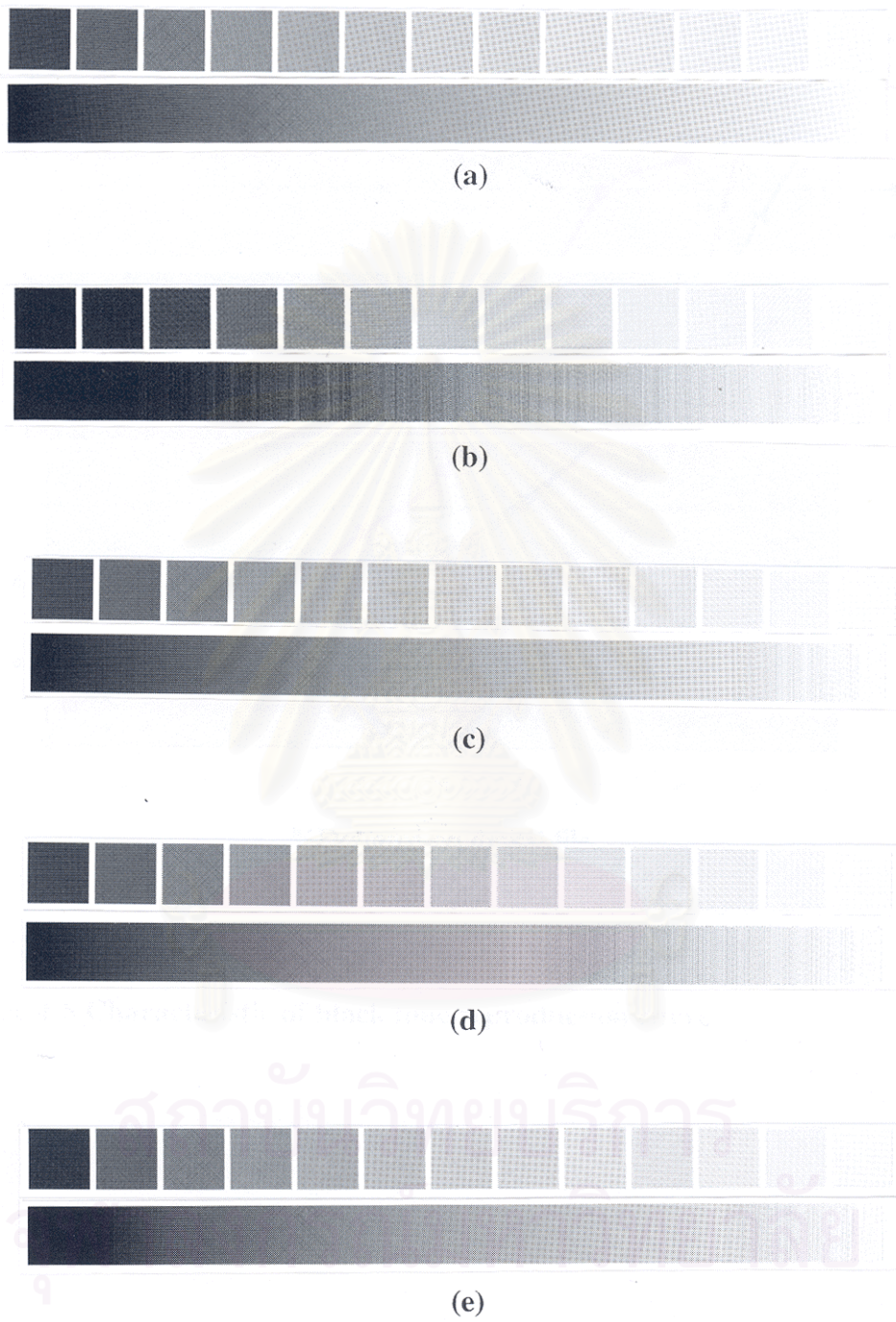


Figure 4-6 Characteristic of yellow tone reproduction curve

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**Figure 4-7 Tone reproduction of print(black) (a) AM Screen (b) FM Screen (c) Hybrid Screen (d) Half-hybrid Screen (e) Full-hybrid Screen**

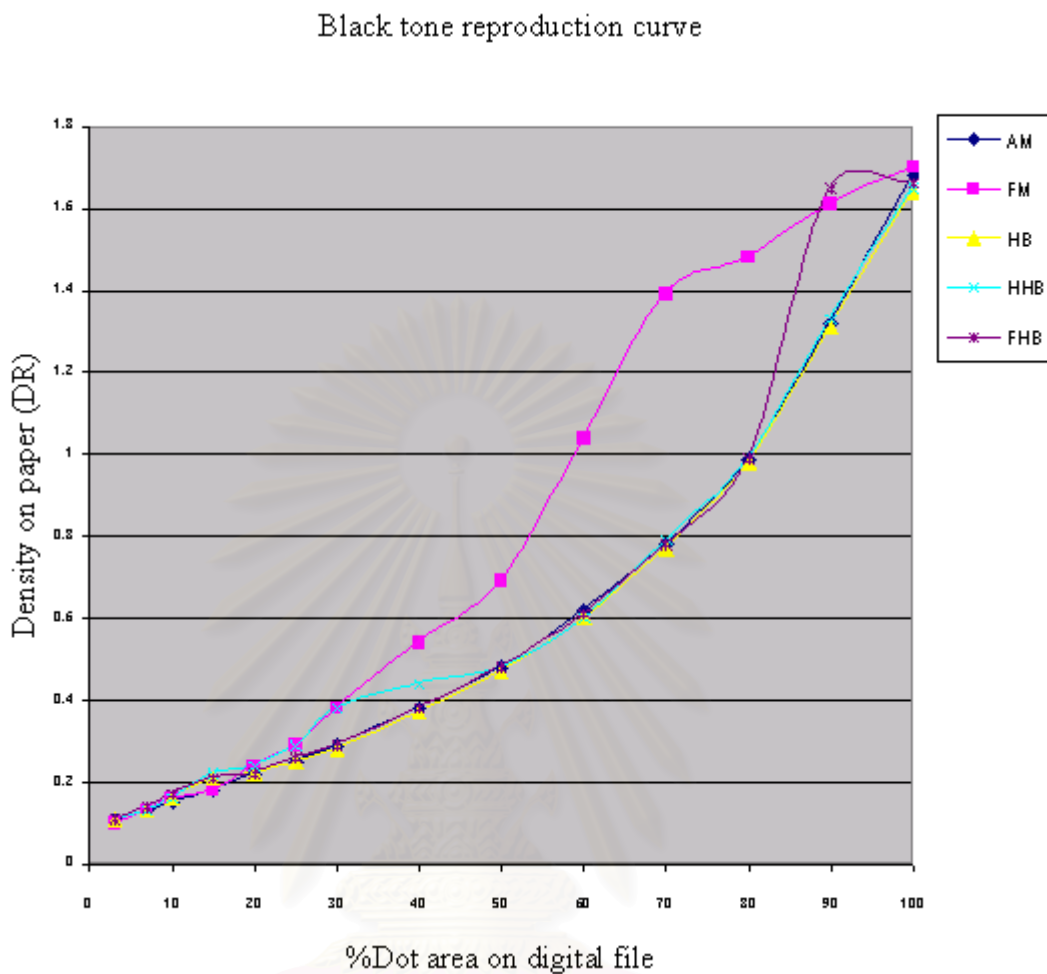
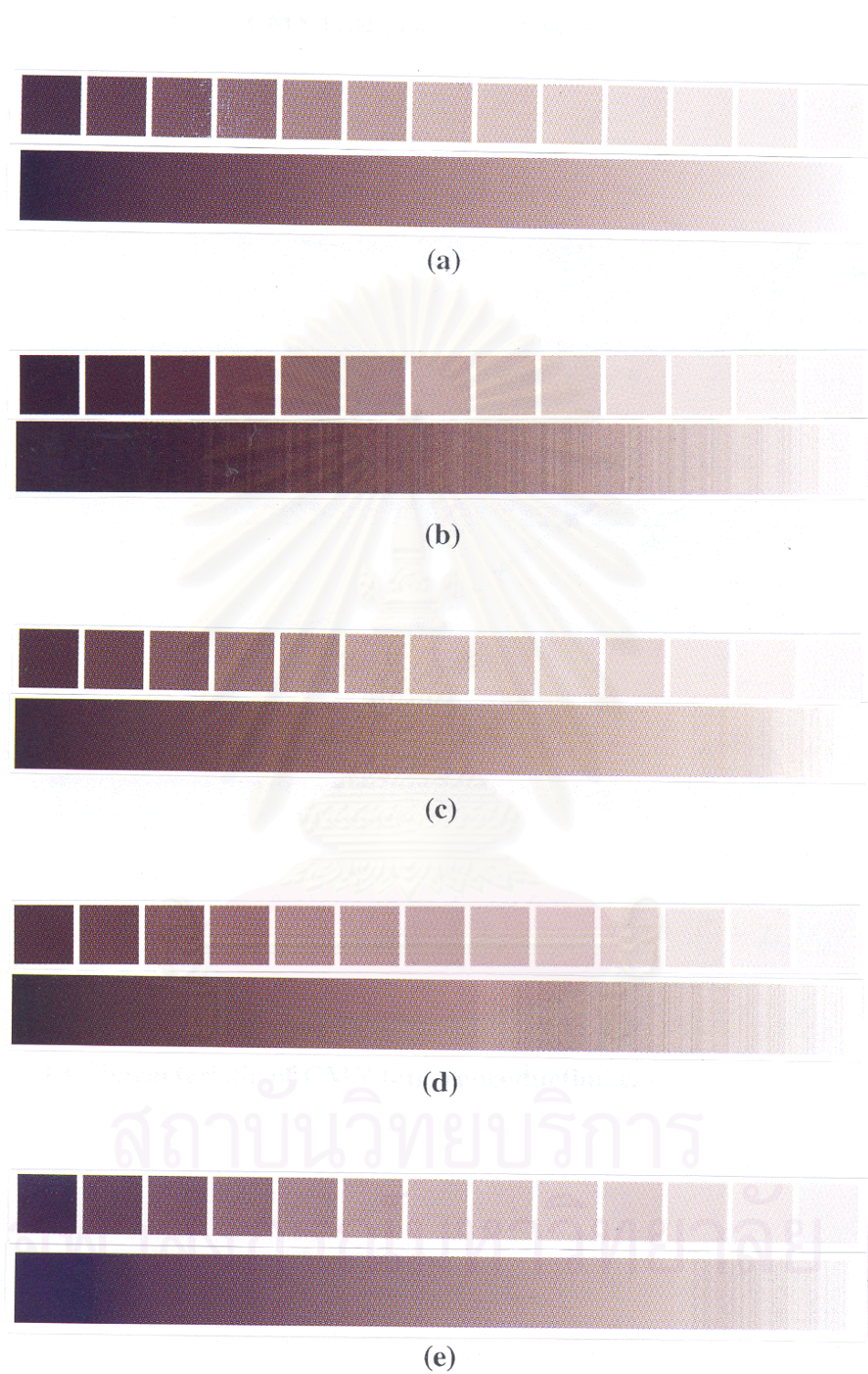


Figure 4-8 Characteristic of black tone reproduction curve

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**Figure 4-9 Tone reproduction of print(CMY) (a) AM Screen (b) FM Screen (c) Hybrid Screen (d) Half-hybrid Screen (e) Full-hybrid Screen**

CMY tone reproduction curve

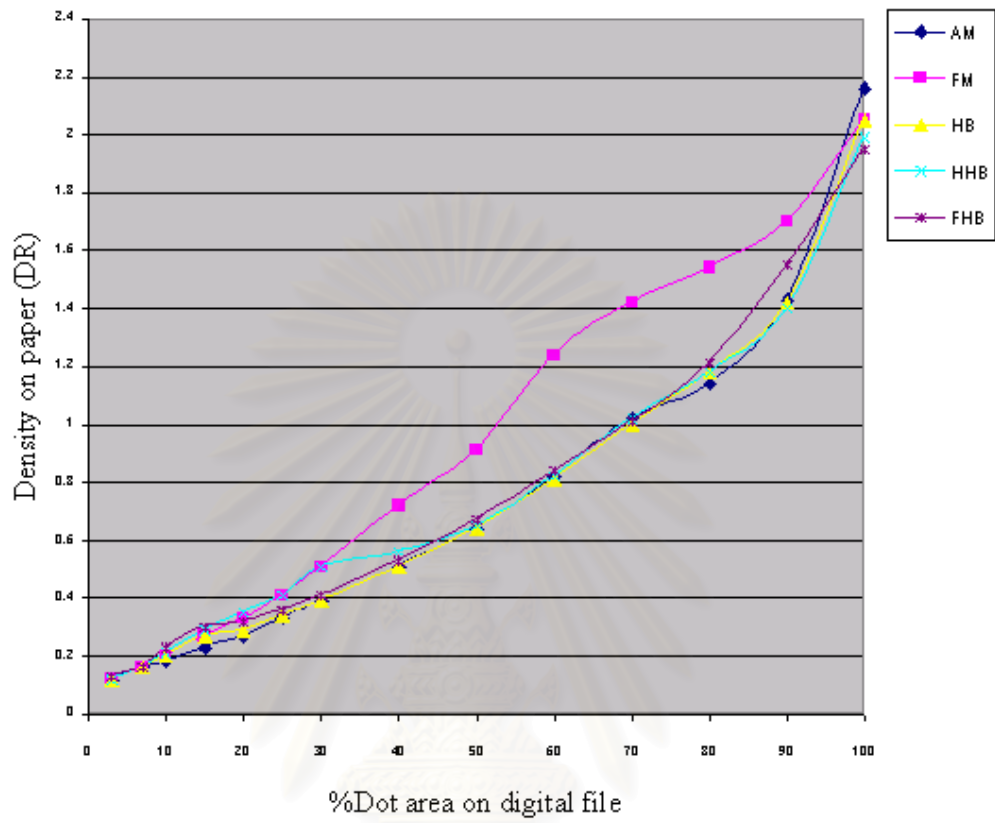


Figure 4-10 Characteristic of CMY tone reproduction curve

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#### 4.2.2 Detail of image

From the print results of experiment the detail of image cannot detect by naked eyes, It is due to higher resolution (120 Line per inch). Thus, CMYK density curve may be useful to analyze the different quantity of detail. If the CMYK in highlight area densities have higher value, this means that higher detail appears.

The CMYK tone reproduction curves can represent the different quantity of detail image production from different halftone screen. The density of FM screen area shows higher than that of AM screen area at the equal density level of original image. Thus, the increased density of FM screen can assume the ability of detail reproduction of FM screen particularly in highlight area.

From the results, it may be concluded that FM screen should be used in highlight area while AM screen will be suitable for midtone to shadow area. The densitometric result gives high density in highlight area and overall smooth tone reproduction. Thus, using hybrid screen technique is better than AM screen in the part of highlight detail and better than FM screen in the part of tone reproduction. Figure 4-11 to 4-25 show there effects.

In printing process, detail of the image is dependent on setting value of resolution. If the printing device cannot print at high resolution, the halftone process will decrease the detail of image and gradation. The hybrid screen can solve both problems and display the effectiveness in low resolution printing process.

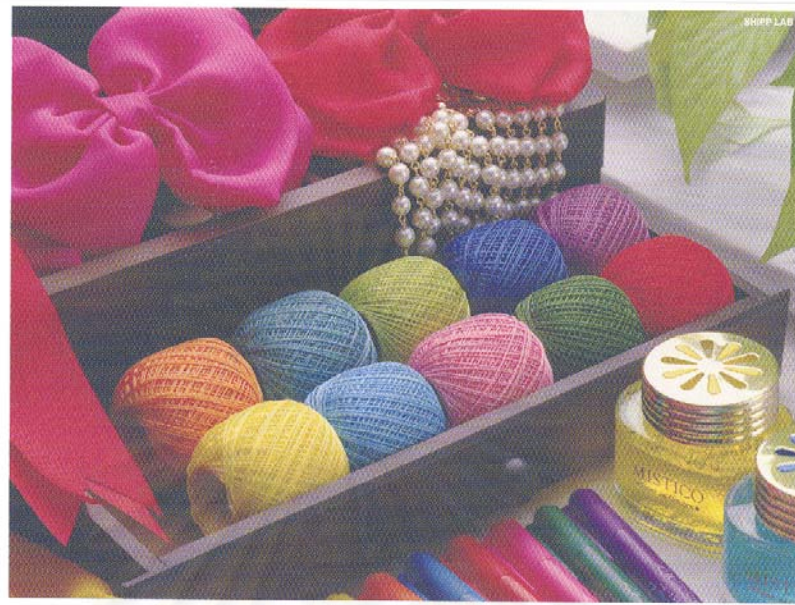


Figure 4-11 Testform print of AM screen



Figure 4-12 Color patches print of AM screen



Figure 4-13 RGB color patches print of AM screen



Figure 4-14 Testform print of FM screen



Figure 4-15 Color patches print of FM screen

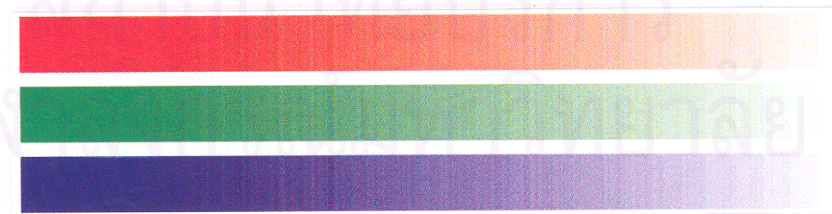


Figure 4-16 RGB color patches print of FM screen



Figure 4-17 Testform print of Hybrid screen



Figure 4-18 Color patches print of Hybrid screen

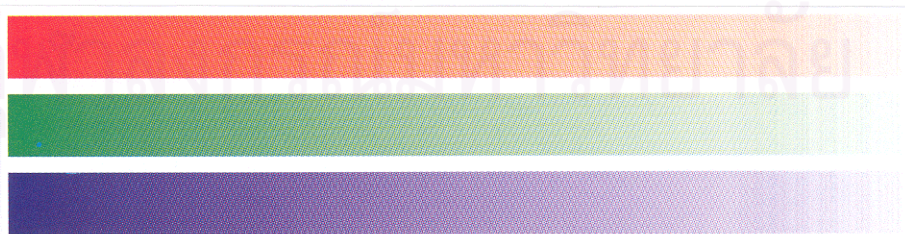


Figure 4-19 RGB color patches print of Hybrid screen





Figure 4-20 Testform print of Half-hybrid screen



Figure 4-21 Color patches print of Half-hybrid screen

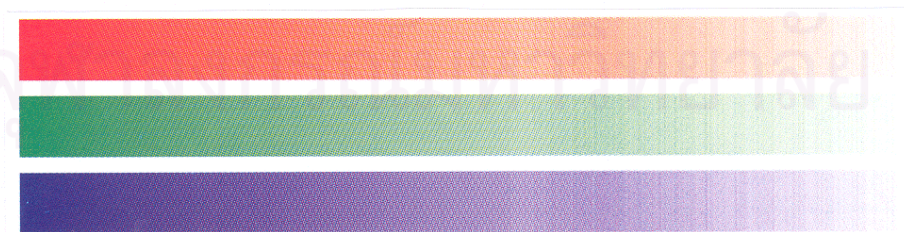


Figure 4-22 RGB color patches print of Half-hybrid screen



Figure 4-23 Testform print of Full-hybrid screen



Figure 4-24 Color patches print of Full-hybrid screen

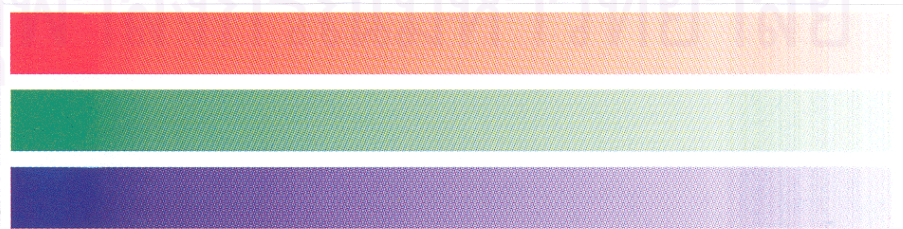


Figure 4-25 RGB color patches print of Full-hybrid screen

### 4.3 Moire pattern appearance

For repairing incorrect data image algorithm, it is successful in checking and repairing the incorrect data image from rotate image algorithm. The obtained image can have correct data giving required tone reproduction.

The module of reverse screen angles algorithm, shows efficient hybrid halftone image, whose screen angles can be changed to suitable value.

As the result, moire pattern of print image can be solved at any resolutions via different printing systems. Even in the resolution printing condition which moire easily appear, this algorithm supports it.



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## CHAPTER V

### CONCLUSION AND SUGGESTION

#### 5.1 Conclusion

The Irrational Tangent technique can be used effectively as a tool for generating proper hybrid screen angles. The continuity at the AM/FM interface can be obtained for the whole tonal range.

The advantages not only improve tone reproduction, detail information; but also reduce moire problem.

The cutoff used to quantify the amount of the FM screen in an image should have the code value 180-200 depending on the characteristic of an image and the user's need.

If the cut off were too low, the discontinuity at the boundary would be visually detected easier than one with a high code value. Furthermore, the cut off with low code value can be more influenced by dot gain. About the mixture area, an appropriate mixing bandwidth should be around 10-30. If the bandwidth were too small, the discontinuity caused by the difference in screen sizes will occur.

Regarding the sharpness of the image, the number of the FM screen dots in a matrix (group of pixel) should not be more than 25 (5\*5). The higher the matrix is, the more, the tone tends to disperse throughout the cell, by which the detail of the original image is disturbed.

To define the proper area for screening, it is recommend that FM screen be in the highlight area this gives better image detail than that produced by AM screen. The

loss of an image detail in the shadow area could not be reduced by the use of the FM screen. It is because the dot loss of FM screen reduce the detail image in shadows area.

## 5.2 Suggestion

The solution to improve image detail in the shadow area, FM screen is used. Dot gain compensation curve is needed before making halftone separation. The right compensation could help the system produce an image detail in shadow area better.

Based on this research, 4-color printing, color management system (CMS) has not included in the process. Further work should be included.

In addition, the effect of the position of mixing area of each color (CMYK) in hybrid screen has not studied. There is important aspect, that the position of mixing area of each color should be varied for different color, depending on original scene such as high key and low key. Finally, this algorithm should be tested under various printing systems to find out the proper specifications in hybrid printing.

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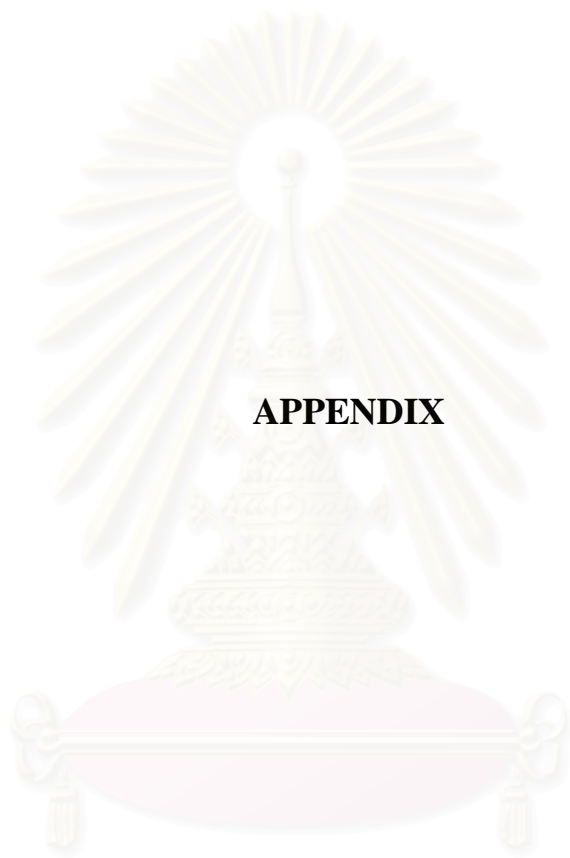
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**APPENDIX**

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## APPENDIX A

### HYBRID SCREEN ANGLES PROGRAM

```
#include <stdio.h>

#include <stdlib.h>

#include <math.h>

#define PI 3.141592654

int xsize;

int ysize;

float angle;

int  ixr,iyr;    /* coordinate after rotation */

int maxx,maxy;

float  s,c;

float  xrm;      /* maximum negative xr value after rotation */

unsigned char *filein,*fileout,*temp;

char name1[20];

char name2[20];

void  intePart(void);

void  alloPart(void);
```

```
void readPart(void);

void procPart(void);

void writPart(void);

void alloPart_RV(void);

void readPart_RV(void);

void procPart_RV(void);

void writPart_RV(void);

/*Start of main*/

void main(void)
{
    int typerr;

    printf("--- Program ---\n");

    intePart();

RR:    printf("Please input [1] Rotate or [2] Reverse Image. :");

    scanf ("%d",&typerr);

    if(typerr==1)
    {
        printf("Allocating Memory\n");
        alloPart();

        printf("Reading Image...  %30s\n",&name1);

        readPart();

        printf("Processing Image...  %30s\n",&name1);

        procPart();
```

```
printf("Writing Image...  %20s\n",name2);
    writPart();
printf("Xsize of Image = %d\n",ixr);
printf("ysize of Image = %d\n",iyr);
printf("Success! Goodbye\n");
}
if(ryperr==2)
{
printf("Allocating Memory\n");
    alloPart_RV();
printf("Reading Image...  %30s\n",&name1);
    readPart_RV();
printf("Processing Image...  %30s\n",&name1);
    procPart_RV();
printf("Writing Image...  %20s\n",name2);
    writPart_RV();
printf("Xsize of Image = %d\n",xsize);
printf("ysize of Image = %d\n",ysize);
printf("Success! Goodbye\n");
}
if(ryperr!=1&&ryperr!=2)
{
    goto RR;
}
```

```
    getch();
}

/*Interface Part*/
void intePart(void)
{
    printf("Please Type The Filename Of Input Image  : ");
    scanf("%s", name1);
    printf("Please Type The Filename Of Output Image : ");
    scanf("%s", name2);
    printf("Please Type The X SIZE      Of Input Image  : ");
    scanf("%d", &xsize);
    printf("Please Type The Y SIZE      Of Input Image  : ");
    scanf("%d", &ysize);
    printf("Please Insert Angle to Rotate Image  : ");
    scanf("%f", &angle);
    angle= angle*PI/180.0;
    maxx=(ysize*sin(angle))+(xsize*cos(angle));
    maxy=(ysize*cos(angle))+(xsize*sin(angle));
    s=sin(angle);
    c=cos(angle);
    xrm = ysize*s;
}
```

```
void alloPart(void)
{

    int a,b;

    filein = (unsigned char *)malloc(sizeof(unsigned char)*xsize*yysize);

    if(filein == (unsigned char *)NULL)
    {
        printf("Missing Memory...\n");
        exit(1);
    }

    temp = (unsigned char *)malloc(sizeof(unsigned char)*maxx*maxy);

    if(temp == (unsigned char *)NULL)
    {
        printf("Missing Memory...\n");
        exit(1);
    }

    b=maxx*maxy;
    for(a=0;a<b;a++)
    {
        temp[a]=255;
    }
}
```

```
void alloPart_RV(void)
```

```
{  
  
    int a,b;  
  
    fileout = (unsigned char *)malloc(sizeof(unsigned char)*xsize*ysize);  
  
    if(fileout == (unsigned char *)NULL)  
    {  
        printf("Missing Memory...\n");  
        exit(1);  
    }  
  
    filein = (unsigned char *)malloc(sizeof(unsigned char)*maxx*maxy);  
  
    if(filein == (unsigned char *)NULL)  
    {  
        printf("Missing Memory...\n");  
        exit(1);  
    }  
  
    b=maxx*maxy;  
  
    for(a=0;a<b;a++)  
    {  
        filein[a]=255;  
    }  
}  
  
void readPart(void)  
{
```

```
long i;
FILE *fp;
fp = fopen(name1,"rb");
if(fp == (FILE *)NULL)
{
    printf("fileOpenError\n");
    exit(1);
}
for(i=0;i<xsize*ysize;i++)
{
    filein[i] = fgetc(fp);
}
fclose(fp);
}
```

```
void readPart_RV(void)
```

```
{
    long i;
    FILE *fp;
    fp = fopen(name1,"rb");
    if(fp == (FILE *)NULL)
    {
        printf("fileOpenError\n");
        exit(1);
    }
}
```

```
}  
for(i=0;i<maxx*maxy;i++)  
{  
    filein[i] = fgetc(fp);  
}  
fclose(fp);  
}
```

```
void procPart(void)  
{  
    long i,j,x,y;  
    float xr,yr;  
    i=j=x=y=0;  
    for( y = 0 ; y < ysize ; y++)  
    {  
        for( x = 0 ; x < xsize ; x++)  
        {  
            xr = x*c - y*s;  
            yr = x*s + y*c;  
            ixr = xr;  
            iyr = yr;  
            j=((iyr*maxx)+ixr);  
            temp[j] = filein[i];  
        }  
    }  
}
```

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```
        ++i;
        j=0;
    }
}
}
```

```
void procPart_RV(void)
{
    long  i,j,x,y;
    float  xr,yr;
    i=j=x=y=0;
    for( y = 0 ; y < ysize ; y++)
    {
        for( x = 0 ; x < xsize ; x++)
        {
            xr = x*c - y*s;

            xr+=xrm ;
            ixr = xr;
            yr = x*s + y*c;
            iyr = yr;

            j=((iyr*maxx)+ixr);
            fileout[i] = filein[j];

            ++i;
            j=0;
        }
    }
}
```

```

    }
}
}

void writPart(void)
{
    long x,y,j;
    float a,b,x1,x2;
    long int xout,yout;
    long int point;
    FILE *fp;
    double output;
    fp = fopen(name2,"wb");

    if(fp == (FILE *)NULL)
    {
        printf("fileOpenError\n");
        exit(1);
    }
    ixr=(ysize*sin(angle))+(xsize*cos(angle));
    iyr=(ysize*cos(angle))+(xsize*sin(angle));
    j=0;
    for(y=0;y<iyr;y++)
    {

```

```
for(x=0;x<ixr;x++)
{
    if(temp[j]==255&&temp[j-1]!=255&&temp[j+1]!=255)
    {
        a=x-xrm;
        b=y;
        a=a*c;
        b=b*s;
        x1=a+b;
        x2=((c*c)+(s*s));
        xout= (x1/x2);
        yout= ((y-(xout*s))/c);
        point= ((yout*xsize)+xout);
        output=filein[point];
    }
    else
    {
        output = temp[j];
    }
    fputc((int)output,fp);
    j++;
}
fclose(fp);
```

```
}  
  
void writPart_RV(void)  
{  
    long x,y,i;  
    FILE *fp;  
  
    double output;  
    fp = fopen(name2,"wb");  
    if(fp == (FILE *)NULL)  
    {  
        printf("fileOpenError\n");  
        exit(1);  
    }  
    i=0;  
    for(y=0;y<yssize;y++)  
    {  
        for(x=0;x<xssize;x++)  
        {  
            output = fileout[i];  
            fputc((int)output,fp);  
            i++;  
        }  
    }  
  
    fclose(fp);  
}
```



**APPENDIX B**

**Print Density measured from the Print Sample**

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Table B-1 Density of cyan color

%Dot area on digital file

Screen type	%Dot area on digital file														
	DENSITY	3%	7%	10%	15%	20%	25%	30%	40%	50%	60%	70%	80%	90%	100%
AM	0.11	0.13	0.14	0.17	0.20	0.24	0.27	0.35	0.44	0.56	0.71	0.89	1.15	1.61	
FM	0.11	0.14	0.16	0.21	0.23	0.28	0.34	0.50	0.63	0.84	1.08	1.38	1.52	1.57	
HB	0.11	0.13	0.16	0.20	0.21	0.23	0.27	0.34	0.43	0.56	0.70	0.88	1.14	1.54	
HHB	0.11	0.14	0.16	0.21	0.24	0.28	0.35	0.40	0.45	0.57	0.71	0.88	1.14	1.55	
FHB	0.11	0.14	0.17	0.22	0.23	0.25	0.28	0.37	0.45	0.57	0.73	0.90	1.38	1.57	

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Table B-2 Density of magenta color

%Dot area on digital file

Screen type	%Dot area on digital file														
	DENSITY	3%	7%	10%	15%	20%	25%	30%	40%	50%	60%	70%	80%	90%	100%
AM	0.11	0.13	0.15	0.18	0.22	0.26	0.29	0.37	0.47	0.60	0.76	0.92	1.13	1.46	
FM	0.11	0.13	0.16	0.21	0.25	0.30	0.38	0.56	0.69	0.94	1.16	1.38	1.43	1.44	
HB	0.11	0.13	0.16	0.21	0.22	0.25	0.28	0.37	0.46	0.59	0.74	0.89	1.13	1.33	
HHB	0.11	0.13	0.17	0.21	0.24	0.29	0.36	0.42	0.47	0.60	0.75	0.89	1.10	1.26	
FHB	0.11	0.14	0.17	0.22	0.23	0.26	0.28	0.37	0.47	0.59	0.73	0.89	1.23	1.25	

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Table B-3 Density of yellow color

%Dot area on digital file

Screen type	%Dot area on digital file														
	DENSITY	3%	7%	10%	15%	20%	25%	30%	40%	50%	60%	70%	80%	90%	100%
AM	0.09	0.11	0.12	0.15	0.18	0.21	0.24	0.30	0.38	0.47	0.57	0.66	0.77	0.85	
FM	0.09	0.11	0.14	0.16	0.22	0.26	0.32	0.45	0.54	0.69	0.78	0.85	0.86	0.84	
HB	0.09	0.11	0.14	0.18	0.19	0.21	0.24	0.31	0.39	0.47	0.56	0.66	0.77	0.83	
HHB	0.09	0.11	0.14	0.19	0.21	0.26	0.32	0.35	0.38	0.47	0.57	0.66	0.77	0.86	
FHB	0.09	0.11	0.14	0.19	0.20	0.22	0.24	0.31	0.38	0.48	0.58	0.66	0.81	0.82	

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Table B-4 Density of black color

%Dot area on digital file

Screen type	%Dot area on digital file														
	DENSITY	3%	7%	10%	15%	20%	25%	30%	40%	50%	60%	70%	80%	90%	100%
AM	0.11	0.13	0.15	0.18	0.22	0.25	0.29	0.38	0.48	0.62	0.78	0.99	1.32	1.68	
FM	0.10	0.13	0.16	0.18	0.24	0.29	0.38	0.54	0.69	1.04	1.39	1.48	1.61	1.70	
HB	0.11	0.13	0.16	0.21	0.22	0.25	0.28	0.37	0.47	0.60	0.77	0.98	1.31	1.64	
HHB	0.11	0.13	0.16	0.22	0.24	0.29	0.38	0.44	0.48	0.60	0.79	0.99	1.33	1.65	
FHB	0.11	0.14	0.17	0.21	0.22	0.26	0.29	0.38	0.48	0.61	0.78	0.99	1.65	1.66	

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Table B-5 Density of CMY color

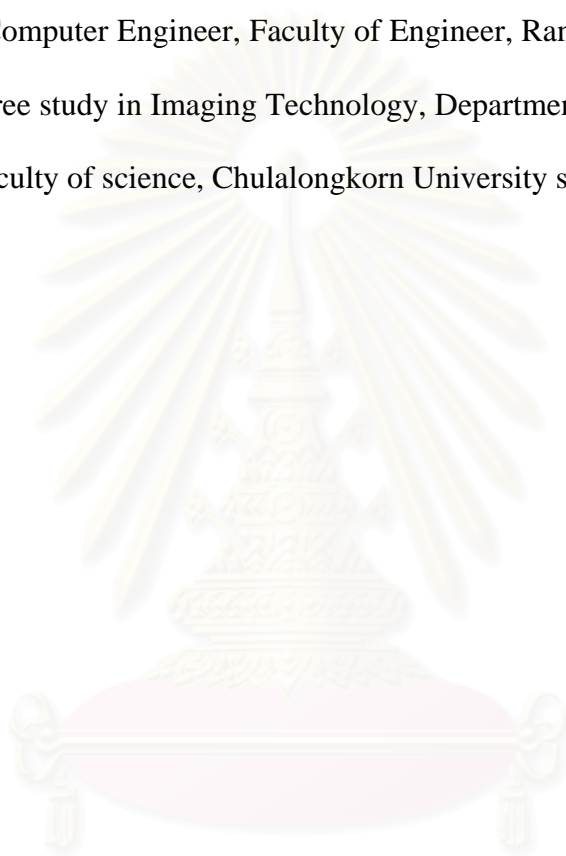
<b>DENSITY</b>	<b>3%</b>	<b>7%</b>	<b>10%</b>	<b>15%</b>	<b>20%</b>	<b>25%</b>	<b>30%</b>	<b>40%</b>	<b>50%</b>	<b>60%</b>	<b>70%</b>	<b>80%</b>	<b>90%</b>	<b>100%</b>
<b>AM</b>	0.12	0.16	0.18	0.23	0.27	0.33	0.39	0.51	0.64	0.82	1.02	1.19	1.43	2.16
<b>FM</b>	0.12	0.16	0.20	0.27	0.33	0.41	0.51	0.72	0.91	1.24	1.42	1.54	1.70	2.05
<b>HB</b>	0.12	0.16	0.20	0.27	0.29	0.34	0.39	0.51	0.64	0.81	1.00	1.18	1.42	2.05
<b>HHB</b>	0.12	0.16	0.21	0.29	0.35	0.41	0.51	0.56	0.65	0.82	1.02	1.18	1.40	1.99
<b>FHB</b>	0.13	0.16	0.23	0.30	0.32	0.36	0.41	0.53	0.67	0.84	1.01	1.21	1.55	1.95

Screen type

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## VITA

Mr. Thammasan Thiprangsri was born on February 28,1977, in Bangkok, Thailand. He receives her B.Eng. in Computer Engineer from Department of Electrical and Computer Engineer, Faculty of Engineer, Rangsit University. He began him master degree study in Imaging Technology, Department of Imaging and Printing Technology, Faculty of science, Chulalongkorn University since 2000.



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