CHAPTER III
EXPERIMENTAL

3.1 Hybrid Halftone Algorithm

Hybrid Halftone Algorithm applied in generating mixing screen 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. Follows are abbreviated concepts of the three algorithms.

3.1.1 Area Selection

Area Selection is one of the three major algorithms that directly affect image quality. Area Selection is working as a separation module that determines and matches suitable area with suitable screen techniques, AM or FM screen. For choosing screen types, Area Selection plays a rule part in concerning image tone. To process entire image area effectively and efficiently, there are two magnificent subjects having to be considered.

3.1.1.1 Banding boundary

In order to avoid non-smooth area at the boundary of the different screen types, Algorithm has to generate a band called Mixture Area between low cutoff point and high cutoff point shown in Figure 3-1. The Mixture Area is provided for gradually changing from AM screen to FM screen. Therefore, it needs proper band to enable smoothly changing. At the boundary, the technique of screening is different from the ordinary one. It consists of both AM and FM characteristics that have special 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.

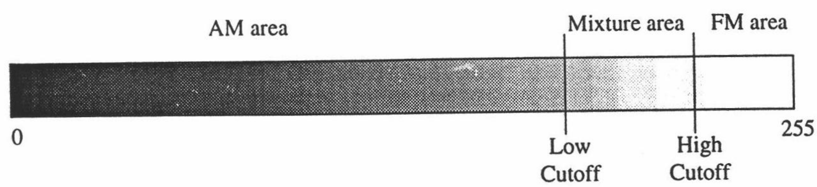

Figure 3-1 The three areas of different screen techniques and the appropriate wide band can smoothen the gradation of screening techniques.

3.1.1.2 Hybrid Threshold

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 in the following subject.

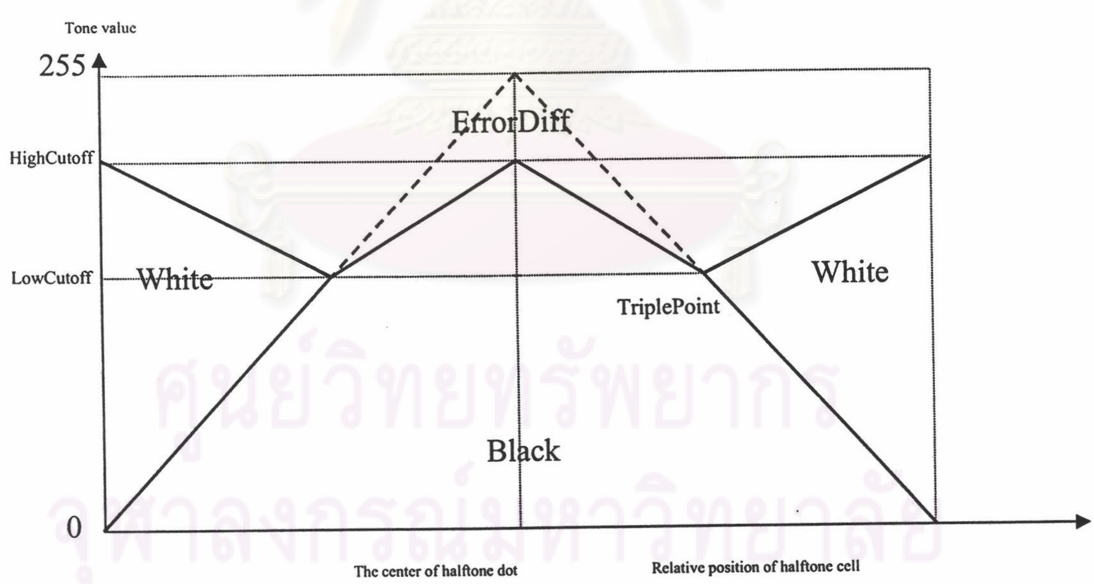

Figure 3-2 The threshold of hybrid algorithm using for Area Selection

In Figure 3-2 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 using for AM technique. Blue area is screened by FM technique.

3.1.2 AM Screen Algorithm

In order 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 in Figure 3-3 shows schematically the sequence of creating AM screen.

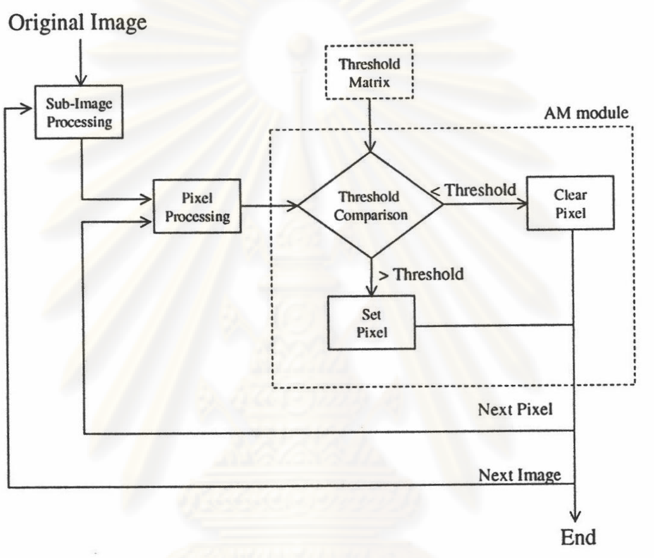

Figure 3-3 The flowchart of AM algorithm

AM screen algorithm will be started 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 a cell. A cell is applied to Pixel Processing, which is working by concentrating each pixel in the cell following processing route. Then obtained pixels would be sent to Threshold matrix for comparison. If the pixel has more value high than that of threshold matrix member, it would be set to be one, In contrast, if the pixel has value lower than that of the threshold matrix member, the pixel would be clear to be 0. This process will be completed when all pixels in a cell and all cells in an image, and adjusted.

3.1.3 FM Algorithm

FM algorithm used technique Spiral Error Diffusion developing 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.

3.1.3.1 Spiral processing

Spiral processing is base on sub-image processing, by which any process would be enforced in sequence from the center of cell and spiral to the edge of cell as shown in Figure 3-4.

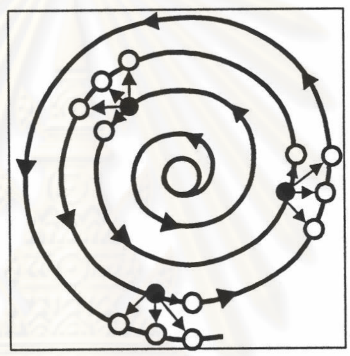

Figure 3-4 Processing route and dispersing of error

3.1.3.2 Error diffusion

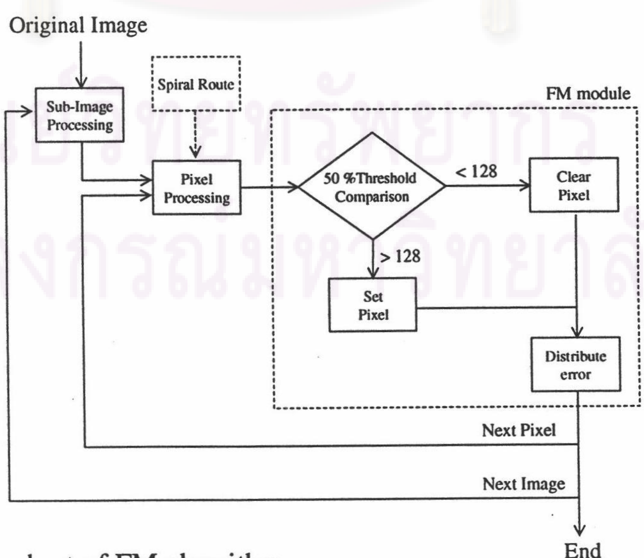

Figure 3-5 Flowchart of FM algorithm

Error diffusion is a method that tries to disperse an error value to the neighbor pixel. The target pixel is found out error by representing the pixel data with binary pattern value. The errors value are propagated to the adjacent pixel with different weight, which depends on distance between the target pixel and the adjacent pixels: The closer pixels will obtain more effect. Figure 3-4 shows the model of error diffusion, and the algorithm described in flowchart as Figure3-5.

The FM algorithm starts the process by analyzing an original image through Sub-image and Pixel processing. Pixel processing will analyze each pixel in a cell though Spiral Processing technique by using Spiral Route. After that, 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 are computed by subtraction the output pixel from the input pixel. The result is the error values, 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.

3.2 Digital Workflow

The main algorithm used in processing halftone was changed to C programming on personal computer. However, other processes, which are used in manipulating image such as resolution adjusting, printing, and so were on not included in this thesis. It has still used image-processing software. The related software and entire process are shown as workflow in Figure 3-6.

To Prepare steps an the original color image would be transformed to gray image following scope of thesis, and the adjusted image resolution suitable for output devices. The image from the process would be kept in .RAW file format, since it is convenient in access to the data.

Using C language to convert algorithm and to process the image, The halftone programming composes of many parts such as opening and saving module of .RAW file format. The output was kept as bi-level image which has 8 bits memory.

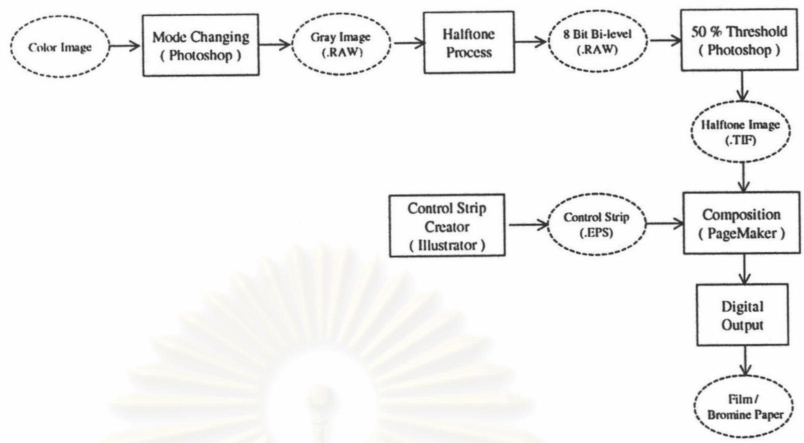

Figure 3-6 Digital workflow

The image was transformed to bi-level as bitmap image by cutting at 50% threshold. To save the .TIF file format was used to save halftone image.

The obtained image, generated from each part, would be brought to composition for printing on output device. If the workflow has control strip creating on foundation of vector image, saved in .EPS file format, it should be composed to other parts from this step.

The composed image would be sent to output device by using suitable application software, mapped to the grid line of output device. Note that for vector image, the output device determines the suitable mapping with the highest quality of output device.

3.3 Conventional Workflow

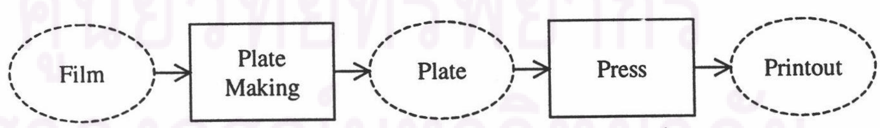

Figure 3-7 Conventional workflow

The screen-printing press was choose. In the preparing plate making, the fabric was cleaned and degreased, then it was coated by blue-emulsion mixed with sensitizer at the ratio 5:1 in the dark room and leave it until dried. Then the block would be exposed by UV radiation though positive images for 40 second to freezing emulsion to be stencil fixed onto the screen, and the unexposed emulsion was washed away to reveal the image area. The stencil was dried properly.

In the printing process the block would be installed in semi-auto printing machine, and print by maintaining the viscosity about 80 pt. and constant press. The fabric would be cleaned every 5 times in printing. Figure 3-7 shows related workflow.

3.4 Test form and Control Strip

To evaluate printing quality, a test form with control strip was to be added into the system. The evaluation is classified into four sections.

Firstly, the image was firstly evaluated by naked eyes. The test form as shown in Figure 3-8 focusing on a hat and flower, it implies the performance of halftone in detail and continuous toning.

Figure 3-8 Tested image

Secondly, gray scale bar in Figure 3-9 displays the result from microdensitometer. This help evaluating the continuous tone.

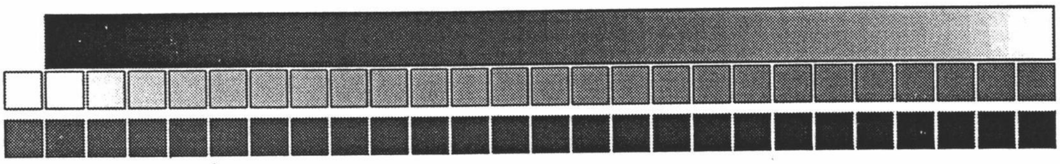

Figure 3-9 Grayscale used for evaluate by microdensitometer

Thirdly, the control strip as shown in Figure 3-10 is designed to control the printing quality. The bar is established from vector image, which related to the output devices. In this research, the setting at 2540 dpi was used.

Figure 3-10 Control strip used for quality control in conventional printing

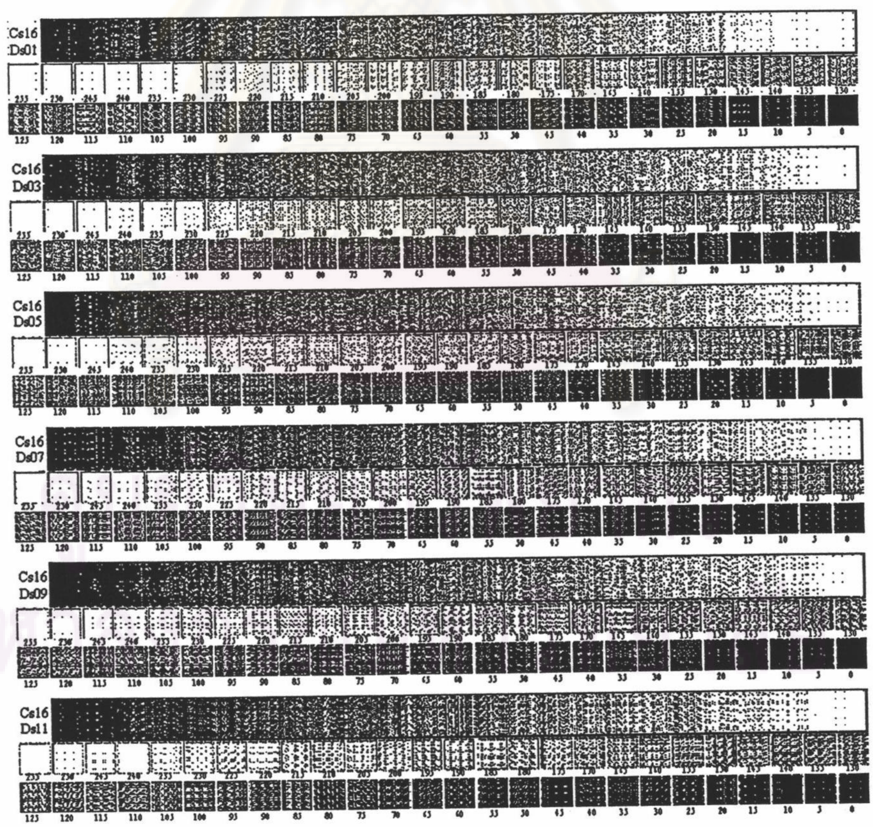

Figure 3-11 Pilot testform used for characterizing conventional printing system

The final part is the test form. It is used to characterize the system of conventional printing in order to search minimum dot size, which can be reproduced with uniformity as shown in Figure3-11.

3.5 Materials

1. Image setter Film : Fuji No. 4ldw
2. Developer : Fuji HR Developer HR-D1
3. Fixer : Fuji Grandex Fixer GR-F1
4. Bromide paper : Anitec 780LD
5. plain laser paper :100 gram A4
6. Fabrics : Nylon Fabrics No.120 per/cm.
7. Ink :Solvent based ink
8. Diazo emulsion and Sensitizer
9. Squeegees Square Edge

3.6 Apparatus

1. Personal Computer :Pentium166 MMx
2. Image setter :Linotronic 260, Linotype-Hell
3. Laser Printer :Apple LasorPro 630
4. Microdensitometer :Konika PDM -7
5. Software PhotoShop v.5 :Adobe California, USA.
6. Software Illustrator v.8 :Adobe California, USA.

7. Software Visual C++ v.6 :Microsoft Washington, USA.

8. Screen Printing Machine

9. Self Contained Exposure Unit

3.7 Experiment

Halftoning technique depends on an output device. The system in conventional printing has many steps in series. The effect from previous step would directly influence next steps inconsequence. Therefore, only a few arms in each step in processing would strongly affect the quality of output, image, and finally this gathering error would impact on printout. In order to enable the system to be possible to use in realistic work, program development is separated into 3 catagories as follow.

3.7.1 Establishment of Skeleton

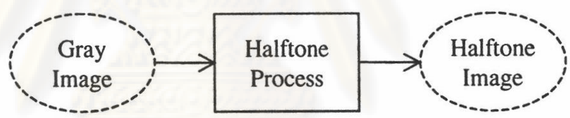

Figure 3-12 Workflow of Establishment of Skeleton

Algorithms of AM, FM, and Hybrid screening were developed. The cell size in process has to be fixed as 8x8 pixel. The program was converted from algorithm based on Dos operating systems. It supports only a low-resolution image. The workflow related to halftone process, is shown in Figure.3-12.

3.7.1.1 The algorithm, as shown in Figure 3-13, is converted to halftone image by using C program.

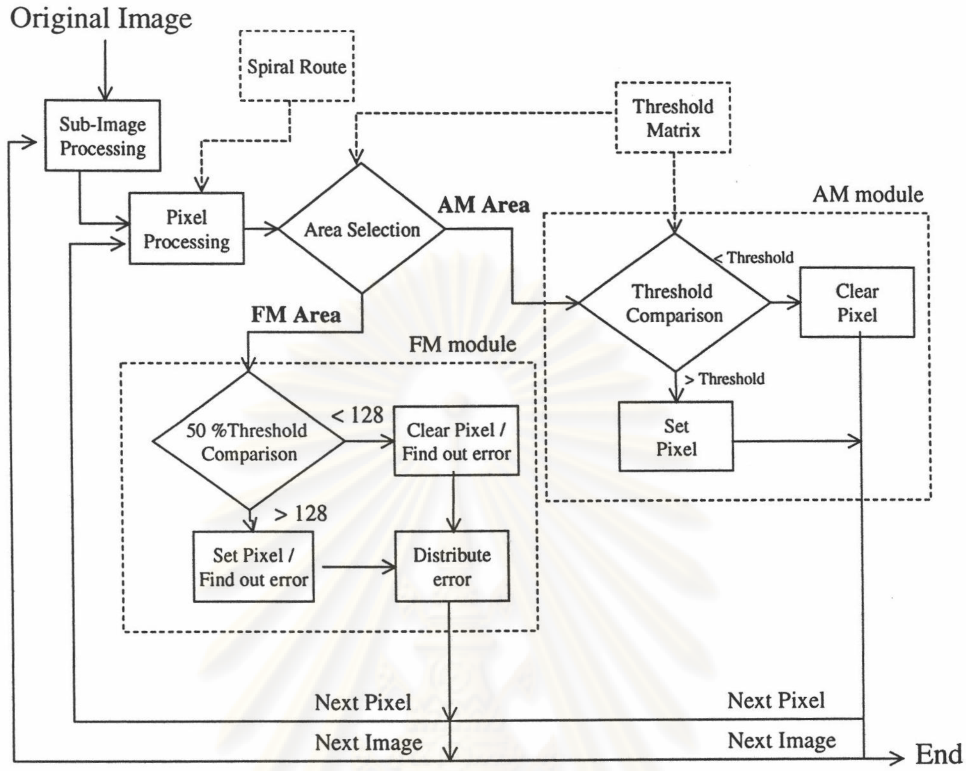

Figure 3-13 Flowchart of Establishment of skeleton algorithm

The algorithm start with Sub-Image Processing and Pixel Processing modules. The pixel data is sent to compute in Area Selection module, which calculates and chooses the most of suitable screen technique for processing pixel. The computation is processed by comparing the pixel data with the member of threshold matrix. Then, the pixel data is sent to AM or FM module that described in topic 3.1.2 and 3.1.3. The process would follow this routine until finishing all pixels in a cell and all cell in an image.

3.7.1.2 The test form image was processed with following parameters as described in Table 3-1 below.

Table 3-1 Parameter of Establishment of skeleton

Condition	Image No.	Test Form	dpi	Cell Size (pixel)	lpi	Cutoff (code value)	Span
AM algorithm	1	Tested Image	300	8	38	-	-
FM algorithm	2	Tested Image	300	8	38	-	-
Hybrid algorithm	3	Tested Image	300	8	38	200	20
Hybrid algorithm	4	Tested Image	300	8	38	210	20

3.7.1.3 The digital workflow in topic 3.2 created an output image by Apple Laser Pro 630.

3.7.1.4 The output image were analyzed by human eyes.

3.7.2 Compatibility of Digital Output

In this step, algorithm of halftoning deeply concerns with digital output device. It can create an effective halftone image when the adjustment of resolution has to do before halftoning process in the Preprocessing step as shown in Figure 3-14.

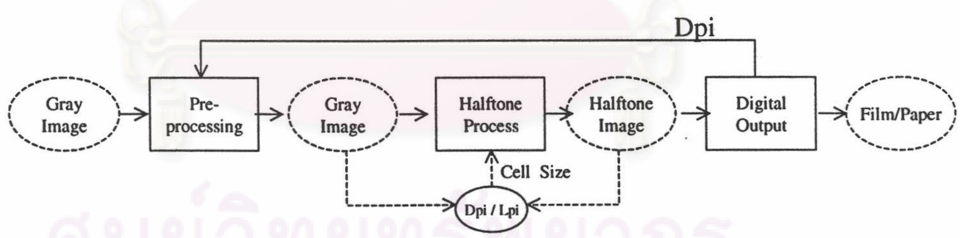

Figure 3-14 Related parameters in the workflow of The Compatibility of Digital Output

The objective of this step aims to emphasize the efficiency and effectiveness of algorithms working with high resolution output image. Moreover, varying size of cell is outlined. Besides, this step highlights the error diffusion method that propagates the error values to the neighboring pixel in position.

3.7.2.1 The program was converted by the algorithm shown in Figure 3-15 base on C programming. In this algorithm, there is a cell size parameters added in the system. The cell size parameter previously affects the three processes. Firstly, the size parameter is applied to generate Threshold Matrix by Creating Threshold module. Secondly, the size parameter is used to create spiral route. Finally, it is used to Creating Mask block to generate the Diffuse Mask that localizes the adjacent pixels, which are dispersed by error values.

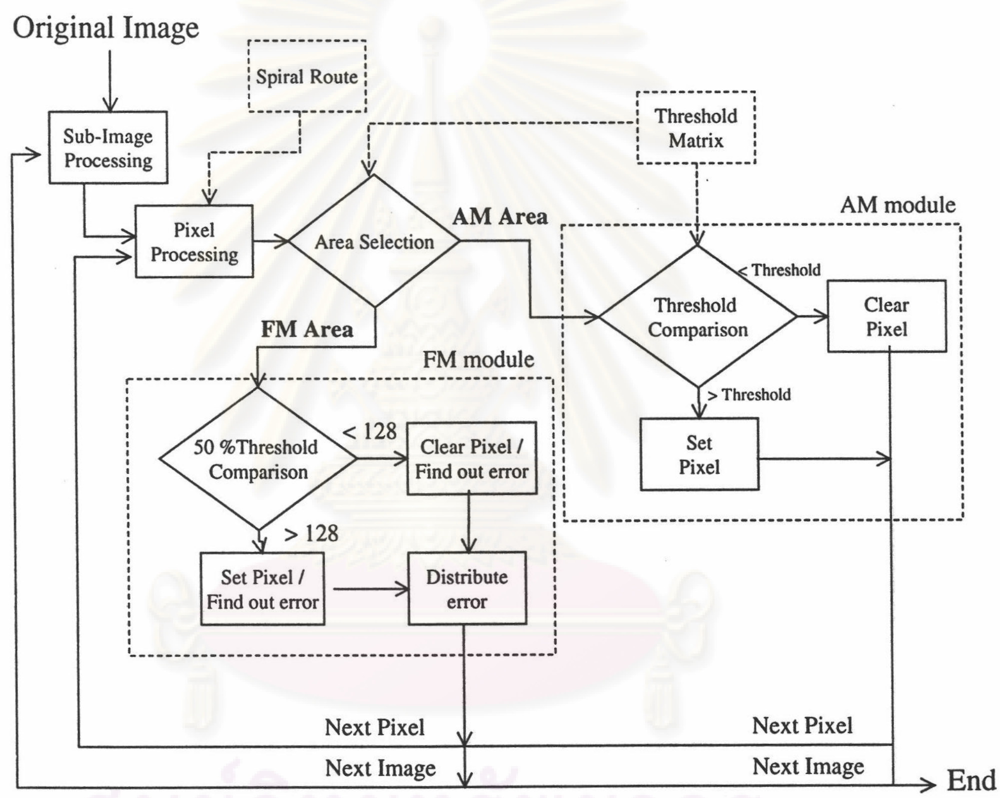

Figure 3-15 The Compatibility of Digital Printing algorithm

Similar to the structure of establishment of skeleton, it begins with the process of Sub-Image Processing. The Pixel Processing uses spiral route from the create route module. Then, the pixel is analyzed by the Area Selection to choose a suitable screen technique, towards AM or FM modules. The size parameter affects the error diffusion in FM module, while the diffuse mask determines the position of neighboring pixels, with gain error. This technique enables error diffusion to be successful and steady.

The routine process will be complete until finishing all pixels in a cell and all cells in an image.

3.7.2.2 Each base algorithm for AM, FM, and Hybrid screening were separately tested using parameter from Table 3-2,3-3 and 3-4 respectively.

3.7.2.3 The halftone output images were obtained by using digital workflow which mentioned in section 3.2.

3.7.2.4 The quality of image were measured and analyzed.

Table 3-2 Parameters of AM algorithm

Condition	Image No.	Test Form	dpi	lpi	Cell Size (pixel)
Vary lpi, Fix dpi	1	Tested Image	400	60	7
	2	Tested Image	1270	60	21
Vary dpi, Fix lpi	1	Tested Image	400	40	10
	2	Tested Image	400	100	4
Vary dpi/ lpi	1	Grayscale	635	127	5
	2	Grayscale	635	106	6
	3	Grayscale	635	90	7
	4	Grayscale	635	80	8
	5	Grayscale	635	70	9
	6	Grayscale	635	64	10

Table 3-3 Parameters of FM algorithm

Condition	Image No.	Test Form	dpi	lpi	Cell Size (pixel)
Vary lpi, Fix dpi	1	Tested Image	635	80	8
	2	Tested Image	1270	80	16
Vary dpi, Fix lpi	1	Tested Image	635	40	16
	2	Tested Image	635	127	5
Vary dpi/ lpi	1	Grayscale	635	127	5
	2	Grayscale	635	90	7
	3	Grayscale	635	70	9
	4	Grayscale	635	58	11
	5	Grayscale	635	48	13
	6	Grayscale	635	42	15

Table 3-4 Parameters of hybrid algorithm

Condition	Image No.	Test Form	dpi	lpi	Cell Size (pixel)	Cutoff	Span
2.1 Vary Cutoff	1	Tested Image	635	58	11	200	20
	2	Tested Image	635	58	11	180	20
	3	Grayscale	635	58	11	120	20
	4	Grayscale	635	58	11	140	20
	5	Grayscale	635	58	11	160	20
	6	Grayscale	635	58	11	180	20
	7	Grayscale	635	58	11	200	20
	8	Grayscale	635	58	11	220	20
2.1 Vary Span	1	Tested Image	635	58	11	200	10
	2	Tested Image	635	58	11	200	30
	3	Grayscale	635	58	5	200	20
	4	Grayscale	635	58	10	200	20
	5	Grayscale	635	58	15	200	20
	6	Grayscale	635	58	20	200	20
	7	Grayscale	635	58	25	200	20
	8	Grayscale	635	58	30	200	20

3.7.3 Compatibility of Conventional Printout (Screen printing)

This category considers the entire influences from the realistic system in conventional printing (Screen printing). To extend effective gamut, An FM dot size is separated form dpi parameter. Consequently, the image elements are together grouped to create FM screen dot. The algorithm is designed to have a channel for parameter to control the size of FM screen dot. Furthermore, the size of screen dot should relate to that of conventional printing system. The smallest dot size that can be printed is a vital characteristic. As a result, the minimum dot size parameter is measured and sent to the halftone program for processing. The related workflow of this step is shown in Figure 3-16.

3.7.3.1 Program is converted from algorithm as flowchart shown in Figure 3-17 base on C programming. The added parameter is the minimum dot size. It combines with the cell size parameter by, which the Group Mask Module is created. The Group Mark is used for the FM module.

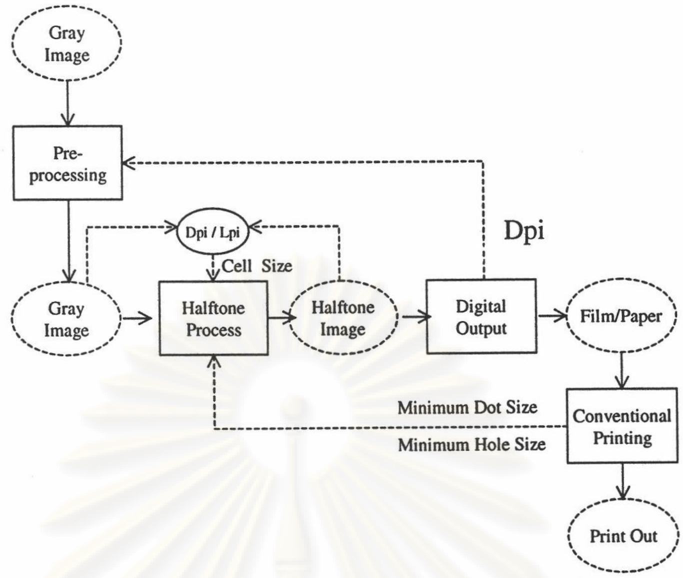

Figure 3-16 Workflow of the Compatibility of Conventional Printout

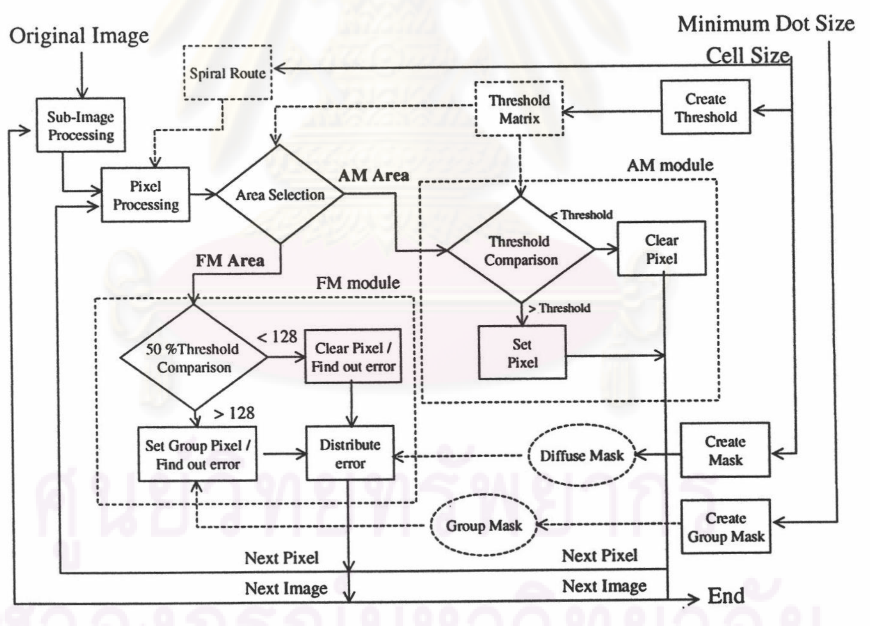

Figure 3-17 Flowchart of Compatibility of Conventional Printout

The workflow of this process is the same as the compatibility of digital printing step with the exception that the calculated pixels were set as a group through new algorithm, which is able to calculate the group size as screen dot. The location of adjacent element is set as a group by algorithm. After setting or clearing pixel data, the error diffusion would be processed.

3.7.3.2 A new effective gamut is reconsidered the number of shade, which FM algorithm can be created. The numbers of shade are related with total area in a cell over the area of a group dot and related parameters shown in Table 3-5, Table 3-6 and Table 3-7.

Table 3-5 Parameters of group dot FM Algorithm at 40 lpi.

Condition	Image No.	Test Form	dpi	lpi	Cell Size (pixel)	Group Size
Vary group size	1	Grayscale	1270	40	32	1
	2	Grayscale	1270	40	32	3
	3	Grayscale	1270	40	32	5
	4	Grayscale	1270	40	32	7
	5	Grayscale	1270	40	32	9
	6	Grayscale	1270	40	32	11
	7	Grayscale	1270	40	32	13
	8	Grayscale	1270	40	32	15
	9	Grayscale	1270	40	32	17

Table 3-6 Parameters of group dot FM Algorithm at 80 lpi.

Condition	Image No.	Test Form	dpi	lpi	Cell Size (pixel)	Group Size
Vary group size	1	Grayscale	1270	80	16	1
	2	Grayscale	1270	80	16	3
	3	Grayscale	1270	80	16	5
	4	Grayscale	1270	80	16	7
	5	Grayscale	1270	80	16	9
	6	Grayscale	1270	80	16	11
	7	Grayscale	1270	80	16	13
	8	Grayscale	1270	80	16	15
	9	Grayscale	1270	80	16	17

Table 3-7 Parameters of group dot FM Algorithm at 120 lpi.

Condition	Image No.	Test Form	dpi	lpi	Cell Size (pixel)	Group Size
Vary group size	1	Grayscale	1270	120	11	1
	2	Grayscale	1270	120	11	3
	3	Grayscale	1270	120	11	5
	4	Grayscale	1270	120	11	7
	5	Grayscale	1270	120	11	9
	6	Grayscale	1270	120	11	11
	7	Grayscale	1270	120	11	13
	8	Grayscale	1270	120	11	15
	9	Grayscale	1270	120	11	17

3.7.3.3 Printed Minimum dot size is measured by using the pilot test form as mentioned in topic 3.4.4.

3.7.3.4 Final images were produced using parameters in Table 3-8 respectively through Digital printing workflow described in topic 3.2 and 3.3.

Table 3-8 Parameters of group dot Hybrid Algorithm for printout.

Condition	Image No.	Test Form	dpi	lpi	Cell Size	Group Size	Cutoff (code value)	Span
AM algorithm	1	Tested Image	1270	80	16	15	-	-
FM algorithm	2	Tested Image	1270	80	16	15	-	-
Hybrid algorithm	3	Tested Image	1270	80	16	15	200	20
Hybrid algorithm	4	Tested Image	1270	80	16	15	180	20

3.7.3.5 The image quality were measured and analyzed.