ขั้นตอนวิธีในการสร้างเม็ดสกรีนเฟล็กโซกราฟี

นางสาว จุฬีภรณ์ กัลยาจิตร์โกศล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

สาขาวิชาเทคโนโลยีทางภาพ ภาควิชาวิทยาศาสตร์ทางภาพถ่ายและเทคโนโลยีทางการพิมพ์

คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2543

ISBN 974-13-0436-6

ALGORITHM FOR GENERATING FLEXOGRAPHIC SCREEN DOTS

Miss Juleeporn Kunlayajitkoson

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Imaging Technology
Department of Imaging and Printing Technology
Faculty of Science
Chulalongkorn University
Academic Year 2000
ISBN 974-13-0436-6

Thesis Title	ALGORITHM FOR GENERATING FLEXOGRAPHIC SCREEN DOTS
By	Miss Juleeporn Kunlayajitkoson
Department	Imaging and Printing Technology
Thesis Advisor	Associate Professor Pontawee Pungrassamee, M.S.
Thesis Co-advisor	Associate Professor Aran Hansuebsai, Ph.D.

Accepted by the Faculty of Science, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

.... Dean of Faculty of Science

(Associate Professor Wanchai Phothiphichitr, Ph.D.)

THESIS COMMITTEE

.... Chairman

(Professor Suda Kiatkamjornwong, Ph.D.)

.... Thesis Advisor

(Associate Professor Pontawee Pungrassamee, M.S.)

.... Thesis Co-advisor

(Associate Professor Aran Hansuebsai, Ph.D.)

.... Member

(Mr. Yujiro Ando, M.S.)

.... Member

(Professor Chidchanok Lursinsap, Ph.D.)

นางสาว จุฬีภรณ์ กัลยาจิตร์โกศล : ขั้นตอนวิธีในการสร้างเม็ดสกรีนเฟล็กโซกราฟี
(ALGORITHM FOR GENERATING FLEXOGRAPHIC SCREEN DOTS)
อ. ที่ปรึกษา : รศ.พรทวี พึ่งรัศมี, อ.ที่ปรึกษาร่วม : รศ.ดร.อรัญ หาญสืบสาย; 69 หน้า.
ISBN 974-13-0436-6.

วิทยานิพนธ์นี้ศึกษาอัลกอริธึมในการสร้างเม็ดสกรีนสำหรับการพิมพ์เฟล็กโซกราฟีและเปรียบเทียบคุณภาพการผลิตน้ำหนักสีที่ได้กับภาพพิมพ์ที่ใช้โปรแกรมสำเร็จรูป การสร้างเม็ดสกรีนใช้เทคนิคแบบ Cluster dot order dither การทำงานประกอบด้วย screen function, threshold array และ multicenter dot โดยพิจารณาการเรียงลำดับค่าขีดเริ่มเปลี่ยน (Threshold value) และขนาดของเมทริกซ์ของค่าขีดเริ่มเปลี่ยนที่ใช้ในการสร้างเม็ดสกรีนแบบกลม ในการทดลองกำหนดการเรียงลำดับพิกเซลของค่าขีดเริ่มเปลี่ยนแบบเวียนวนเพื่อเพิ่มขนาดเม็ดสกรีนจนกระทั่งเม็ดสกรีนเริ่มเชื่อมกันจึงใช้เทคนิคนี้กำหนดลักษณะพื้นที่ที่ไม่ใช่ภาพ เพื่อควบคุมพื้นที่เม็ดสกรีนในบริเวณเงาให้สามารถผลิตน้ำหนักสีได้เหมาะสม สกรีนลักษณะนี้มีข้อดีที่สามารถคงรูปแบบกลมเป็นช่วงยาว ช่วยให้สามารถผลิตน้ำหนักสีได้กว้างมากขึ้นเหมาะสำหรับการพิมพ์เฟล็กโซกราฟีและอัลกอริธึมนี้สามารถเปลี่ยนรูปร่างเม็ดสกรีนให้เหมาะกับลักษณะเฉพาะของแต่ละระบบการพิมพ์ได้ ปัจจัยอีกอย่างคือ ขนาดของเมทริกซ์ ผลการทดลองที่ความละเอียด 50 เส้นต่อนิ้ว พบว่าเม็ดสกรีนที่สร้างจากเมทริกซ์ขนาด 50x50 มีคุณภาพดีกว่าเม็ดสกรีนที่สร้างจากเมทริกซ์ 24x24 การผลิตน้ำหนักสีของสกรีนที่สร้างขึ้นสามารถผลิตน้ำหนักสีได้ดีเทียบเท่ากับของโปรแกรมสำเร็จรูป

ภาควิชา วิทยาศาสตร์ทางภาพถ่ายและเทคโนโลยีทางการพิมพ์ ลายมือชื่อนิสิต ....

สาขาวิชา เทคโนโลยีทางภาพ ลายมือชื่ออาจารย์ที่ปรึกษา ....

ปีการศึกษา 2543 ลายมือชื่ออาจารย์ที่ปรึกษาร่วม ....

4172260923: MAJOR IMAGING TECHNOLOGY

KEY WORD: HALFTONING / CLUSTERED-DOT-ORDERED DITHER / SCREEN / FLEXOGRAPHY

JULEEPORN KUNLAYAJITKOSON: ALGORITHM FOR GENERATING FLEXOGRAPHIC SCREEN DOTS.

THESIS ADVISOR: ASSOC. PROF. PONTAWEE PUNGRASSAMEE, M.S.

THESIS COADVISOR: ASSOC. PROF. ARAN HANSUEBSAI, Ph.D.,

69 pp. ISBN 974-13-0436-6.

The thesis attempts to define the appropriate algorithm needed to generate screen dot for flexographic printing. The printed image is compared with that obtained available commercial Flexo Software based on tone reproduction. To create the screen, the Cluster-dot-ordered dither technique is proposed. This includes screen function, threshold array and multicenter dot. The process has to determine the dot growth sequence of the threshold value and the size of the threshold matrix used to generate round halftone dots. The former is based on spiral dot structure in order to increase dot size until dot joint and to control non-image area of the image. It is found to give the better reproduction. The result shows the capability to retain round shape of dot screen through the tonal range, which resulted in wider tone range for the flexographic printing. The important of these algorithms are the flexibility to design or control shape of dot screen suitable for other printing systems. Another consideration is threshold matrix size used to generate dot screen. Based on 50 lpi, it is found that a 50x50-matrix size is better than a 24x24-matrix size, regarding the tone reproduction.

Department ....Imaging and printing technology....	Student's signature ....
Field of study ..Imaging Technology..................	Advisor's signature ....
Academic year 2000..................................	Co-advisor's signature..........................

ACKNOWLEDGMENT

First of all, I would like to express my sincere appreciation to my advisor, Associate Professor Pontawee Pungrassamee, and my co-advisor, Associate Professor Aran Hansuebsai, for their kind supervision, invaluable guidance and constant encouragement, for their review of the thesis content.

Thankful to Mr. Yujiro Ando, Head of Thai project of Canon Incorporation for his kind instruction, invaluable suggestions through the experiments.

I would like to thank the thesis committee for their comments and invaluable suggestions. And also Mr. Sumpun Wachirasakulchai, Comform for the printing test.

Thanks also especially go to my companions; Mr. Thamrongruj Huntrakura, Somporn Suksawad, Prasit Cunthasaksiri, Supachai Theravithayangkura, Kitirochna Rattanakasamsuk, Ms.Saranya Pouvilai(Yimlamai) who has charitably participated suggestions and given me moral supports.

Finally, I wish to express my deep gratitude to my family for their love, inspiration, understanding and endless encouragement throughout this entire study.

Juleeporn Kunlayajitkoson

CONTENTS

PAGE

CONTENTS(continued)

PAGE

CONTENTS(continued)

CONTENTS(continued)

PAGE

LIST OF TABLES

TABLE **PAGE**

LIST OF FIGURES

FIGURE **PAGE**

LIST OF FIGURES(continued)

CHAPTER I

INTRODUCTION

1.1 Scientific rational

Final print quality is determined by the dot shape effect when making a halftone image reproduction. The round dot shape is preferred over both square dot and ellipse dots because of the ability of the round dot to produce more subtle gradations than both square and ellipse dots in highlight areas[1]. When working with a high contrast image, the square dot is preferable.

Flexographic printing has a thick ink film layer. This is because the flexible plate has more dot gain than in offset printing. There are substantial differences in dot generation from highlights to shadows in color separation. The highlight is the same shape, but the midtones are always different. In actual practice there is a unique program used in color separation for Flexographic printing but it is very expensive. This program, Flexo Software, is propietary with the company that designed it, and licensed only at a high price, regardless it is used by several companies in Thailand. The ultimate purpose of this research is to create a lower price and more open system, still effective dot generation program for image processing. Most of all to establish fundamental knowledge in making digital halftone dots for other printing processes and to encourage Thai Printing industry to start research and development in this field. The program would organize the image data by setting a threshold to create dot shapes used in desktop publishing that an individual could use instead of such programs as Adobe Photoshop or commercial Flexo software.

1.2 Objectives

1.2.1 To define the appropriate algorithm needed to generate screen dot for flexographic printing

1.2.2 To compare tone reproduction of the designed dot and with the one available from commercial Flexo Software.

1.3 Scope of the Research

This research covers the study on the effect of algorithm to generate the digital screen dot for flexographic printing. Define the appropriate algorithm to be related with the matrix size of halftone threshold matrix, designing dot growth sequence, output resolution, screen frequency of print out and effected of flexographic operation.

1.4 Content of the Thesis

Chapter 2 deals with the overview of the theoretical considerations and literature reviews. Chapter 3 gives the description on materials under study, the experimental procedures and apparatuses. Chapter 4 contains the result and the discussion on the tone reproduction and visual evaluation. Finally the results are concluded in Chapter 5 along with some possible suggestions.

CHAPTER II

THEORETICAL AND LITERATURE REVIEW

The halftone image is a method of representing the images as a range of tones from white to black using only the black ink. The white tones could be represented by the white of the paper and the black by areas of solid ink, but the remaining tones would have no way of printing. The solution to the problem is to introduce the concept of 'screening' the image. That is to convert the various densities of the image into small dots of the same density (black ink) but which vary in area; the minimum density of the image (the white) is represented by very small dots which will increase in size as the density of the image increases. The obvious solution would be to print the white with no dots and the black with 100% dots.[2]

A major difference between the classical and digital halftones is that classical halftoning operates in Euclidean space; in theory, it can have any screen angle and any dot size and shape (in practice, the size is limited by the ability of the imaging device to place the dot). Digital halftoning does not have this freedom; it has to be confined in a digital grid that is defined by the device's resolution. The size and position of each pixel are fixed.[3]

2.1 Theoretical Background

2.1.1 Tone

The well-developed human visual system can detect tonal subtleties in a wide range of ambient light conditions from deep shadows to bright sunlight. This corresponds to a dynamic range or tonal range of about a million to one, or six orders of magnitude from the darkest black to the whitest white.[4]

2.1.2 Digital halftoning

In digital halftoning, the binary image is generated by comparing each pixel of a continuous-tone image to an array of image independent thresholds. The binary image is black when the gray level of the image pixel is greater than the corresponding threshold and white otherwise. The thresholds can be generated randomly (random dither), or they can be periodic (ordered dither).

2.1.2.1.1 Pixel

In a digital image system the smallest image element is the pixel, short for picture element. Imagesetter output consists of binary pixels-the image is actually a very dense bitmap. Each of these pixels has its own unique address on the grid[4].

2.1.2.1.2 Halftone cell

Implicit in a dither is a region of pixels-often called the halftone cell containing a specific, repeatable halftone pattern.

2.1.2.1.3 Dot shape

The halftone dotshape is the result of pixel arrangement within a halftone cell such as round, square and elliptical

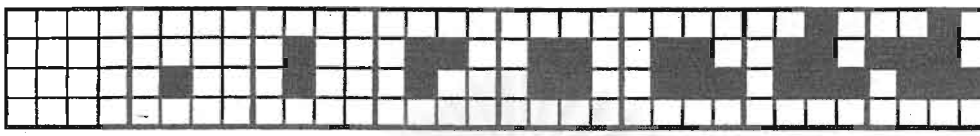
2.1.2.1.4 Gray level

The tonal resolution of an ordered dither pattern depends on the number of pixels in the cell; any given dither pattern can represent a number of values (gray level) equal to the number of pixels in the cell, plus one.

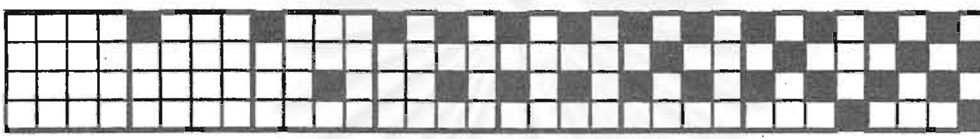
And one characteristic of digital halftoning is the discontinuity of density.[3] It is difficult to achieve a smooth tone range owing to the discrete nature and frequency tone level tradeoff. Because the pixel size and location are fixed, one can only obtain the area coverage (or tone level) in discrete steps with the following order:

0, 1/16, 1/8, 3/16, 1/4, 5/16, 3/8, 7/16, 1/2, 9/16, 5/8, 11/16, 3/4, 13/16, 7/8, 15/16, 1,

for the 4 x 4 cell given in Fig. 2-1, assuming each pixel is a perfect square. It is not possible to obtain tone density between two discrete tone levels such as 13/32, which is between tone levels 3/8 and 7/16. This means that one can achieve only discrete levels of density. The step size between tone levels can be reduced by increasing the number of tone levels. Theoretically, with respect to gray levels, the halftone becomes contone if the step size approaches zero. For a 4 x 4 cell, there are 17 tone levels. To have more tone levels, one needs to increase the halftone cell size. However, a large cell lowers the screen frequency and produces a coarse appearance.



(a) cluster dot



(b) Dispersed-dot

Figure 2-1 An example of digital halftoning.

2.1.2.2 Cluster- Disperse

Digital dots are generated by dividing the image plane into a repetitive, uniform grid of larger cells containing a fixed number of pixels.[3] The cells tile seamlessly and cover the whole image plane without gaps and overlapping. Various tone levels are simulated by varying the number of pixels that is on within the cell; in this way the tone density is modulated by modulating the area. Figure 2-1 gives two examples of a 4 x 4 halftone cell. This cell contains 16 pixels and gives 17 tone levels (the white background is counted as one tone level) by sequentially turning pixels to black. Two sequences (or patterns) of turning pixels on are shown in Fig. 2-1; one sequence groups pixels in a cluster and the other sequence disperses pixels in the highlight and midtone regions. They are called clustered-dot and dispersed-dot halftones, respectively.

2.1.2.3 Model-Based Halftoning

Halftoning algorithms generate binary patterns of pixels that are printed and perceived by the eye. As illustrated in Fig. 2-2, model-based halftoning techniques exploit models of the printer (or other display device) and visual perception to produce high quality images.[5]

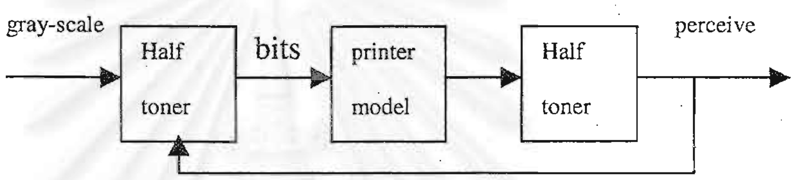


Figure 2-2 Model-Based Halftoning.

2.1.2.4 Eye models

Halftoning relies on the fact that the eye acts as a spatial low-pass filter. The eye models we consider here are based on estimates of the spatial frequency sensitivity of the eye, often called the modulation transfer function (MTF). A typical estimate of the MTF was obtained by Mannos and Sakrison.

$$H(f) = 2.6(0.0192 + 0.114f)exp\{-(0.1\ 14f)1.1\} \qquad (1)$$

where f is in cycles/degree. This function is plotted in Fig. 2-3 as a solid line.

A simple eye model consists of a two-dimensional finite impulse response (FIR) filter. This model can be obtained as a separable combination of one-dimensional approximations to the MTF of Eq. (1). The frequency and impulse responses of the one-dimensional filter used in are shown in Fig. 2-3 as a dotted line.

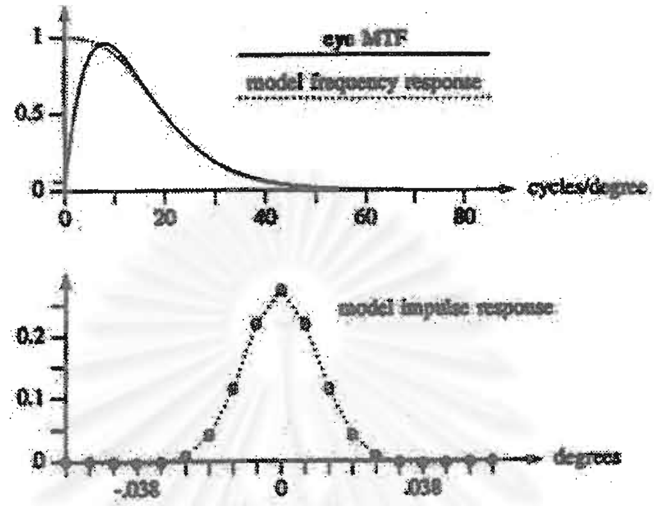


Figure 2-3 Eye MTF and FIR approximation.

2.1.2.5 Printer models

Laser printers are capable of producing black dots on a piece of paper, usually on a rectangular grid. Most halftoning techniques assume that the printed black dots are square. However, most printers produce roughly circular black dots, as shown in Fig 2-4. Thus, there is overlap between adjacent dots, and black dots cover adjacent space that should be white. This results in significant distortion in the printed images[5].

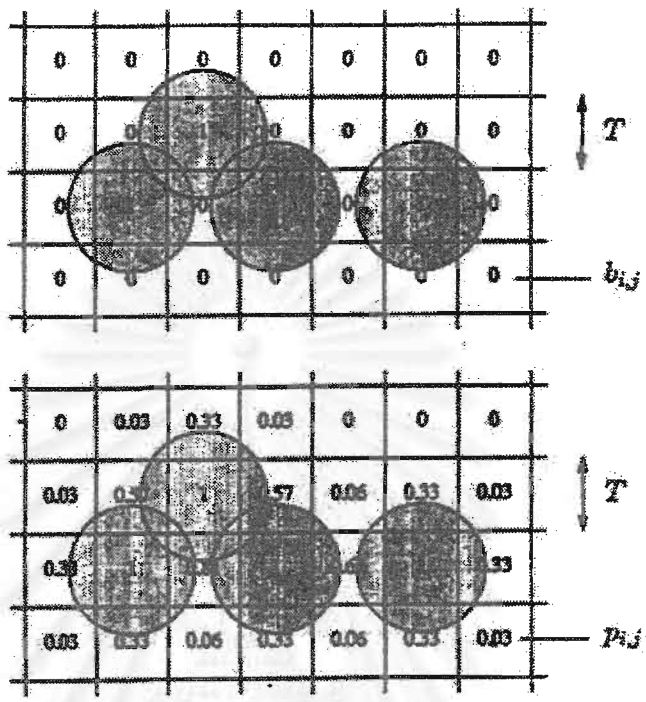


Figure 2-4 Circular dot-overlap model.

2.1.3 Designing clustered-dot-ordered-dither

2.1.3.1 Screen function

Mathematical functions are used for computing the threshold order. For example, the round dot screen function s (x, y) is[7]

$$s(x,y) = 1 - (x^2 + y^2). \quad (2)$$

2.1.3.2 Threshold array

Historically, the threshold array evolved from noise encoding[7]. A threshold array is a discrete representation of a spatially varying 2D-dither signal, adjusted by a fixed threshold. It provides the dot pattern in the form of threshold values for comparison with input pixels on a pixel-by-pixel basis. It gives the order of turning pixels on within a halftone cell that obeys the stacking constraint. Uses threshold values to control tone reproduction and screen pattern to control detail texture.

2.1.3.3 Rational-Irrational tangent screens

A digital halftone cell is constructed in a pixel grid[8]. Depending on the relative position of the cell with respect to the grid, angled screens are classified as rational and irrational tangents. A screen is called a "rational tangent" if the tangent angle is a ratio of integers. The four corners of a rational tangent cell fall exactly on the intersection points of the pixel grid (see Fig. 2-5). Rational tangent cells have exactly the same size and shape; they line up in the same way with respect to the digital grid. Only one screen function is needed for all halftone cells. This results in a relatively small threshold array that acts like a lookup table for a given image plane.

Irrational tangent screens are developed to overcome the screen angle limitation. An irrational screen has a noninteger tangent ratio. This means that one or more of the corners is not located at the intersection point. Without confining itself to the digital grid, it can have any angle and frequency. The consequence of this freedom is that irrational cells are different in size and shape

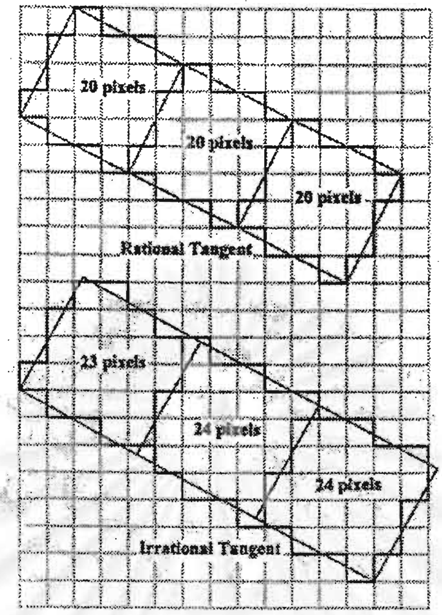


Figure 2-5 Examples of rational and irrational tangent screens

2.1.3.4 Supercell

As mentioned earlier, there are only a limited number of integer tangents.[8] Rational tangent screens cannot accurately produce angles of particular interest, such as 15' and 75% if the cell size is small. Large halftone cells, having large integers for the tangent ratio, allow small angular increments. It is therefore possible to achieve very accurate 15' and 75' angles. Accurate angles can be produced, but the dot will become very large and the frequency will become very low. The remedy for these problems is to divide the large cell into many smaller subcells to increase the screen frequency and reduce the tone level. This approach is called the supercell, and an example is given in Fig. 2-6. The supercell is a rational tangent screen composed of many smaller subcells that need not be uniform in size and shape

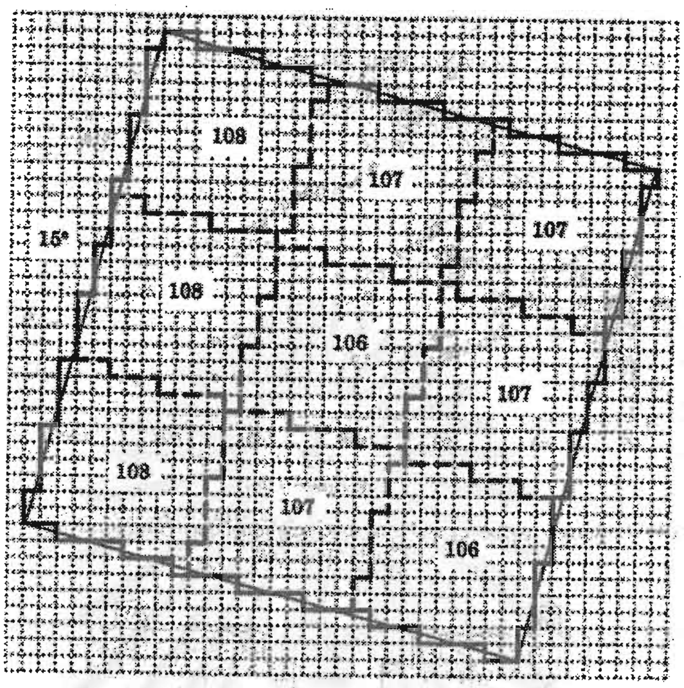


Figure 2-6 An example of supercell.

2.1.3.5 Multicenter dot

An idea similar to the supercell but applicable on a much smaller scale is known as the multicenter dot.[8] A cell is divided into equal parts, usually two (dual dot) or four (quad dot); each partial dot has a nucleus and grows into a separate cluster. The purpose is to increase the apparent screen frequency without reducing the tone level. An example is given in Fig. 2-7, where the 40-level dot is divided into 4 subcells with 10 pixels each. The dot pattern is grown alternately from one subcell to another. Within each subcell, the microdot is grown in a clustered spiral fashion. By slicing a large dot into four small components, the apparent screen frequency is increased by a factor of 2. Figure 2-8 shows the relationships of the tone level and screen frequency of simple dots, dual dots, and quad dots. For a given tone level, the frequency is increased by a factor of -4- for dual dots and 2 for quad dots. The virtues of the multicenter dot are less low-frequency content and almost equal stability compared with a single clustered dot. The drawbacks are the slight texture contouring and tone jump in highlighted regions that result from the alternate growth from nucleus to nucleus.

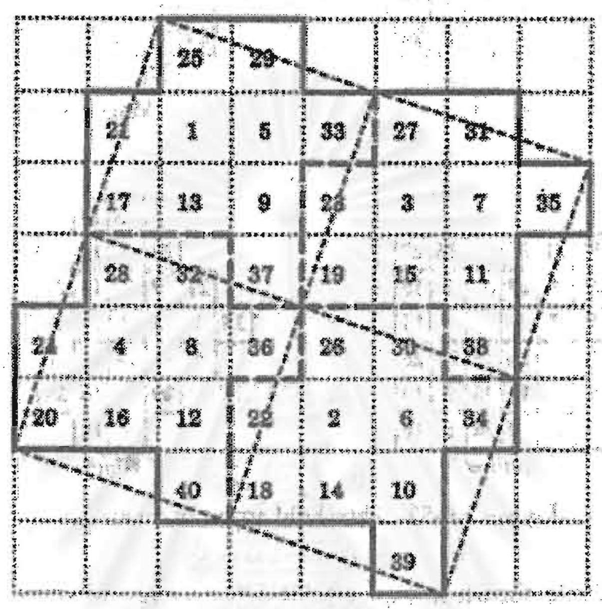


Figure 2-7 An example of a multicenter dot.

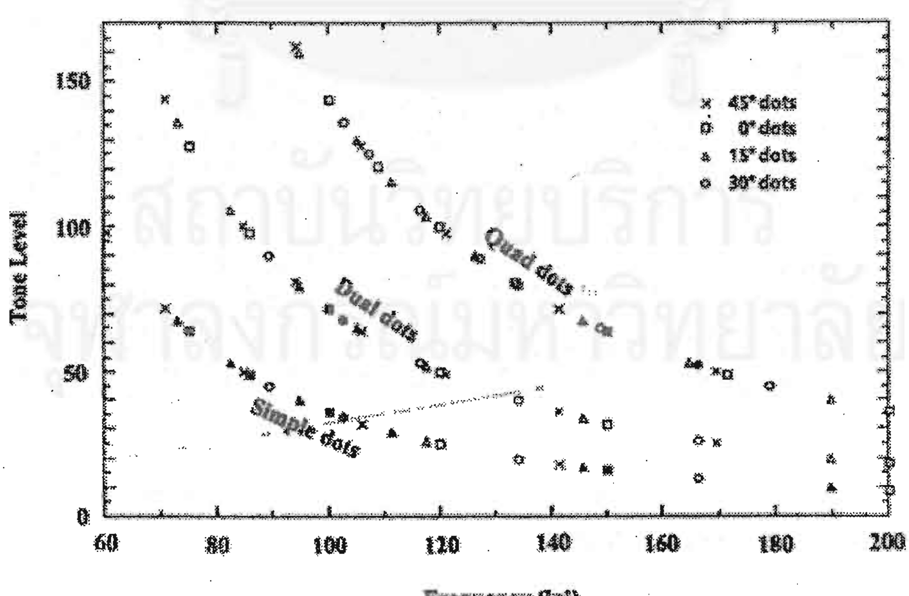


Figure 2-8 Screen frequency and tone level relationships of multicenter dots.

2.1.4 Designing dot growth sequence

2.1.4.1 Classical spiral

2	12	16	8	4
5	18	24	20	11
14	22	25	23	15
9	19	21	17	7
3	6	13	10	1

2.1.4.2 Clockwise spiral

3	10	16	11	4
9	20	21	17	12
15	24	25	22	13
8	19	23	18	5
2	7	14	6	1

2.1.4.3 Counterclockwise spiral

1	5	13	12	4
6	18	22	17	11
14	23	25	21	16
7	19	24	20	10
2	8	15	9	3

2.1.5 Threshold operation

The threshold array is compared with the input image. The array is replicated to tile through the entire image plane so that the rightmost column is immediately followed by the leftmost column of the same screen in the next tile, so it wraps around and appears as continuous in the spatial domain. Input pixel values are compared with the corresponding threshold elements to determine the output pixel values in binary. Many threshold algorithms can be used to determine output pixel value.[7]

2.1.5.1 Average intensity

The darkest element growth to the percentage of the average intensity.

242	233	166	35	43
231	143	37	42	56
169	41	45	44	162
44	49	35	156	232
48	39	165	248	237

input

Average = 118

118 / 255 = 46% white

46% x 25 dots = 12 white

25 - 12 = 13 black

Turn darkest 13 to black

1	1	1	0	0
1	1	0	0	0
1	0	0	0	1
0	0	0	1	1
0	0	1	1	1

output

2.1.5.2 Average value

Threshold by comparing with the average value, then turn black pixels on with a threshold level greater than the average value.

242	233	166	35	43
231	143	37	42	56
169	41	45	44	162
44	49	35	156	232
48	39	165	248	237

input

Avg. 118

5	118	160	58	17
48	201	232	170	99
129	211	252	242	150
89	191	221	181	68
38	78	140	108	27

Threshold matrix

1	1	0	1	1
1	0	0	0	1
0	0	0	0	0
1	0	0	0	1
1	1	0	1	1

output

2.1.5.3 Direct comparison

242	233	166	35	43
231	143	37	42	56
169	41	45	44	162
44	49	35	156	232
48	39	165	248	237

input

5	118	160	58	17
48	201	232	170	99
129	211	252	242	150
89	191	221	181	68
38	78	140	108	27

Threshold matrix

1	1	1	0	1
1	0	0	0	0
1	0	0	0	1
0	0	0	0	1
1	0	1	1	1

output

2.2 Literature Review

Hains [3] provided several practical rules for clustered-dot design: minimize the edge-to-area ratio, keep the dot-center, dot joint, cell boundary, dot growth and the effect of dot gain should be taken into consideration through TRC adjustment or physical dot overlap models.

Suzuki et al.[9] provided a halftone image processing method which allows several kinds of tone representation with smooth gradation and different density characteristics to be selectively used. This method uses several matrix pattern groups having different density characteristics. Each of the matrix pattern groups comprises a certain number of matrix patterns which is larger in number than dots contained in a single matrix pattern. Particular one of the matrix pattern groups is specified in conformity to a required density characteristic, while particular one of the matrix pattern in the selected group is specified in response to tone data.

Lin [10] present an algorithm that incorporates a printer dot model to improve the uniformity and tonal response of halftone patterns generated by the void-and-cluster algorithm. Result of using the dot model in producing a dither matrix with linear reflectance.

CHAPTER III

EXPERIMENTAL

3.1 Materials

3.1.1 Imagesetter Photosensitive bromide paper: Anitec 780LD

3.1.2 Imagesetter Color sensitivity infrared film: Fuji No.4LDW

3.1.3 Imagesetter Developer: Fuji HR Developer HR-D1

3.1.4 Imagesetter Fixer : Fuji Grandex Fixer GR-F1

3.1.5 Flexographic photopolymer plate : BASF FA II thickness 1.7 mm.

3.1.6 Washing solvent for Flexographic plate : Nylosolve

3.1.7 Flexographic ink : water-based ink pantone No.293u of Rocket (6-A3409/p293u)

3.1.8 Substrates for flexographic press : Thermal paper

3.2 Apparatus

3.2.1. Personal computer : Pentium II ,Ram 512MB

3.2.2. Printer : Apple Laser WriterPro

3.2.3. Imagesetter : Linotronic 260, Linotype-Hell

3.2.4. Flexographic platemaking machine : Combi L FII, BASF

3.2.5. Flexographic printing machine : MarkAndy

3.2.6. Densitometer : RD 915, Macbeth Corporation

3.3 Procedure

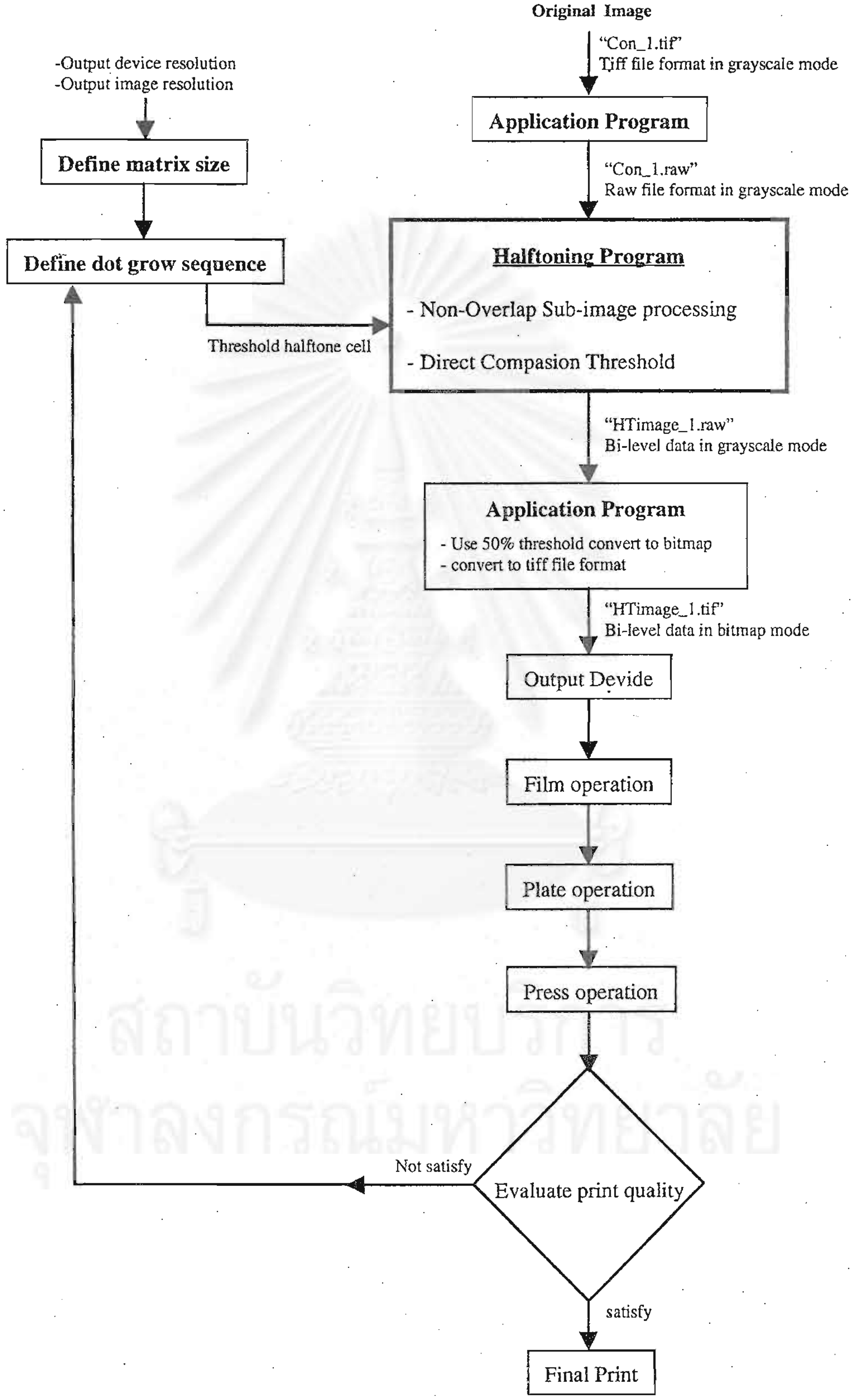


Figure 3-1 experimental workflow

3.3.1 Designing matrix size

The first halftone design principle is to determine the matrix size. Digital representation has a finite resolution in the spatial domain (the pixel size and shape) and a limited precision in the intensity domain (tone level). Image quality of a digital multilevel representation is affected by the sampling rate (image resolution) and quantization. If the intensity domain is quantized to 8 bits (256 levels) or higher, it is considered a continuous signal because the eye cannot resolve this small tone step. If the quantization level is low (<16), a combination of multilevel rendering and halftoning may be required to provide good image quality. The second level is the difference between the digital multilevel representation and the halftone. This step contributes most of the image degradation.

3.3.2 Designing dot growth sequence

Designing dot growth sequence is the process using equal-intensity pixels computed from a screen function $s(x,y) = 1-(x^2+y^2)$ add some flexibility to the pixel ordering that provide an opportunity for fine tuning halftone dots.

HT_Type1

The screen was built with 24x24 matrix. A Threshold matrix was divided into two parts. Each partial dot has a nucleus and grows into a separate cluster. The HT_Type1 array grows clockwise from pixel 1 to pixel 448 then changed the arrangement in order to square for the remaining pixels. The screen design is measured clockwise from horizontal axis to agree with the Cartesian coordinate system.

1	19	31	71	111	181	261	333	411	433	445	553	570	483	427	397	303	243	191	129	75	41	15	7
9	29	53	97	139	197	289	331	409	453	551	480	446	574	493	399	305	283	207	149	93	59	25	17
43	61	87	109	157	231	329	379	461	497	490	438	436	454	572	503	365	307	225	171	131	85	51	27
77	95	107	155	215	259	377	469	549	500	422	420	418	416	462	570	525	367	245	209	173	133	103	69
105	137	153	213	257	327	477	545	518	388	352	350	348	346	386	470	568	527	309	247	211	175	151	135
179	195	229	255	325	511	543	520	390	354	294	272	270	292	344	384	478	566	529	311	249	227	193	177
253	287	323	375	509	541	522	356	274	236	202	186	184	200	234	268	342	516	564	475	369	313	285	251
319	321	373	507	539	472	358	276	220	164	144	120	118	142	162	218	266	340	514	562	467	371	315	317
405	407	505	537	464	360	278	222	166	122	90	72	64	98	116	160	216	264	382	512	560	459	401	403
431	495	535	456	362	296	238	168	124	82	56	46	34	54	80	114	158	232	338	380	498	558	451	429
485	533	448	392	298	280	204	146	100	48	36	12	20	32	62	88	140	198	290	336	414	488	556	443
531	440	424	394	300	240	188	126	66	38	22	4	2	10	44	78	112	182	262	334	412	434	486	554
571	482	426	396	302	242	190	128	74	40	14	6	0	18	30	70	110	180	260	332	410	432	444	552
447	575	492	398	304	282	206	148	92	58	24	16	8	28	52	96	138	196	288	330	408	452	550	481
437	455	573	502	364	306	224	170	130	84	50	26	42	60	86	108	156	230	328	378	460	496	491	439
419	417	463	571	524	366	244	208	172	132	102	68	76	94	106	154	214	258	376	468	548	501	423	421
349	347	387	471	569	526	308	246	210	174	150	134	104	136	152	212	256	326	476	544	519	389	353	351
271	293	345	385	479	567	528	310	248	226	192	176	178	194	228	254	324	510	542	521	391	355	295	273
185	201	235	269	343	517	565	474	368	312	284	250	252	286	322	374	508	540	523	357	275	237	203	187
119	143	163	219	267	341	515	563	466	370	314	316	318	320	372	506	538	473	359	277	221	165	145	121
65	99	117	161	217	265	383	513	561	458	400	402	404	406	504	536	465	361	279	223	167	123	91	73
35	55	81	115	159	233	339	381	499	559	450	428	430	494	534	457	363	297	239	169	125	83	57	47
21	33	63	89	141	199	291	337	415	489	557	442	484	532	449	393	299	281	205	147	101	49	37	13
3	11	45	79	113	183	263	335	413	435	487	555	530	441	425	395	301	241	189	127	67	39	23	5

Figure 3-2 Threshold value in HT_Type1 threshold matrix.

3.3.3 Algorithm operation

3.3.3.1 Input digital file "Con_1.raw" as the original image.

3.3.3.2 Put the threshold matrix in halftoning program (Appendix A)

3.3.3.3 Halftoning programs operate by non-overlapping sub-image processing and direct comparison Threshold operation.

3.3.3.4 In application program, change mode from Grayscale to bitmap by 50% threshold method using Adobe Photoshop program. Then, change the file format from RAW to TIFF and save the file as HTimage_1.tif.

3.3.3.5 Compose HTimage_1.tif with original grayscale image using Adobe Pagemaker program.

3.3.4 Film operation

Calibrate and output film from imagesetter. Set round dot screen command while operate for commercial *flexo screen*. Output film is 50 lpi screen frequency and 45 degree screen angle. Negative film densities are more than 3.5. In experiment used commercial *flexo screen* film that made from T.Thai General Incorporation.

3.3.5 Flexographic plate making

3.3.5.1 The plate making process.

- Back-exposure: Expose the photopolymer base to UV light to make floors and establishes relief depth [6].
- Main exposure: Expose the photopolymer surface to UV light through the negative to make the relief-printing image.
- Wash out: the photopolymer platen is washed by solvent. Then, the unexposed part is removed.
- Drying: The washed photopolymer plate is dried in the oven of 65°C. The process either to remove absorbed solvent and restores gauge thickness, or removes surface water and render plate pressready.
- Post-exposures to finally cure all remaining photopolymer.
- In order to reduce the tackiness of the plate surface, the plate is exposed to the high energy UVC light (with the wavelength of 254 nm.)

The testform is used for quality control of plate making process.

3.3.6 Press operation

The test image was printed on MarkAndy flexographic printing machine with the specific printing speed, impression, ink, anilox roll resolution and substrate.

3.3.7 Evaluation of print quality

%Dot area was measured film and printout by transmission and reflection densitometer, which was calibrated to be zero on the same type of paper surface. Dot gain was calculated from difference between %dot area of input and output data. Solid ink density was measured printout by a reflection densitometer. And Tone reproduction was analysed visually by experienced printing operators.

3.3.8 Various Designing dot growth sequence (II)

Image reproduction were the similar technique as in section 3.3.1 – 3.3.7 but change design dot growth sequence of threshold matrix as:

HT_Type2

Screen was built with 24x24 matrix. A Threshold matrix was one halftone cell. The type 1 array grows in a clockwise spiral pattern.

575	570	562	554	542	526	506	482	466	414	406	398	399	407	415	467	483	507	527	543	555	563	571	572
569	547	534	518	498	474	458	422	370	346	338	330	331	339	347	371	423	459	475	499	519	535	544	564
561	533	511	490	450	438	390	362	322	306	278	270	271	279	307	323	363	391	439	451	491	508	528	556
553	517	489	443	430	382	354	298	262	238	222	214	215	223	239	263	299	355	383	431	440	484	512	548
541	497	449	429	375	314	290	254	230	194	170	162	163	171	195	231	255	291	315	372	424	444	492	536
525	473	437	381	313	283	246	206	178	154	126	110	111	127	155	179	207	247	280	308	376	432	468	520
505	457	389	353	289	245	199	186	146	118	102	82	83	103	119	147	187	196	240	284	348	384	452	500
481	421	361	297	253	205	185	139	134	94	74	58	59	75	95	135	136	180	200	248	292	356	416	476
465	369	321	261	229	177	145	133	87	66	42	36	37	46	67	84	128	140	172	224	256	316	364	460
413	345	305	237	193	153	117	93	65	50	28	20	21	29	51	60	88	112	148	188	232	300	340	408
405	337	277	221	169	125	101	73	45	27	13	6	7	14	30	47	68	96	120	164	216	272	332	400
397	329	269	213	161	109	81	57	35	19	5	0	1	8	22	38	52	76	104	156	208	264	324	392
396	328	268	212	160	108	80	56	34	18	4	3	2	9	23	39	53	77	105	157	209	265	325	393
404	336	276	220	168	124	100	72	41	26	12	11	10	15	31	43	69	97	121	165	217	273	333	401
412	344	304	236	192	152	116	92	64	49	25	17	16	24	48	61	89.	113	149	189	233	301	341	409
464	368	320	260	228	176	144	132	86	63	44	33	32	40	62	85	129	141	173	225	257	317	365	461
480	420	360	296	252	204	184	138	131	91	71	55	54	70	90	130	137	181	201	249	293	357	417	477
504	456	388	352	288	244	198	183	143	115	99	79	78	98	114	142	182	197	241	285	349	385	453	501
524	472	436	380	312	282	243	203	175	151	123	107	106	122	150	174	202	242	281	309	377	433	469	521
540	496	448	428	374	311	287	251	227	191	167	159	158	166	190	226	250	286	310	373	425	445	493	537
552	516	488	442	427	379	351	295	259	235	219	211	210	218	234	258	294	350	378	426	441	485	513	549
560	532	510	487	447	435	387	359	319	303	275	267	266	274	302	318	358	386	434	446	486	509	529	557
568	546	531	515	495	471	455	419	367	343	335	327	326	334	342	366	418	454	470	494	514	530	545	565
574	567	559	551	539	523	503	479	463	411	403	395	394	402	410	462	478	502	522	538	550	558	566	573

Figure 3-3 Threshold value in HT_Type2 threshold matrix.

HT_Type3

Screen was built with 24x24 matrix. A Threshold matrix was divided into quad parts. Each partial dot has a nucleus and grows into a separate cluster. The HT_Type3 array grows in a clockwise spiral pattern.

568	540	492	460	396	348	344	392	456	488	536	564	570	542	494	462	398	350	346	394	458	490	538	566
544	520	428	316	284	220	216	280	312	424	516	532	546	522	430	318	286	222	218	282	314	426	518	534
496	432	376	252	188	132	128	184	248	372	420	484	498	434	378	254	190	134	130	186	250	374	422	486
464	320	256	164	100	68	64	96	160	244	308	452	466	322	258	166	102	70	66	98	162	246	310	454
400	288	192	104	48	44	40	60	124	180	276	388	402	290	194	106	50	46	42	62	126	182	278	390
352	224	136	72	16	12	8	36	92	156	212	340	354	226	138	74	18	14	10	38	94	158	214	342
356	228	140	76	20	0	4	32	88	152	208	336	358	230	142	78	22	2	6	34	90	154	210	338
404	292	196	108	52	24	28	56	120	176	272	384	406	294	198	110	54	26	30	58	122	178	274	386
468	324	260	168	112	80	84	116	172	240	304	448	470	326	262	170	114	82	86	118	174	242	306	450
500	436	380	264	200	144	148	204	268	368	416	480	502	438	382	266	202	146	150	206	270	370	418	482
548	524	440	328	296	232	236	300	332	444	512	528	550	526	442	330	298	234	238	302	334	446	514	530
572	552	504	472	408	360	364	412	476	508	556	560	574	554	506	474	410	362	366	414	478	510	558	562
571	543	495	463	399	351	347	395	459	491	539	567	569	541	493	461	397	349	345	393	457	489	537	565
547	523	431	319	287	223	219	283	315	427	519	535	545	521	429	317	285	221	217	281	313	425	517	533
499	435	379	255	191	135	131	187	251	375	423	487	497	433	377	253	189	133	129	185	249	373	421	485
467	323	259	167	103	71	67	99	163	247	311	455	465	321	257	165	101	69	65	97	161	245	309	453
403	291	195	107	51	47	43	63	127	183	279	391	401	289	193	105	49	45	41	61	125	181	277	389
355	227	139	75	19	15	11	39	95	159	215	343	353	225	137	73	17	13	9	37	93	157	213	341
359	231	143	79	23	3	7	35	91	155	211	339	357	229	141	77	21	1	5	33	89	153	209	337
407	295	199	111	55	27	31	59	123	179	275	387	405	293	197	109	53	25	29	57	121	177	273	385
471	327	263	171	115	83	87	119	175	243	307	451	469	325	261	169	113	81	85	117	173	241	305	449
503	439	383	267	203	147	151	207	271	371	419	483	501	437	381	265	201	145	149	205	269	369	417	481
551	527	443	331	299	235	239	303	335	447	515	531	549	525	441	329	297	233	237	301	333	445	513	529
575	555	507	475	411	363	367	415	479	511	559	563	573	553	505	473	409	361	365	413	477	509	557	561

Figure 3-4 Threshold value in HT_Type3 threshold matrix.

3.3.9 Varying matrix size and dot growth sequence(III)

Reproduction halftone images were the similar technique as in section 3.3.1 – 3.3.7. And in 3.3.4 section add compare with halftone image from photoshop screening operation. Photoshop screen uses select round dot in pagesetup function. Change matrix size and design dot growth sequence of threshold matrix as:

HT_Type4

Screen was built with 50x50 matrix. A Threshold matrix was one halftone cell. The HT_Type4 array grows in a clockwise spiral pattern. Figure 3-5 shows ¼ part of threshold (Q1) in HT_Type4 threshold matrix. In operated program, used repeat value method as in figure 3-7.

243	245	246	249	254	257	260	264	269	274	278	282	286	292	296	300	304	308	312	315	318	320	322	323	324
226	227	228	231	233	238	241	247	255	259	267	271	277	284	289	293	298	303	307	311	314	317	319	321	323
205	206	210	213	215	219	222	230	236	242	251	258	266	273	279	285	291	297	302	306	310	313	316	319	322
189	190	191	194	198	202	204	212	217	225	232	240	252	261	268	276	283	290	295	301	305	309	313	317	320
171	174	175	178	181	183	188	195	201	207	216	224	234	244	256	265	275	281	288	294	299	305	310	314	318
155	157	159	161	165	167	173	179	185	192	200	209	218	229	239	253	263	272	280	287	294	301	306	311	315
140	142	144	146	149	153	158	164	168	177	184	193	203	214	223	237	250	262	270	280	288	295	302	307	312
125	126	129	132	134	137	143	148	154	163	169	180	187	199	211	221	235	248	262	272	281	290	297	303	308
113	114	115	118	121	124	131	135	141	147	156	166	176	186	197	208	220	235	250	263	275	283	291	298	304
99	101	103	105	107	111	117	122	128	136	145	152	162	172	182	196	208	221	237	253	265	276	285	293	300
86	89	90	93	96	98	104	110	116	123	133	139	151	160	170	182	197	211	223	239	256	268	279	289	296
76	77	80	81	84	88	94	97	106	112	120	130	138	150	160	172	186	199	214	229	244	261	273	284	292
65	66	69	71	73	78	82	87	95	102	109	119	127	138	151	162	176	187	203	218	234	252	266	277	286
56	57	58	61	64	68	72	79	85	92	100	108	119	130	139	152	166	180	193	209	224	240	258	271	282
46	48	50	52	54	59	63	70	75	83	91	100	109	120	133	145	156	169	184	200	216	232	251	267	278
38	40	41	44	45	51	55	62	67	74	83	92	102	112	123	136	147	163	177	192	207	225	242	259	274
31	32	34	36	39	43	49	53	60	67	75	85	95	106	116	128	141	154	168	185	201	217	236	255	269
24	25	28	29	33	37	42	47	53	62	70	79	87	97	110	122	135	148	164	179	195	212	230	247	264
19	20	21	23	27	30	35	42	49	55	63	72	82	94	104	117	131	143	158	173	188	204	222	241	260
13	15	16	18	22	26	30	37	43	51	59	68	78	88	98	111	124	137	153	167	183	202	219	238	257
9	10	12	14	17	22	27	33	39	45	54	64	73	84	96	107	121	134	149	165	181	198	215	233	254
6	7	8	11	14	18	23	29	36	44	52	61	71	81	93	105	118	132	146	161	178	194	213	231	249
3	4	5	8	12	16	21	28	34	41	50	58	69	80	90	103	115	129	144	159	175	191	210	228	246
1	2	4	7	10	15	20	25	32	40	48	57	66	77	89	101	114	126	142	157	174	190	206	227	245
0	1	3	6	9	13	19	24	31	38	46	56	65	76	86	99	113	125	140	155	171	189	205	226	243

Figure 3-5 Part of threshold (Q1) in HT_Type4 threshold matrix.

HT_Type5

Screen was built with 50x50 matrix. A Threshold matrix was one halftone cell. The HT_Type5 array grows clockwise from pixel 1 to pixel 257, then changes the arrangement in order to inverse circle for the remaining pixels. Figure 3-6 shows ¼ part of threshold (Q1) in HT_Type5 threshold matrix. In operated program, used repeat value method as in figure 3-7.

243	245	246	249	254	257	258	259	261	263	265	268	270	274	279	286	294	300	306	311	315	319	321	323	324
226	227	228	231	233	238	241	247	255	260	264	266	269	273	277	285	292	299	304	310	314	317	320	322	323
205	206	210	213	215	219	222	230	236	242	251	262	267	272	276	283	290	297	303	308	312	316	318	320	321
189	190	191	194	198	202	204	212	217	225	232	240	252	271	275	281	289	295	301	305	309	313	316	317	319
171	174	175	178	181	183	188	195	201	207	216	224	234	244	256	278	284	291	296	302	307	309	312	314	315
155	157	159	161	165	167	173	179	185	192	200	209	218	229	239	253	280	287	293	298	302	305	308	310	311
140	142	144	146	149	153	158	164	168	177	184	193	203	214	223	237	250	282	288	293	296	301	303	304	306
125	126	129	132	134	137	143	148	154	163	169	180	187	199	211	221	235	248	282	287	291	295	297	299	300
113	114	115	118	121	124	131	135	141	147	156	166	176	186	197	208	220	235	250	280	284	289	290	292	294
99	101	103	105	107	111	117	122	128	136	145	152	162	172	182	196	208	221	237	253	278	281	283	285	286
86	89	90	93	96	98	104	110	116	123	133	139	151	160	170	182	197	211	223	239	256	275	276	277	279
76	77	80	81	84	88	94	97	106	112	120	130	138	150	160	172	186	199	214	229	244	271	272	273	274
65	66	69	71	73	78	82	87	95	102	109	119	127	138	151	162	176	187	203	218	234	252	267	269	270
56	57	58	61	64	68	72	79	85	92	100	108	119	130	139	152	166	180	193	209	224	240	262	266	268
46	48	50	52	54	59	63	70	75	83	91	100	109	120	133	145	156	169	184	200	216	232	251	264	265
38	40	41	44	45	51	55	62	67	74	83	92	102	112	123	136	147	163	177	192	207	225	242	260	263
31	32	34	36	39	43	49	53	60	67	75	85	95	106	116	128	141	154	168	185	201	217	236	255	261
24	25	28	29	33	37	42	47	53	62	70	79	87	97	110	122	135	148	164	179	195	212	230	247	259
19	20	21	23	27	30	35	42	49	55	63	72	82	94	104	117	131	143	158	173	188	204	222	241	258
13	15	16	18	22	26	30	37	43	51	59	68	78	88	98	111	124	137	153	167	183	202	219	238	257
9	10	12	14	17	22	27	33	39	45	54	64	73	84	96	107	121	134	149	165	181	198	215	233	254
6	7	8	11	14	18	23	29	36	44	52	61	71	81	93	105	118	132	146	161	178	194	213	231	249
3	4	5	8	12	16	21	28	34	41	50	58	69	80	90	103	115	129	144	159	175	191	210	228	246
1	2	4	7	10	15	20	25	32	40	48	57	66	77	89	101	114	126	142	157	174	190	206	227	245
0	1	3	6	9	13	19	24	31	38	46	56	65	76	86	99	113	125	140	155	171	189	205	226	243

Figure 3-6 Part of threshold (Q1) in HT_Type5 threshold matrix.

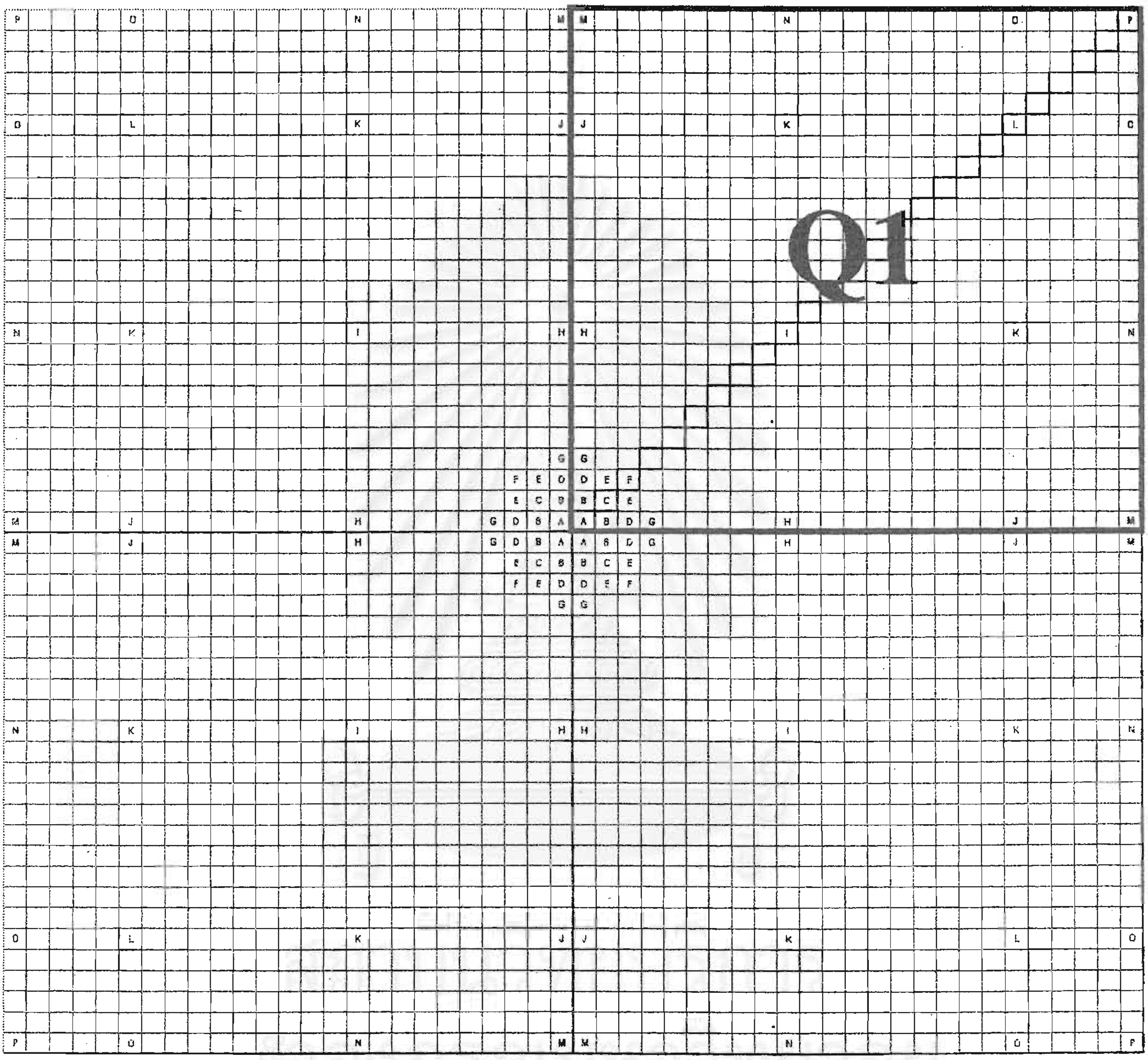


Figure 3-7 Step of threshold matrix.

CHAPTER IV

RESULTS AND DISCUSSION

The evaluation process was measure the solid ink density and percent dot area of the flexographic printout, which is respected to each algorithm. All of the print to have control solid density at 1.37±0.05

4.1 Effect of HT_Type1 compare with *Flexo screen*

4.1.1 Dot growth sequence of HT_Type1 algorithm

The printout, which is obtained from this algorithm, , is shown in figure 4-1. It can hold tone range of the image from 2-89%dot area as shown in Table 4-2, which mean that the printout has no detail in shadow range 90-100%dot area.

The printout of flexographic commercial halftone dot algorithm, is shown in figure 4-1.It can hold tone range of the image from 2-97%dot area as shown in Table 4-2, which means that the printout can hold almost whole detail of the image.

As shown in the result, the HT_Type1 is the algorithm that its threshold value grows as clockwise spiral from the nucleus at the pixel 1^{th} to the pixel 400^{th}, after that it is changed to be square pattern. This algorithm aims to keep a gap among each halftone cell belong in the shadow area.

However, the Figure 4-4 shows that it is become fill-in all the above 90%dot area.

Flexo screen　　　　HT_Type 1

Figure 4-1 Print out image made from HT_Type1 threshold matrix and commercial flexo screen.

4.1.2 Data of film operation

Table 4-1 %Dot area on film of HT_Type 1 threshold matrix and commercial flexo screen.

Digital	Ideal	HT_Type1	Flexo(I)
10	90	92	90
20	80	84	79
30	70	74	68
40	60	66	58
50	50	56	48
60	40	47	39
70	30	37	28
80	20	25	19
90	10	13	10
100	0	0	0

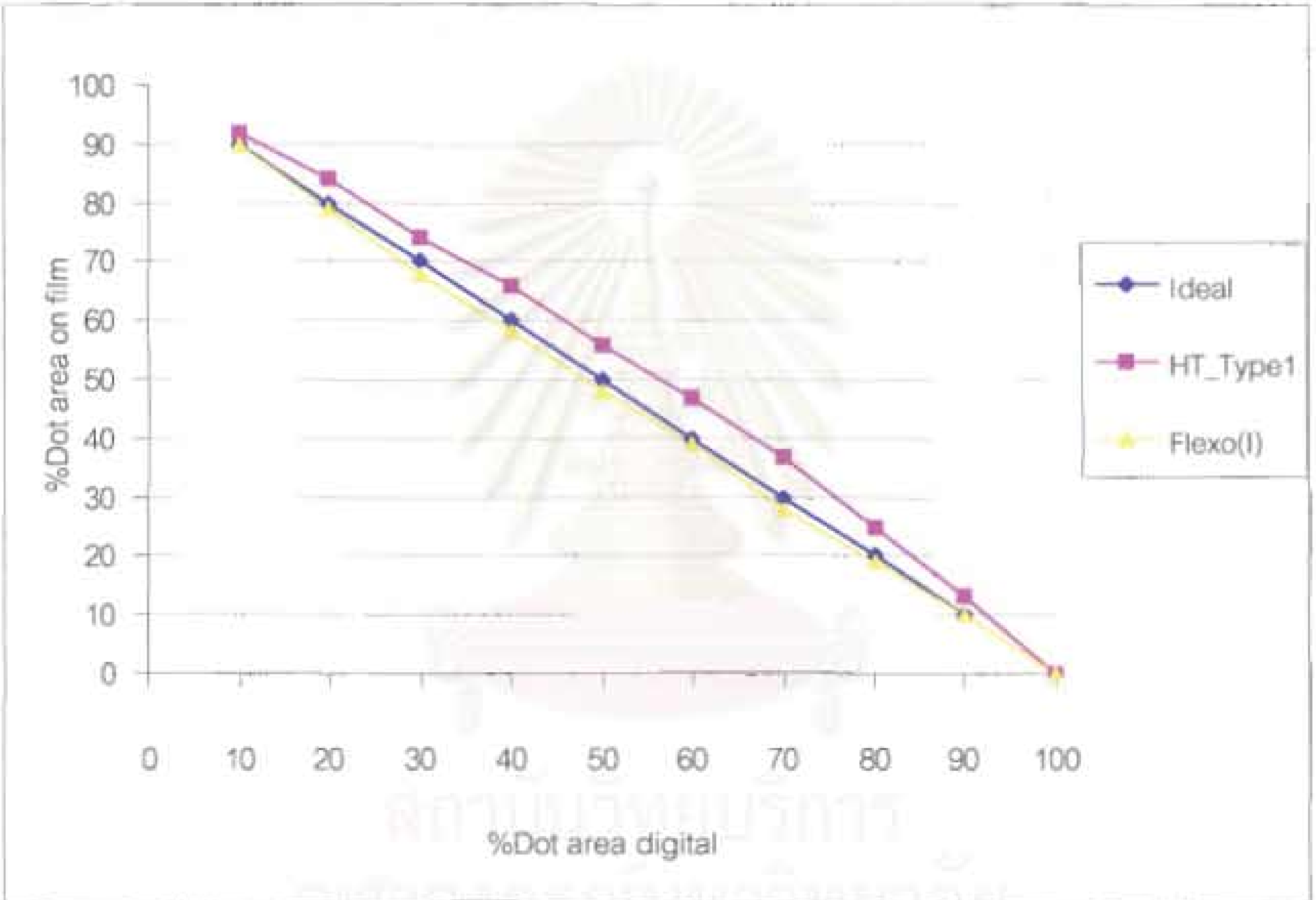


Figure 4-3 Tone reproduction curve of HT_Type 1 threshold matrix and commercial flexo screen on film.

4.1.3 Data of Print operation

Table 4-2 %dot area on print of HT_Type 1 threshold matrix and commercial flexo screen.

Digital	Ideal	HT_Type1	flexo(I)
10	10	8	11
20	20	18	20
30	30	28	29
40	40	36	40
50	50	46	51
60	60	55	62
70	70	67	74
80	80	83	83
90	90	98	92
100	100	99	100

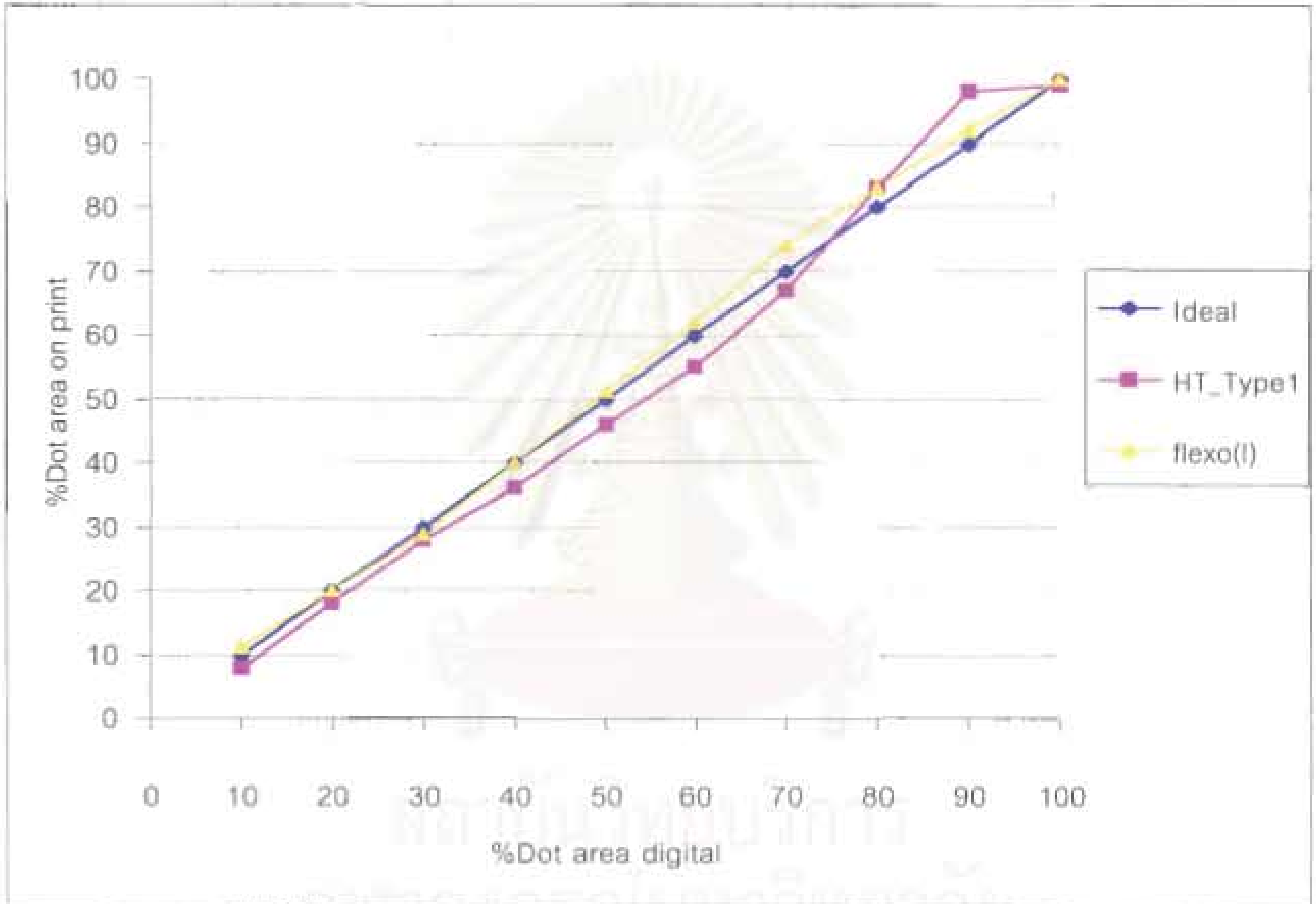


Figure 4-4 Tone reproduction curve of HT_Type 1 threshold matrix and commercial flexo screen on pint.

4.2 Effect of HT_Type2 and HT_Type 3 compare with *Flexo screen*

The HT_Type2 and 3 aims to reduce dot gain effect in the shadow area. These algorithms change the route of *dot growth sequence* to be spiral after the pixel 400^{th}.

4.2.1 Dot growth sequence with HT_Type2 algorithm

The printout, which is obtained from this algorithm, is shown in figure 4-5. It can hold tone range of the image 2-96%dot area, which mean that the printout holds detail of the image in shadow area till 96%dot area.

4.2.2 Dot growth sequence with HT_Type3 algorithm

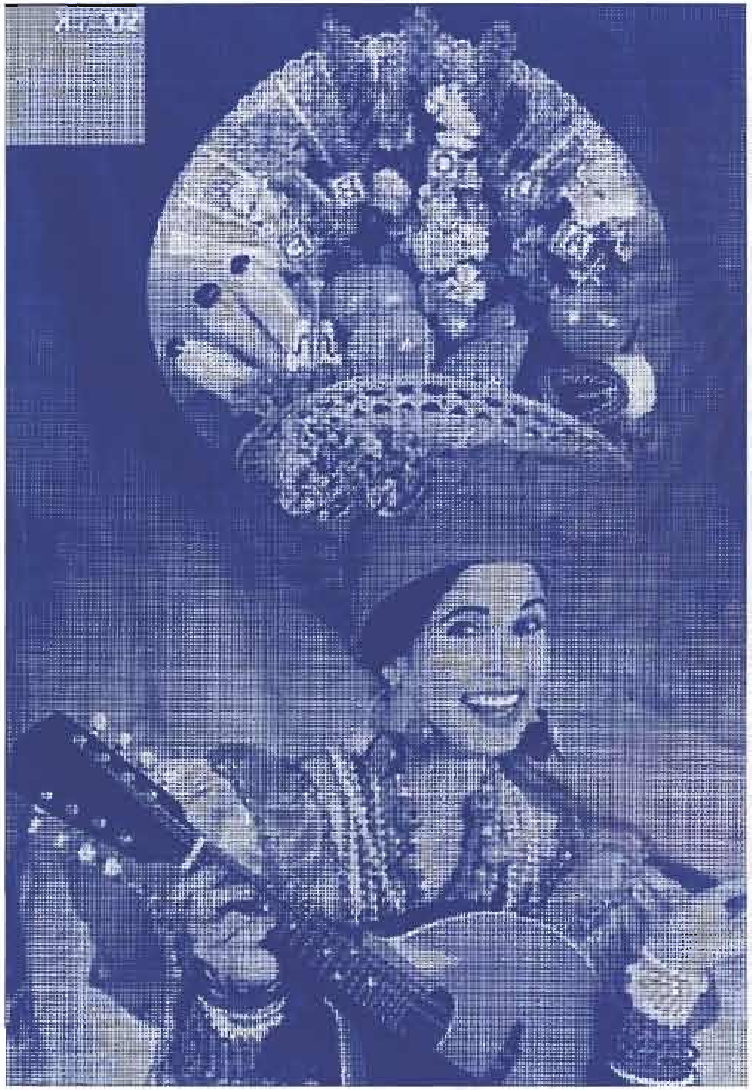
The printout, which is obtained from this algorithm, is shown in figure 4-5. It can hold tone range of the image 2-96%dot area, which that the printout holds detail of the image in shadow area till 96%dot area.

The printout of flexographic commercial halftone dot algorithm, is shown in figure 4-6.It can hold tone range of the image 2-97%dot area, which that the printout holds detail of the image in shadow area till 97%dot area.

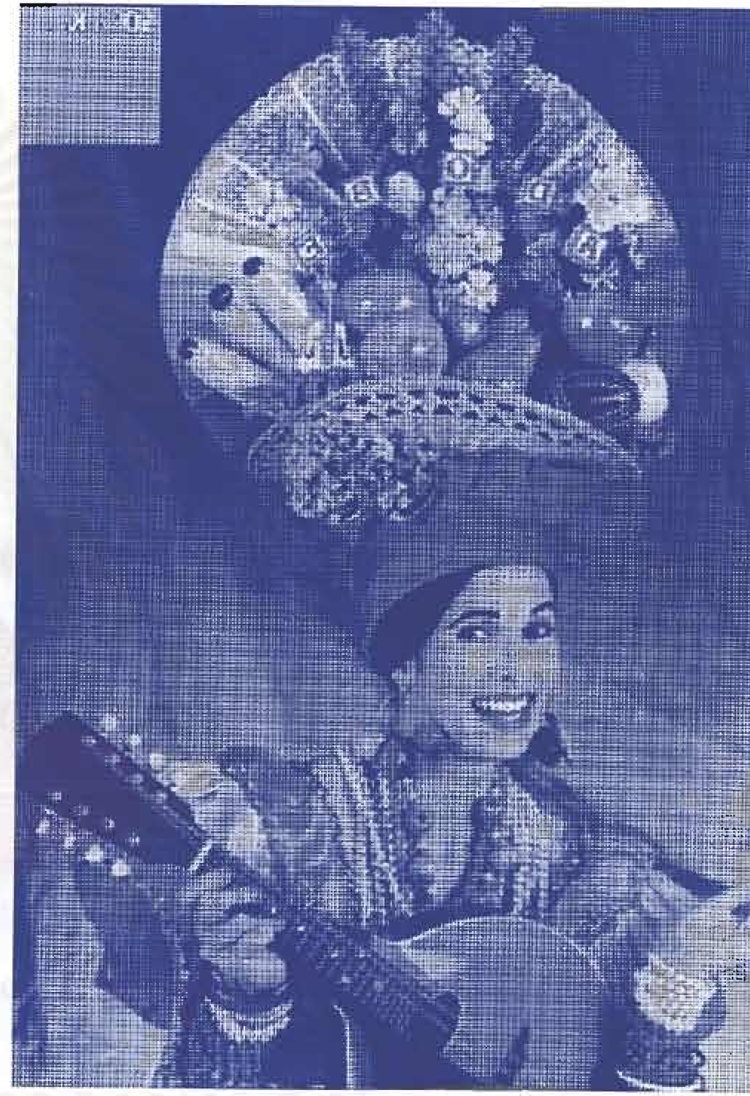
It should be noticed that these comparison done base on same film exposure condition only for the HT_Type2 and HT_Type3 algorithm as shown in Figure 4-9.

The Flexo screen printout is obtained from the Flexo screen film (I).

These two algorithms almost approach to the *Flexo screen* for handling of shadow image detail.



HT_TYPE2

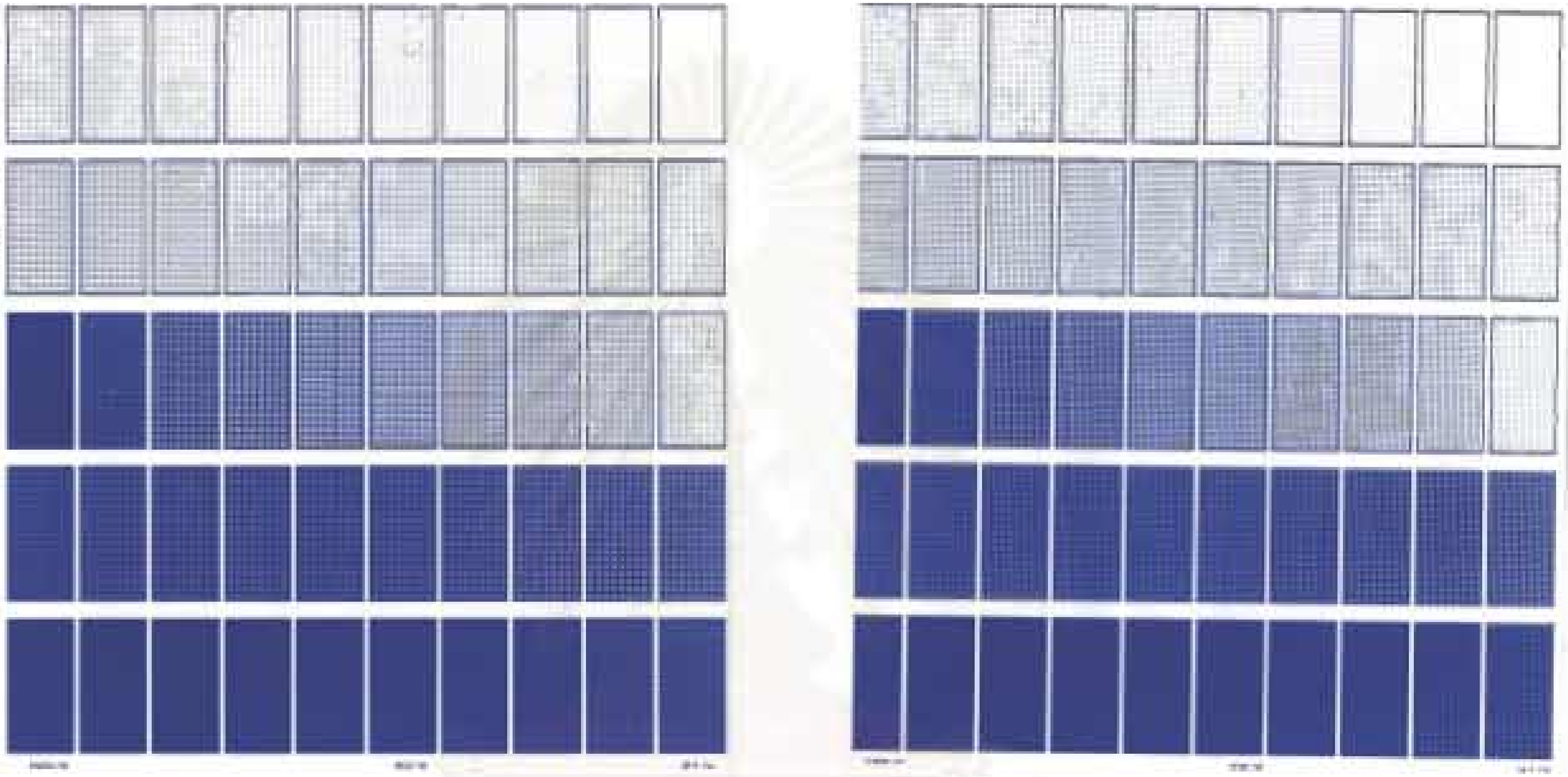


HT_TYPE3

Figure 4-5 Print out image made from HT_Type 2 and HT_Type 3 threshold matrix.

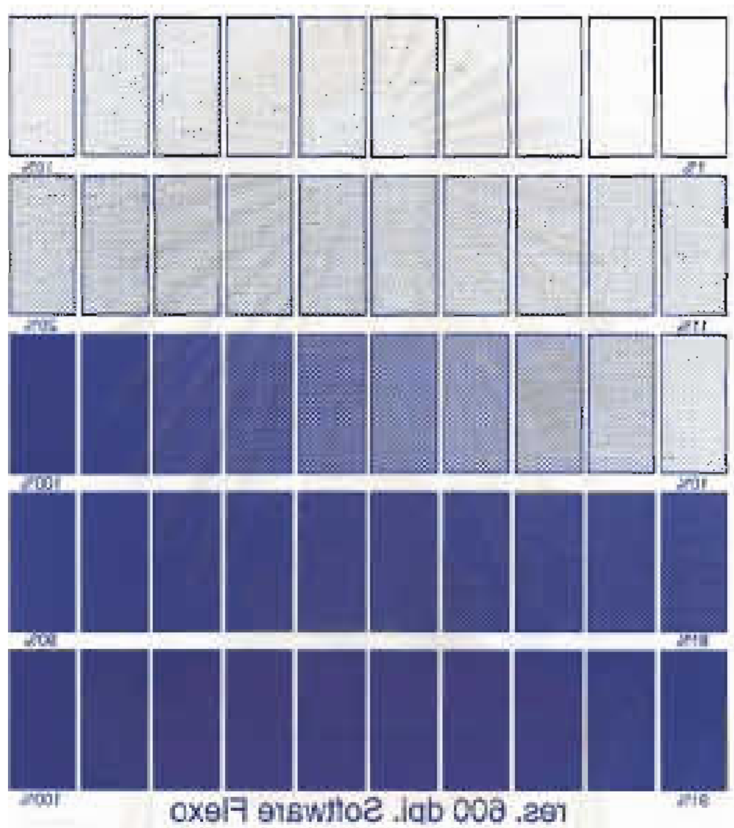
Flexo screen

Figure 4-6 Print out image made from commercial flexo screen.



HT_Type 2 HT_Type 3

Figure 4-7 Print out stepwedge made from HT_Type 2 and HT_Type 3 threshold matrix.



Flexo screen

Figure 4-8 Print out stepwedge made from commercial flexo screen.

4.2.3 Data of film operation

Table 4-3 %dot area on film of HT_Type 2 and HT_Type 3 threshold matrix and commercial flexo screen.

Digital	Ideal	HT_Type2	HT_Type3	Flexo(II)
10	90	92	92	90
20	80	84	84	79
30	70	75	75	68
40	60	67	66	58
50	50	58	56	48
60	40	48	48	39
70	30	40	36	28
80	20	29	26	19
90	10	15	12	10
100	0	0	0	0

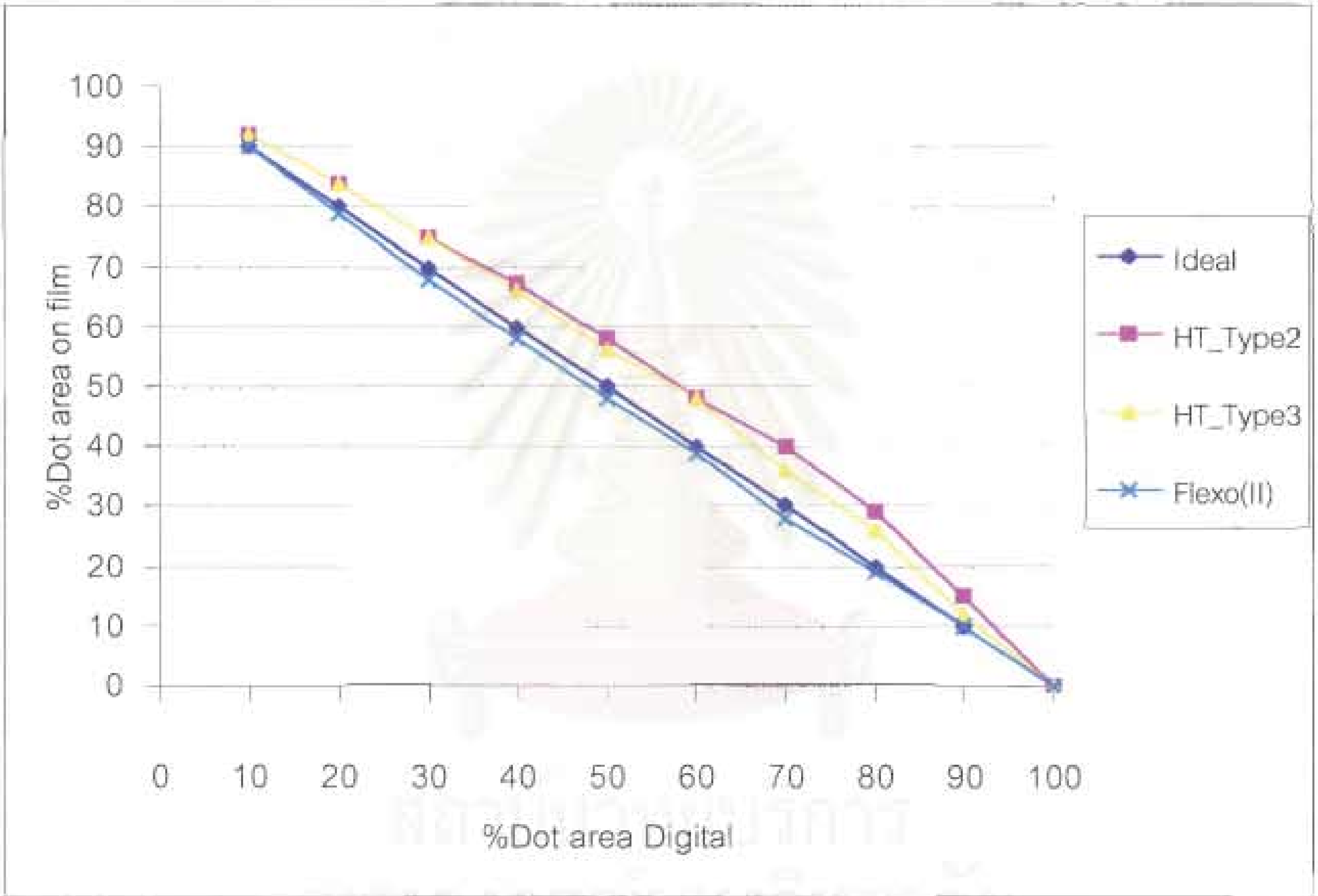


Figure 4-9 Tone reproduction curve of HT_Type 2, HT_Type 3 threshold matrix and commercial flexo screen on film.

4.2.4 Data of Print operation

Table 4-4 %dot area on print of HT_Type 2, HT_Type 3 threshold matrix and commercial flexo screen.

Digital	Ideal	HT_Type2	HT_Type3	flexo(II)
10	10	11	7	14
20	20	18	20	21
30	30	27	28	30
40	40	36	38	41
50	50	45	47	51
60	60	54	55	63
70	70	64	67	75
80	80	72	75	84
90	90	88	89	93
100	100	100	100	100

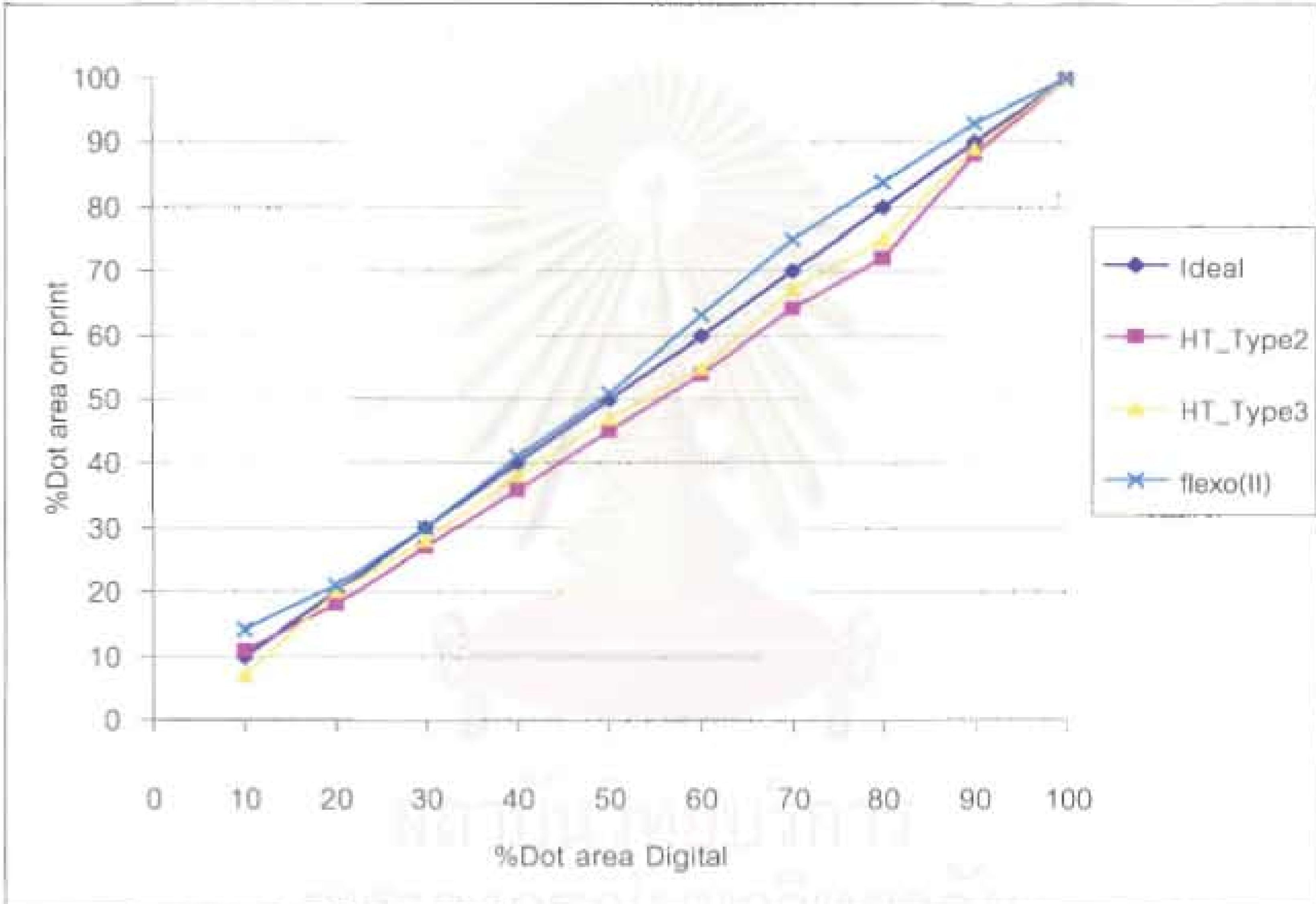


Figure 4-10 Tone reproduction curve of HT_Type 2, HT_Type 3 threshold matrix and commercial flexo screen on print.

4.3 Effect of HT_Type4 and 5 compare with *Flexo screen*

The HT_Type4 and 5 aims to compensate the ragged dot shape in the highlight area. These algorithm are increased the matrix size to 50x50.

4.3.1 Effect of dot growth sequence with HT_Type4 algorithm

The printout, which is obtained from this algorithm, is shown in figure 4-12. It can hold tone range of the image 2-98%dot area, which mean that the printout holds detail of the image in shadow area till 98%dot area.

4.3.2 Effect of dot growth sequence with HT_Type5 algorithm

The printout, which is obtained from this algorithm, is shown in figure 4-12. It can hold tone range of the image 2-98%dot area, which that the printout holds detail of the image in shadow area till 98%dot area.

4.3.3 Effect of Photoshop Round Dot screen algorithm

The printout, which is obtained from this algorithm, is shown in figure 4-11. It can hold tone range of the image 2-98%dot area, which that the printout holds detail of the image in shadow area till 98%dot area.

The printout of flexographic commercial halftone dot algorithm, is shown in figure 4-11. It can hold tone range of the image 1-98%dot area, which that the printout holds detail of the image in shadow area till 98%dot area.

It should be noticed that these all comparison done base on same film exposure condition as shown in Figure 4-14.

These two algorithms almost approach to the *Flexo screen* for handling of shadow image detail. And it is also compensated the ragged dot shape in the highlight.

Flexo screen

Photoshop

Figure 4-11 Print out image made from Adobe Photoshop round dot screen and commercial flexo screen.

HT_Type 4 HT_Type 5

Figure 4-12 Print out image made from HT_Type 4, HT_Type5 threshold matrix.

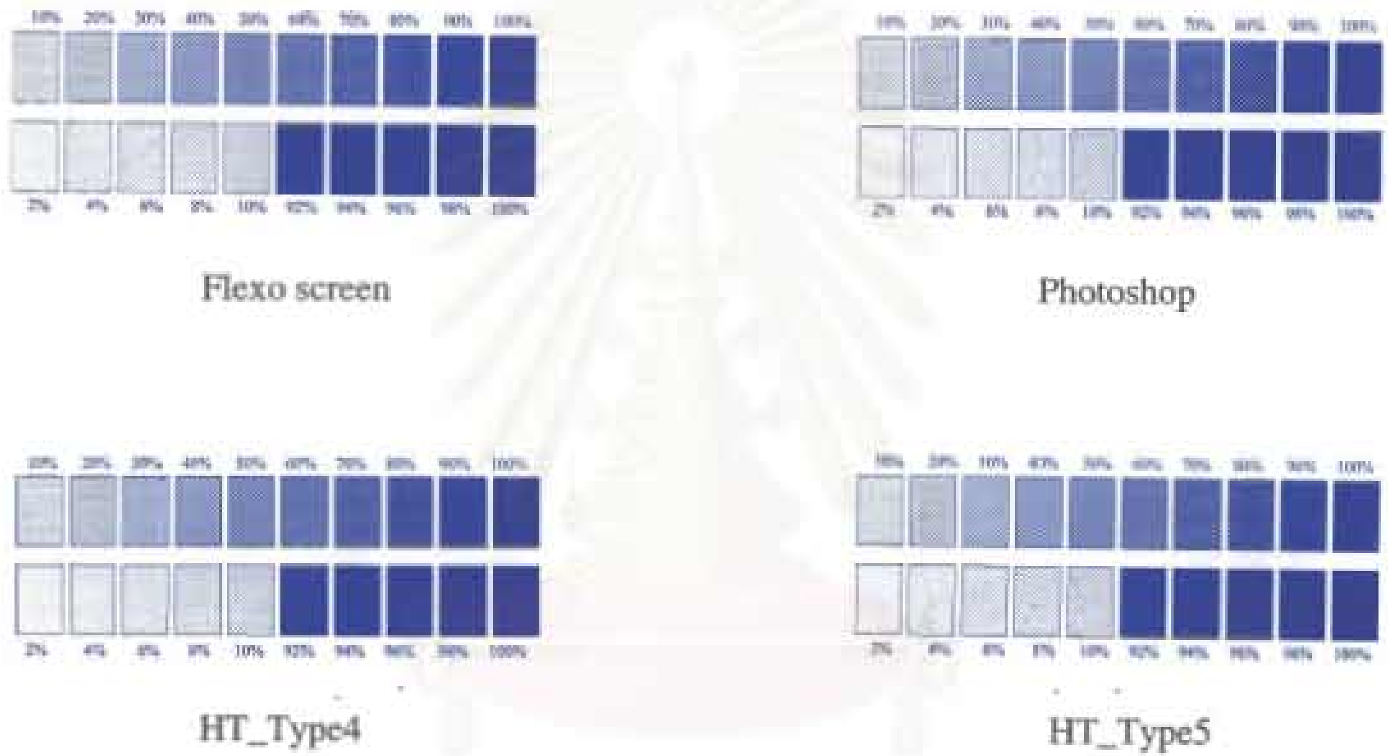


Figure 4-13 Print out stepwedge made from HT_Type 4, HT_Type 5, Adobe Photoshop round dot screen and commercial flexo screen.

4.3.4 Data of film operation

Table 4-5 %dot area on film of HT_Type 4, HT_Type 5 threshold matrix, Photoshop and commercial flexo screen.

Digital	Ideal	Flexo(III)	Photoshop	HT_Type4	HT_Type5
10	90	91	91	91	92
20	80	82	82	83	82
30	70	73	73	73	73
40	60	63	64	65	64
50	50	54	54	54	54
60	40	44	43	44	43
70	30	34	33	34	34
80	20	23	22	22	22
90	10	11	11	11	10
100	0	0	0	0	0

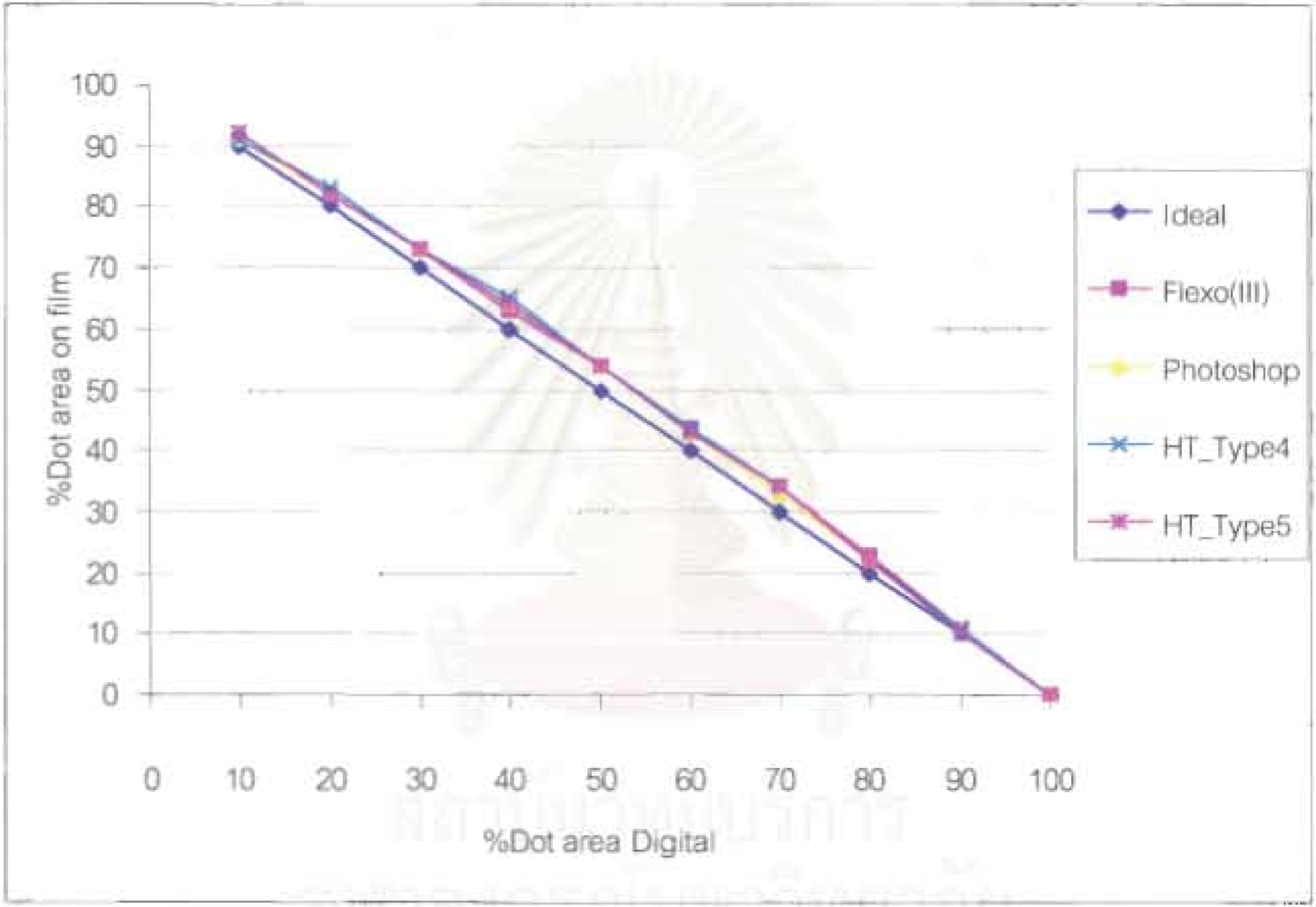


Figure 4-14 Tone reproduction curve of HT_Type 4, HT_Type 5 threshold matrix, Photoshop and commercial flexo screen on film.

4.3.5 Data of print operation

Table 4-6 %dot area on print of HT_Type 4, HT_Type 5 threshold matrix, Photoshop and commercial flexo screen.

Digital	Ideal	Flexo(III)	Photoshop	HT_Type4	HT_Type5
10	10	13	13	12	11
20	20	23	22	24	21
30	30	34	34	35	31
40	40	43	40	45	41
50	50	53	53	53	50
60	60	64	65	63	61
70	70	73	71	72	71
80	80	83	82	83	80
90	90	93	95	92	91
100	100	100	101	99	98

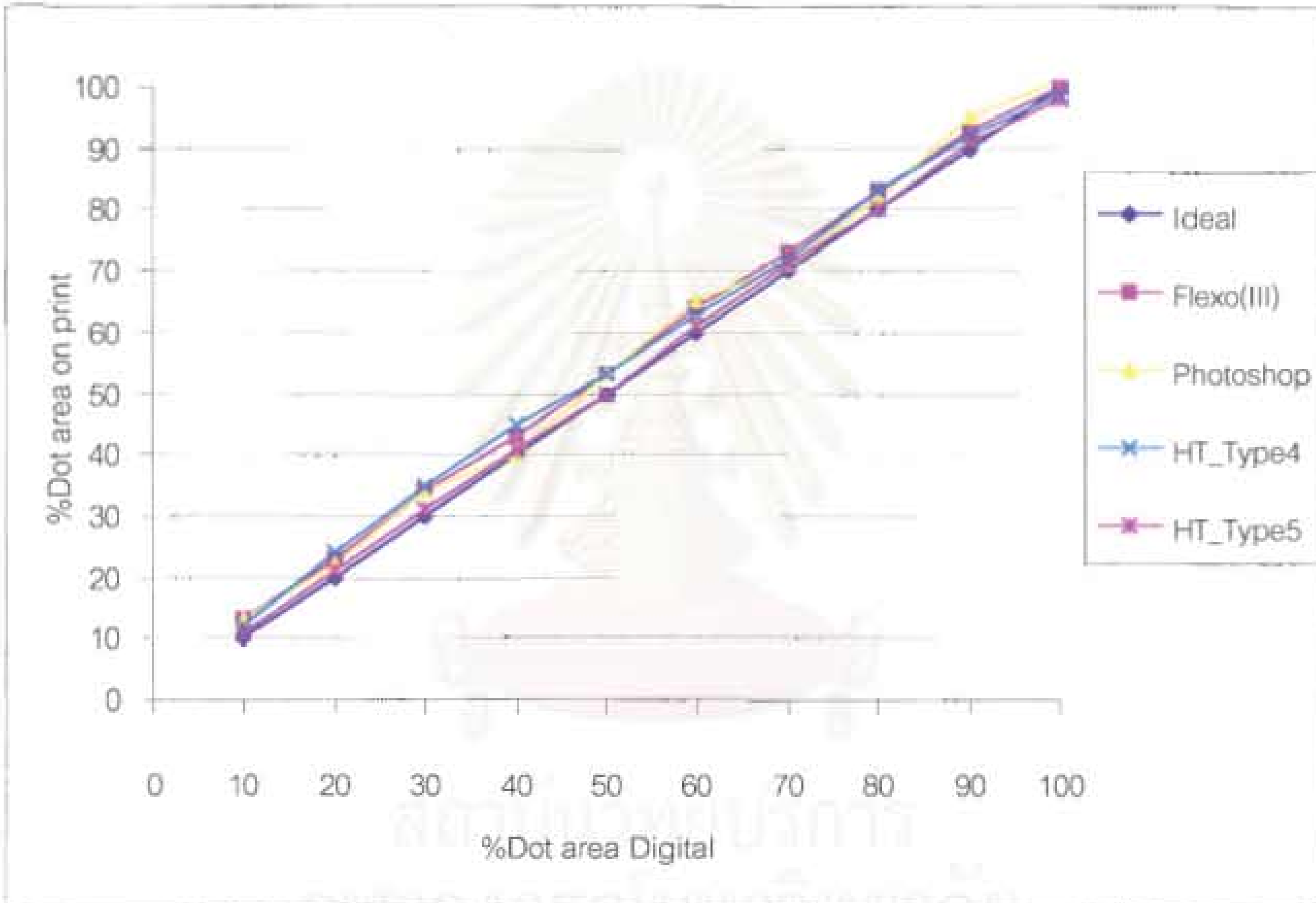


Figure 4-15 Tone reproduction curve of HT_Type 4, HT_Type 5 threshold matrix, Photoshop and commercial flexo screen on print.

CHAPTER 5

CONCLUSION AND SUGGESTION

5.1 Conclusion

From the previous results and discussion, it can be concluded that the appropriated screening for flexographic printing is round dot shape, which base on spiral dot growth sequence technique. Its outstanding is the capable to retain round shape of dot screen through the tonal range, which resulted in wider tone range reproduction of the flexographic printing. In this research, the HT_Type4 and HT_Type5 algorithm can reproduce 2-98% dot area of the original image, which is accepted in the flexograhic industries. The important of these algorithms are the capability to design or control dot shape suitable for characteristic of other printing systems. It can be used with many available application programs, which are already commonly used in printing industry.

Another constituent is threshold matrix size that uses to generate dot screen. The results show that the 50x50-matrix size is better than 24x24-matrix size to originate the dot screen. The raggedness of both dot screens in the highlight area is effortlessly observed. To reduce the raggedness effect can be done by the size of the matrix.

5.2 Suggestion

In this research, the matrix size and dot growth sequences were investigated. There are many factors that could be continued to investigate its effect such as the effect of dot screen angle and screen frequency. And other printing system should be concerned such as screen-printing and gravure-printing which very sensitive to dot gain effect.

Also, the process color reproduction could be continually investigated base on this research.

REFERENCES

1. Blatner, D., Fleishman, G. and Roth, S. Real World Scanning and Halftones. 2nd ed., CA: Peachpit Press, 1998: pp. 241-252.
2. Davies, A., and Fennessy P. An Introduction to Electronic Imaging for Photographers, 1st ed. , Oxford, Focal Press, 1994: pp. 81-90.
3. Kang, H. R. Digital Color Halftoning. 1st ed., Washington, IEEE Press, 1999: pp. 172-174.
4. Fink, P., Postscript Screening: Adobe Accurate Screens. CA, Adobe Press, 1992: pp. 6-40.
5. Pappas, T. N. Digital Halftoning Techniques for Printting in *Recent progress in Digital Halftoning*. Springfield, IS&T, 1994, pp. 42-45.
6. Dykes, Y. Flexography: Principles & Practices. 5th ed., NewYork, Foundation of Flexographic Technical Association Press, 1999: pp. 27-36.
7. Kang, H. R. Digital Color Halftoning. 1st ed., Washington, IEEE Press, 1999: pp. 214-234.
8. Kang, H. R. Digital Color Halftoning. 1st ed., Washington, IEEE Press, 1999: pp. 252-274.
9. Suzuki, K, Noboru, M., Masahiro, I. and Kei, S. Halftone Image Processing Method. U.S. 4,698,691,1987.
10. Lin, Q. Improving Halftone Uniformity and Tonal Response in *Recent progress in Digital Halftoning*. Springfield, IS&T, 1994, pp. 6-9.

REFERENCES

1. Blatner, D., Fleishman, G. and Roth, S. Real World Scanning and Halftones. 2nd ed., CA: Peachpit Press, 1998: pp. 241-252.
2. Davies, A., and Fennessy P. An Introduction to Electronic Imaging for Photographers, 1st ed. , Oxford, Focal Press, 1994: pp. 81-90.
3. Kang, H. R. Digital Color Halftoning. 1st ed., Washington, IEEE Press, 1999: pp. 172-174.
4. Fink, P., Postscript Screening: Adobe Accurate Screens. CA, Adobe Press, 1992: pp. 6-40.
5. Pappas, T. N. Digital Halftoning Techniques for Printting in *Recent progress in Digital Halftoning*. Springfield, IS&T, 1994, pp. 42-45.
6. Dykes, Y. Flexography: Principles & Practices. 5th ed., NewYork, Foundation of Flexographic Technical Association Press, 1999: pp. 27-36.
7. Kang, H. R. Digital Color Halftoning. 1st ed., Washington, IEEE Press, 1999: pp. 214-234.
8. Kang, H. R. Digital Color Halftoning. 1st ed., Washington, IEEE Press, 1999: pp. 252-274.
9. Suzuki, K, Noboru, M., Masahiro, I. and Kei, S. Halftone Image Processing Method. U.S. 4,698,691,1987.
10. Lin, Q. Improving Halftone Uniformity and Tonal Response in *Recent progress in Digital Halftoning*. Springfield, IS&T, 1994, pp. 6-9.

APPENDIX A

HALFTONING PROGRAM

```
#include <stdio.h>
#include <stdlib.h>
#include <math.h>

#define MAX 6
#define PI 3.141592654

int xsize;
int ysize;
int kind;
int bit;
int CellSize;        /* use for beyond bi-level output*/

float Angle = 45.0; /* set desired screen angle(0.0-90.0degree) here */

unsigned char *filein,*fileout;

char name1[30];
char *name2="HTimage_1.RAW";

/*dither matrix*/
static int mat[MAX][50][50] = {
/*Number 0 "HT_Type4"*/
    {
{ 324, 323, 322, 320, 318, 315, 312, 308, 304, 300,
  296, 292, 286, 282, 278, 274, 269, 264, 260, 257,
  254, 249, 246, 245, 243, 243, 245, 246, 249, 254,
  257, 260, 264, 269, 274, 278, 282, 286, 292, 296,
  300, 304, 308, 312, 315, 318, 320, 322, 323, 324 },
{ 323, 321, 319, 317, 314, 311, 307, 303, 298, 293,
  289, 284, 277, 271, 267, 259, 255, 247, 241, 238,
  233, 231, 228, 227, 226, 226, 227, 228, 231, 233,
  238, 241, 247, 255, 259, 267, 271, 277, 284, 289,
  293, 298, 303, 307, 311, 314, 317, 319, 321, 323 },
{ 322, 319, 316, 313, 310, 306, 302, 297, 291, 285,
  279, 273, 266, 258, 251, 242, 236, 230, 222, 219,
  215, 213, 210, 206, 205, 205, 206, 210, 213, 215,
  219, 222, 230, 236, 242, 251, 258, 266, 273, 279,
  285, 291, 297, 302, 306, 310, 313, 316, 319, 322 },
{ 320, 317, 313, 309, 305, 301, 295, 290, 283, 276,
  268, 261, 252, 240, 232, 225, 217, 212, 204, 202,
  198, 194, 191, 190, 189, 189, 190, 191, 194, 198,
  202, 204, 212, 217, 225, 232, 240, 252, 261, 268,
  276, 283, 290, 295, 301, 305, 309, 313, 317, 320 },
{ 318, 314, 310, 305, 299, 294, 288, 281, 275, 265,
  256, 244, 234, 224, 216, 207, 201, 195, 188, 183,
  181, 178, 175, 174, 171, 171, 174, 175, 178, 181,
  183, 188, 195, 201, 207, 216, 224, 234, 244, 256,
  265, 275, 281, 288, 294, 299, 305, 310, 314, 318 },
{ 315, 311, 306, 301, 294, 287, 280, 272, 263, 253,
  239, 229, 218, 209, 200, 192, 185, 179, 173, 167,
  165, 161, 159, 157, 155, 155, 157, 159, 161, 165,
  167, 173, 179, 185, 192, 200, 209, 218, 229, 239,
  253, 263, 272, 280, 287, 294, 301, 306, 311, 315 },
{ 312, 307, 302, 295, 288, 280, 270, 262, 250, 237,
  223, 214, 203, 193, 184, 177, 168, 164, 158, 153,
  149, 146, 144, 142, 140, 140, 142, 144, 146, 149,
  153, 158, 164, 168, 177, 184, 193, 203, 214, 223,
  237, 250, 262, 270, 280, 288, 295, 302, 307, 312 },
{ 308, 303, 297, 290, 281, 272, 262, 248, 235, 221,
  211, 199, 187, 180, 169, 163, 154, 148, 143, 137,
  134, 132, 129, 126, 125, 125, 126, 129, 132, 134,
  137, 143, 148, 154, 163, 169, 180, 187, 199, 211,
  221, 235, 248, 262, 272, 281, 290, 297, 303, 308 },
{ 304, 298, 291, 283, 275, 263, 250, 235, 220, 208,
  197, 186, 176, 166, 156, 147, 141, 135, 131, 124,
  121, 118, 115, 114, 113, 113, 114, 115, 118, 121,
  124, 131, 135, 141, 147, 156, 166, 176, 186, 197,
  208, 220, 235, 250, 263, 275, 283, 291, 298, 304 },
```

```
{ 300, 293, 285, 276, 265, 253, 237, 221, 208, 196,
  182, 172, 162, 152, 145, 136, 128, 122, 117, 111,
  107, 105, 103, 101,  99,  99, 101, 103, 105, 107,
  111, 117, 122, 128, 136, 145, 152, 162, 172, 182,
  196, 208, 221, 237, 253, 265, 276, 285, 293, 300 },
{ 296, 289, 279, 268, 256, 239, 223, 211, 197, 182,
  170, 160, 151, 139, 133, 123, 116, 110, 104,  98,
   96,  93,  90,  89,  86,  86,  89,  90,  93,  96,
   98, 104, 110, 116, 123, 133, 139, 151, 160, 170,
  182, 197, 211, 223, 239, 256, 268, 279, 289, 296 },
{ 292, 284, 273, 261, 244, 229, 214, 199, 186, 172,
  160, 150, 138, 130, 120, 112, 106,  97,  94,  88,
   84,  81,  80,  77,  76,  76,  77,  80,  81,  84,
   88,  94,  97, 106, 112, 120, 130, 138, 150, 160,
  172, 186, 199, 214, 229, 244, 261, 273, 284, 292 },
{ 286, 277, 266, 252, 234, 218, 203, 187, 176, 162,
  151, 138, 127, 119, 109, 102,  95,  87,  82,  78,
   73,  71,  69,  66,  65,  65,  66,  69,  71,  73,
   78,  82,  87,  95, 102, 109, 119, 127, 138, 151,
  162, 176, 187, 203, 218, 234, 252, 266, 277, 286 },
{ 282, 271, 258, 240, 224, 209, 193, 180, 166, 152,
  139, 130, 119, 108, 100,  92,  85,  79,  72,  68,
   64,  61,  58,  57,  56,  56,  57,  58,  61,  64,
   68,  72,  79,  85,  92, 100, 108, 119, 130, 139,
  152, 166, 180, 193, 209, 224, 240, 258, 271, 282 },
{ 278, 267, 251, 232, 216, 200, 184, 169, 156, 145,
  133, 120, 109, 100,  91,  83,  75,  70,  63,  59,
   54,  52,  50,  48,  46,  46,  48,  50,  52,  54,
   59,  63,  70,  75,  83,  91, 100, 109, 120, 133,
  145, 156, 169, 184, 200, 216, 232, 251, 267, 278 },
{ 274, 259, 242, 225, 207, 192, 177, 163, 147, 136,
  123, 112, 102,  92,  83,  74,  67,  62,  55,  51,
   45,  44,  41,  40,  38,  38,  40,  41,  44,  45,
   51,  55,  62,  67,  74,  83,  92, 102, 112, 123,
  136, 147, 163, 177, 192, 207, 225, 242, 259, 274 },
{ 269, 255, 236, 217, 201, 185, 168, 154, 141, 128,
  116, 106,  95,  85,  75,  67,  60,  53,  49,  43,
   39,  36,  34,  32,  31,  31,  32,  34,  36,  39,
   43,  49,  53,  60,  67,  75,  85,  95, 106, 116,
  128, 141, 154, 168, 185, 201, 217, 236, 255, 269 },
{ 264, 247, 230, 212, 195, 179, 164, 148, 135, 122,
  110,  97,  87,  79,  70,  62,  53,  47,  42,  37,
   33,  29,  28,  25,  24,  24,  25,  28,  29,  33,
   37,  42,  47,  53,  62,  70,  79,  87,  97, 110,
  122, 135, 148, 164, 179, 195, 212, 230, 247, 264 },
{ 260, 241, 222, 204, 188, 173, 158, 143, 131, 117,
  104,  94,  82,  72,  63,  55,  49,  42,  35,  30,
   27,  23,  21,  20,  19,  19,  20,  21,  23,  27,
   30,  35,  42,  49,  55,  63,  72,  82,  94, 104,
  117, 131, 143, 158, 173, 188, 204, 222, 241, 260 },
{ 257, 238, 219, 202, 183, 167, 153, 137, 124, 111,
   98,  88,  78,  68,  59,  51,  43,  37,  30,  26,
   22,  18,  16,  15,  13,  13,  15,  16,  18,  22,
   26,  30,  37,  43,  51,  59,  68,  78,  88,  98,
  111, 124, 137, 153, 167, 183, 202, 219, 238, 257 },
{ 254, 233, 215, 198, 181, 165, 149, 134, 121, 107,
   96,  84,  73,  64,  54,  45,  39,  33,  27,  22,
   17,  14,  12,  10,   9,   9,  10,  12,  14,  17,
   22,  27,  33,  39,  45,  54,  64,  73,  84,  96,
  107, 121, 134, 149, 165, 181, 198, 215, 233, 254 },
{ 249, 231, 213, 194, 178, 161, 146, 132, 118, 105,
   93,  81,  71,  61,  52,  44,  36,  29,  23,  18,
   14,  11,   8,   7,   6,   6,   7,   8,  11,  14,
   18,  23,  29,  36,  44,  52,  61,  71,  81,  93,
  105, 118, 132, 146, 161, 178, 194, 213, 231, 249 },
{ 246, 228, 210, 191, 175, 159, 144, 129, 115, 103,
   90,  80,  69,  58,  50,  41,  34,  28,  21,  16,
   12,   8,   5,   4,   3,   3,   4,   5,   8,  12,
   16,  21,  28,  34,  41,  50,  58,  69,  80,  90,
```

```
  103, 115, 129, 144, 159, 175, 191, 210, 228, 246 },
{ 245, 227, 206, 190, 174, 157, 142, 126, 114, 101,
   89,  77,  66,  57,  48,  40,  32,  25,  20,  15,
   10,   7,   4,   2,   1,   1,   2,   4,   7,  10,
   15,  20,  25,  32,  40,  48,  57,  66,  77,  89,
  101, 114, 126, 142, 157, 174, 190, 206, 227, 245 },
{ 243, 226, 205, 189, 171, 155, 140, 125, 113,  99,
   86,  76,  65,  56,  46,  38,  31,  24,  19,  13,
    9,   6,   3,   1,   0,   0,   1,   3,   6,   9,
   13,  19,  24,  31,  38,  46,  56,  65,  76,  86,
   99, 113, 125, 140, 155, 171, 189, 205, 226, 243 },
{ 243, 226, 205, 189, 171, 155, 140, 125, 113,  99,
   86,  76,  65,  56,  46,  38,  31,  24,  19,  13,
    9,   6,   3,   1,   0,   0,   1,   3,   6,   9,
   13,  19,  24,  31,  38,  46,  56,  65,  76,  86,
   99, 113, 125, 140, 155, 171, 189, 205, 226, 243 },
{ 245, 227, 206, 190, 174, 157, 142, 126, 114, 101,
   89,  77,  66,  57,  48,  40,  32,  25,  20,  15,
   10,   7,   4,   2,   1,   1,   2,   4,   7,  10,
   15,  20,  25,  32,  40,  48,  57,  66,  77,  89,
  101, 114, 126, 142, 157, 174, 190, 206, 227, 245 },
{ 246, 228, 210, 191, 175, 159, 144, 129, 115, 103,
   90,  80,  69,  58,  50,  41,  34,  28,  21,  16,
   12,   8,   5,   4,   3,   3,   4,   5,   8,  12,
   16,  21,  28,  34,  41,  50,  58,  69,  80,  90,
  103, 115, 129, 144, 159, 175, 191, 210, 228, 246 },
{ 249, 231, 213, 194, 178, 161, 146, 132, 118, 105,
   93,  81,  71,  61,  52,  44,  36,  29,  23,  18,
   14,  11,   8,   7,   6,   6,   7,   8,  11,  14,
   18,  23,  29,  36,  44,  52,  61,  71,  81,  93,
  105, 118, 132, 146, 161, 178, 194, 213, 231, 249 },
{ 254, 233, 215, 198, 181, 165, 149, 134, 121, 107,
   96,  84,  73,  64,  54,  45,  39,  33,  27,  22,
   17,  14,  12,  10,   9,   9,  10,  12,  14,  17,
   22,  27,  33,  39,  45,  54,  64,  73,  84,  96,
  107, 121, 134, 149, 165, 181, 198, 215, 233, 254 },
{ 257, 238, 219, 202, 183, 167, 153, 137, 124, 111.
   98,  88,  78,  68,  59,  51,  43,  37,  30,  26,
   22,  18,  16,  15,  13,  13,  15,  16,  18,  22,
   26,  30,  37,  43,  51,  59,  68,  78,  88,  98,
  111, 124, 137, 153, 167, 183, 202, 219, 238, 257 },
{ 260, 241, 222, 204, 188, 173, 158, 143, 131, 117,
  104,  94,  82,  72,  63,  55,  49,  42,  35,  30,
   27,  23,  21,  20,  19,  19,  20,  21,  23,  27,
   30,  35,  42,  49,  55,  63,  72,  82,  94, 104,
  117, 131, 143, 158, 173, 188, 204, 222, 241, 260 },
{ 264, 247, 230, 212, 195, 179, 164, 148, 135, 122,
  110,  97,  87,  79,  70,  62,  53,  47,  42,  37,
   33,  29,  28,  25,  24,  24,  25,  28,  29,  33,
   37,  42,  47,  53,  62,  70,  79,  87,  97, 110,
  122, 135, 148, 164, 179, 195, 212, 230, 247, 264 },
{ 269, 255, 236, 217, 201, 185, 168, 154, 141, 128,
  116, 106,  95,  85,  75,  67,  60,  53,  49,  43,
   39,  36,  34,  32,  31,  31,  32,  34,  36,  39,
   43,  49,  53,  60,  67,  75,  85,  95, 106, 116,
  128, 141, 154, 168, 185, 201, 217, 236, 255, 269 },
{ 274, 259, 242, 225, 207, 192, 177, 163, 147, 136,
  123, 112, 102,  92,  83,  74,  67,  62,  55,  51,
   45,  44,  41,  40,  38,  38,  40,  41,  44,  45,
   51,  55,  62,  67,  74,  83,  92, 102, 112, 123,
  136, 147, 163, 177, 192, 207, 225, 242, 259, 274 },
{ 278, 267, 251, 232, 216, 200, 184, 169, 156, 145,
  133, 120, 109, 100,  91,  83,  75,  70,  63,  59,
   54,  52,  50,  48,  46,  46,  48,  50,  52,  54,
   59,  63,  70,  75,  83,  91, 100, 109, 120, 133,
  145, 156, 169, 184, 200, 216, 232, 251, 267, 278 },
{ 282, 271, 258, 240, 224, 209, 193, 180, 166, 152,
  139, 130, 119, 108, 100,  92,  85,  79,  72,  68,
   64,  61,  58,  57,  56,  56,  57,  58,  61,  64,
```

```
   68,  72,  79,  85,  92, 100, 108, 119, 130, 139,
  152, 166, 180, 193, 209, 224, 240, 258, 271, 282 },
{ 286, 277, 266, 252, 234, 218, 203, 187, 176, 162,
  151, 138, 127, 119, 109, 102,  95,  87,  82,  78,
   73,  71,  69,  66,  65,  65,  66,  69,  71,  73,
   78,  82,  87,  95, 102, 109, 119, 127, 138, 151,
  162, 176, 187, 203, 218, 234, 252, 266, 277, 286 },
{ 292, 284, 273, 261, 244, 229, 214, 199, 186, 172,
  160, 150, 138, 130, 120, 112, 106,  97,  94,  88,
   84,  81,  80,  77,  76,  76,  77,  80,  81,  84,
   88,  94,  97, 106, 112, 120, 130, 138, 150, 160,
  172, 186, 199, 214, 229, 244, 261, 273, 284, 292 },
{ 296, 289, 279, 268, 256, 239, 223, 211, 197, 182,
  170, 160, 151, 139, 133, 123, 116, 110, 104,  98,
   96,  93,  90,  89,  86,  86,  89,  90,  93,  96,
   98, 104, 110, 116, 123, 133, 139, 151, 160, 170,
  182, 197, 211, 223, 239, 256, 268, 279, 289, 296 },
{ 300, 293, 285, 276, 265, 253, 237, 221, 208, 196,
  182, 172, 162, 152, 145, 136, 128, 122, 117, 111,
  107, 105, 103, 101,  99,  99, 101, 103, 105, 107,
  111, 117, 122, 128, 136, 145, 152, 162, 172, 182,
  196, 208, 221, 237, 253, 265, 276, 285, 293, 300 },
{ 304, 298, 291, 283, 275, 263, 250, 235, 220, 208,
  197, 186, 176, 166, 156, 147, 141, 135, 131, 124,
  121, 118, 115, 114, 113, 113, 114, 115, 118, 121,
  124, 131, 135, 141, 147, 156, 166, 176, 186, 197,
  208, 220, 235, 250, 263, 275, 283, 291, 298, 304 },
{ 308, 303, 297, 290, 281, 272, 262, 248, 235, 221,
  211, 199, 187, 180, 169, 163, 154, 148, 143, 137,
  134, 132, 129, 126, 125, 125, 126, 129, 132, 134,
  137, 143, 148, 154, 163, 169, 180, 187, 199, 211,
  221, 235, 248, 262, 272, 281, 290, 297, 303, 308 },
{ 312, 307, 302, 295, 288, 280, 270, 262, 250, 237,
  223, 214, 203, 193, 184, 177, 168, 164, 158, 153,
  149, 146, 144, 142, 140, 140, 142, 144, 146, 149,
  153, 158, 164, 168, 177, 184, 193, 203, 214, 223,
  237, 250, 262, 270, 280, 288, 295, 302, 307, 312 },
{ 315, 311, 306, 301, 294, 287, 280, 272, 263, 253,
  239, 229, 218, 209, 200, 192, 185, 179, 173, 167,
  165, 161, 159, 157, 155, 155, 157, 159, 161, 165,
  167, 173, 179, 185, 192, 200, 209, 218, 229, 239,
  253, 263, 272, 280, 287, 294, 301, 306, 311, 315 },
{ 318, 314, 310, 305, 299, 294, 288, 281, 275, 265,
  256, 244, 234, 224, 216, 207, 201, 195, 188, 183,
  181, 178, 175, 174, 171, 171, 174, 175, 178, 181,
  183, 188, 195, 201, 207, 216, 224, 234, 244, 256,
  265, 275, 281, 288, 294, 299, 305, 310, 314, 318 },
{ 320, 317, 313, 309, 305, 301, 295, 290, 283, 276,
  268, 261, 252, 240, 232, 225, 217, 212, 204, 202,
  198, 194, 191, 190, 189, 189, 190, 191, 194, 198,
  202, 204, 212, 217, 225, 232, 240, 252, 261, 268,
  276, 283, 290, 295, 301, 305, 309, 313, 317, 320 },
{ 322, 319, 316, 313, 310, 306, 302, 297, 291, 285,
  279, 273, 266, 258, 251, 242, 236, 230, 222, 219,
  215, 213, 210, 206, 205, 205, 206, 210, 213, 215,
  219, 222, 230, 236, 242, 251, 258, 266, 273, 279,
  285, 291, 297, 302, 306, 310, 313, 316, 319, 322 },
{ 323, 321, 319, 317, 314, 311, 307, 303, 298, 293,
  289, 284, 277, 271, 267, 259, 255, 247, 241, 238,
  233, 231, 228, 227, 226, 226, 227, 228, 231, 233,
  238, 241, 247, 255, 259, 267, 271, 277, 284, 289,
  293, 298, 303, 307, 311, 314, 317, 319, 321, 323 },
{ 324, 323, 322, 320, 318, 315, 312, 308, 304, 300,
  296, 292, 286, 282, 278, 274, 269, 264, 260, 257,
  254, 249, 246, 245, 243, 243, 245, 246, 249, 254,
  257, 260, 264, 269, 274, 278, 282, 286, 292, 296,
  300, 304, 308, 312, 315, 318, 320, 322, 323, 324 },
  },
/*Number 1 "HT_Type5"*/
```

```
{
{ 324, 323, 321, 319, 315, 311, 306, 300, 294, 286,
  279, 274, 270, 268, 265, 263, 261, 259, 258, 257,
  254, 249, 246, 245, 243, 243, 245, 246, 249, 254,
  257, 258, 259, 261, 263, 265, 268, 270, 274, 279,
  286, 294, 300, 306, 311, 315, 319, 321, 323, 324 },
{ 323, 322, 320, 317, 314, 310, 304, 299, 292, 285,
  277, 273, 269, 266, 264, 260, 255, 247, 241, 238,
  233, 231, 228, 227, 226, 226, 227, 228, 231, 233,
  238, 241, 247, 255, 260, 264, 266, 269, 273, 277,
  285, 292, 299, 304, 310, 314, 317, 320, 322, 323 },
{ 321, 320, 318, 316, 312, 308, 303, 297, 290, 283,
  276, 272, 267, 262, 251, 242, 236, 230, 222, 219,
  215, 213, 210, 206, 205, 205, 206, 210, 213, 215,
  219, 222, 230, 236, 242, 251, 262, 267, 272, 276,
  283, 290, 297, 303, 308, 312, 316, 318, 320, 321 },
{ 319, 317, 316, 313, 309, 305, 301, 295, 289, 281,
  275, 271, 252, 240, 232, 225, 217, 212, 204, 202,
  198, 194, 191, 190, 189, 189, 190, 191, 194, 198,
  202, 204, 212, 217, 225, 232, 240, 252, 271, 275,
  281, 289, 295, 301, 305, 309, 313, 316, 317, 319 },
{ 315, 314, 312, 309, 307, 302, 296, 291, 284, 278,
  256, 244, 234, 224, 216, 207, 201, 195, 188, 183,
  181, 178, 175, 174, 171, 171, 174, 175, 178, 181,
  183, 188, 195, 201, 207, 216, 224, 234, 244, 256,
  278, 284, 291, 296, 302, 307, 309, 312, 314, 315 },
{ 311, 310, 308, 305, 302, 298, 293, 287, 280, 253,
  239, 229, 218, 209, 200, 192, 185, 179, 173, 167,
  165, 161, 159, 157, 155, 155, 157, 159, 161, 165,
  167, 173, 179, 185, 192, 200, 209, 218, 229, 239,
  253, 280, 287, 293, 298, 302, 305, 308, 310, 311 },
{ 306, 304, 303, 301, 296, 293, 288, 282, 250, 237,
  223, 214, 203, 193, 184, 177, 168, 164, 158, 153,
  149, 146, 144, 142, 140, 140, 142, 144, 146, 149,
  153, 158, 164, 168, 177, 184, 193, 203, 214, 223,
  237, 250, 282, 288, 293, 296, 301, 303, 304, 306 },
{ 300, 299, 297, 295, 291, 287, 282, 248, 235, 221,
  211, 199, 187, 180, 169, 163, 154, 148, 143, 137,
  134, 132, 129, 126, 125, 125, 126, 129, 132, 134,
  137, 143, 148, 154, 163, 169, 180, 187, 199, 211,
  221, 235, 248, 282, 287, 291, 295, 297, 299, 300 },
{ 294, 292, 290, 289, 284, 280, 250, 235, 220, 208,
  197, 186, 176, 166, 156, 147, 141, 135, 131, 124,
  121, 118, 115, 114, 113, 113, 114, 115, 118, 121,
  124, 131, 135, 141, 147, 156, 166, 176, 186, 197,
  208, 220, 235, 250, 280, 284, 289, 290, 292, 294 },
{ 286, 285, 283, 281, 278, 253, 237, 221, 208, 196,
  182, 172, 162, 152, 145, 136, 128, 122, 117, 111,
  107, 105, 103, 101,  99,  99, 101, 103, 105, 107,
  111, 117, 122, 128, 136, 145, 152, 162, 172, 182,
  196, 208, 221, 237, 253, 278, 281, 283, 285, 286 },
{ 279, 277, 276, 275, 256, 239, 223, 211, 197, 182,
  170, 160, 151, 139, 133, 123, 116, 110, 104,  98,
   96,  93,  90,  89,  86,  86,  89,  90,  93,  96,
   98, 104, 110, 116, 123, 133, 139, 151, 160, 170,
   182,197, 211, 223, 239, 256, 275, 276, 277, 279 },
{ 274, 273, 272, 271, 244, 229, 214, 199, 186, 172,
  160, 150, 138, 130, 120, 112, 106,  97,  94,  88,
   84,  81,  80,  77,  76,  76,  77,  80,  81,  84,
   88,  94,  97, 106, 112, 120, 130, 138, 150, 160,
  172, 186, 199, 214, 229, 244, 271, 272, 273, 274 },
{ 270, 269, 267, 252, 234, 218, 203, 187, 176, 162,
  151, 138, 127, 119, 109, 102,  95,  87,  82,  78,
   73,  71,  69,  66,  65,  65,  66,  69,  71,  73,
   78,  82,  87,  95, 102, 109, 119, 127, 138, 151,
  162, 176, 187, 203, 218, 234, 252, 267, 269, 270 },
{ 268, 266, 262, 240, 224, 209, 193, 180, 166, 152,
  139, 130, 119, 108, 100,  92,  85,  79,  72,  68,
   64,  61,  58,  57,  56,  56,  57,  58,  61,  64,
```

```
   68,  72,  79,  85,  92, 100, 108, 119, 130, 139,
  152, 166, 180, 193, 209, 224, 240, 262, 266, 268 },
{ 265, 264, 251, 232, 216, 200, 184, 169, 156, 145,
  133, 120, 109, 100,  91,  83,  75,  70,  63,  59,
   54,  52,  50,  48,  46,  46,  48,  50,  52,  54,
   59,  63,  70,  75,  83,  91, 100, 109, 120, 133,
  145, 156, 169, 184, 200, 216, 232, 251, 264, 265 },
{ 263, 260, 242, 225, 207, 192, 177, 163, 147, 136,
  123, 112, 102,  92,  83,  74,  67,  62,  55,  51,
   45,  44,  41,  40,  39,  38,  40,  41,  44,  45,
   51,  55,  62,  67,  74,  83,  92, 102, 112, 123,
  136, 147, 163, 177, 192, 207, 225, 242, 260, 263 },
{ 261, 255, 236, 217, 201, 185, 168, 154, 141, 128,
  116, 106,  95,  85,  75,  67,  60,  53,  49,  43,
   39,  36,  34,  32,  31,  31,  32,  34,  36,  39,
   43,  49,  53,  60,  67,  75,  85,  95, 106, 116,
  128, 141, 154, 168, 185, 201, 217, 236, 255, 261 },
{ 259, 247, 230, 212, 195, 179, 164, 148, 135, 122,
  110,  97,  87,  79,  70,  62,  53,  47,  42,  37,
   33,  29,  28,  25,  24,  24,  25,  28,  29,  33,
   37,  42,  47,  53,  62,  70,  79,  87,  97, 110,
  122, 135, 148, 164, 179, 195, 212, 230, 247, 259 },
{ 258, 241, 222, 204, 188, 173, 158, 143, 131, 117,
  104,  94,  82,  72,  63,  55,  49,  42,  35,  30,
   27,  23,  21,  20,  19,  19,  20,  21,  23,  27,
   30,  35,  42,  49,  55,  63,  72,  82,  94, 104,
  117, 131, 143, 158, 173, 188, 204, 222, 241, 258 },
{ 257, 238, 219, 202, 183, 167, 153, 137, 124, 111,
   98,  88,  78,  68,  59,  51,  43,  37,  30,  26,
   22,  18,  16,  15,  13,  13,  15,  16,  18,  22,
   26,  30,  37,  43,  51,  59,  68,  78,  88,  98,
  111, 124, 137, 153, 167, 183, 202, 219, 238, 257 },
{ 254, 233, 215, 198, 181, 165, 149, 134, 121, 107,
   96,  84,  73,  64,  54,  45,  39,  33,  27,  22,
   17,  14,  12,  10,   9,   9,  10,  12,  14,  17,
   22,  27,  33,  39,  45,  54,  64,  73,  84,  96,
  107, 121, 134, 149, 165, 181, 198, 215, 233, 254 },
{ 249, 231, 213, 194, 178, 161, 146, 132, 118, 105,
   93,  81,  71,  61,  52,  44,  36,  29,  23,  18,
   14,  11,   8,   7,   6,   6,   7,   8,  11,  14,
   18,  23,  29,  36,  44,  52,  61,  71,  81,  93,
  105, 118, 132, 146, 161, 178, 194, 213, 231, 249 },
{ 246, 228, 210, 191, 175, 159, 144, 129, 115, 103,
   90,  80,  69,  58,  50,  41,  34,  28,  21,  16,
   12,   8,   5,   4,   3,   3,   4,   5,   8,  12,
   16,  21,  28,  34,  41,  50,  58,  69,  80,  90,
  103, 115, 129, 144, 159, 175, 191, 210, 228, 246 },
{ 245, 227, 206, 190, 174, 157, 142, 126, 114, 101,
   89,  77,  66,  57,  48,  40,  32,  25,  20,  15,
   10,   7,   4,   2,   1,   1,   2,   4,   7,  10,
   15,  20,  25,  32,  40,  48,  57,  66,  77,  89,
  101, 114, 126, 142, 157, 174, 190, 206, 227, 245 },
{ 243, 226, 205, 189, 171, 155, 140, 125, 113,  99,
   86,  76,  65,  56,  46,  38,  31,  24,  19,  13,
    9,   6,   3,   1,   0,   0,   1,   3,   6,   9,
   13,  19,  24,  31,  38,  46,  56,  65,  76,  86,
   99, 113, 125, 140, 155, 171, 189, 205, 226, 243 },
{ 243, 226, 205, 189, 171, 155, 140, 125, 113,  99,
   86,  76,  65,  56,  46,  38,  31,  24,  19,  13,
    9,   6,   3,   1,   0,   0,   1,  3,   6,   9,
   13,  19,  24,  31,  38,  46,  56,  65,  76,  86,
   99, 113, 125, 140, 155, 171, 189, 205, 226, 243 },
{ 245, 227, 206, 190, 174, 157, 142, 126, 114, 101,
   89,  77,  66,  57,  48,  40,  32,  25,  20,  15,
   10,   7,   4,   2,   1,   1,   2,   4,   7,  10,
   15,  20,  25,  32,  40,  48,  57,  66,  77,  89,
  101, 114, 126, 142, 157, 174, 190, 206, 227, 245 },
{ 246, 228, 210, 191, 175, 159, 144, 129, 115, 103,
   40,  80,  69,  58,  50,  41,  34,  28,  21,  16,
```

```
  12,   8,   5,   4,   3,   3,   4,   5,   8,  12,
  16,  21,  28,  34,  41,  50,  58,  69,  80,  90,
 103, 115, 129, 144, 159, 175, 191, 210, 228, 246 },
{ 249, 231, 213, 194, 178, 161, 146, 132, 118, 105,
  93,  81,  71,  61,  52,  44,  36,  29,  23,  18,
  14,  11,   8,   7,   6,   6,   7,   8,  11,  14,
  18,  23,  29,  36,  44,  52,  61,  71,  81,  93,
 105, 118, 132, 146, 161, 178, 194, 213, 231, 249 },
{ 254, 233, 215, 198, 181, 165, 149, 134, 121, 107,
  96,  84,  73,  64,  54,  45,  39,  33,  27,  22,
  17,  14,  12,  10,   9,   9,  10,  12,  14,  17,
  22,  27,  33,  39,  45,  54,  64,  73,  84,  96,
 107, 121, 134, 149, 165, 181, 198, 215, 233, 254 },
{ 257, 238, 219, 202, 183, 167, 153, 137, 124, 111,
  98,  88,  78,  68,  59,  51,  43,  37,  30,  26,
  22,  18,  16,  15,  13,  13,  15,  16,  18,  22,
  26,  30,  37,  43,  51,  59,  68,  78,  88,  98,
 111, 124, 137, 153, 167, 183, 202, 219, 238, 257 },
{ 258, 241, 222, 204, 188, 173, 158, 143, 131, 117,
 104,  94,  82,  72,  63,  55,  49,  42,  35,  30,
  27,  23,  21,  20,  19,  19,  20,  21,  23,  27,
  30,  35,  42,  49,  55,  63,  72,  82,  94, 104,
 117, 131, 143, 158, 173, 188, 204, 222, 241, 258 },
{ 259, 247, 230, 212, 195, 179, 164, 148, 135, 122,
 110,  97,  87,  79,  70,  62,  53,  47,  42,  37,
  33,  29,  28,  25,  24,  24,  25,  28,  29,  33,
  37,  42,  47,  53,  62,  70,  79,  87,  97, 110,
 122, 135, 148, 164, 179, 195, 212, 230, 247, 259 },
{ 261, 255, 236, 217, 201, 185, 168, 154, 141, 128,
 116, 106,  95,  85,  75,  67,  60,  53,  49,  43,
  39,  36,  34,  32,  31,  31,  32,  34,  36,  39,
  43,  49,  53,  60,  67,  75,  85,  95, 106, 116,
 128, 141, 154, 168, 185, 201, 217, 236, 255, 261 },
{ 263, 260, 242, 225, 207, 192, 177, 163, 147, 136,
 123, 112, 102,  92,  83,  74,  67,  62,  55,  51,
  45,  44,  41,  40,  38,  38,  40,  41,  44,  45,
  51,  55,  62,  67,  74,  83,  92, 102, 112, 123,
 136, 147, 163, 177, 192, 207, 225, 242, 260, 263 },
{ 265, 264, 251, 232, 216, 200, 184, 169, 156, 145,
 133, 120, 109, 100,  91,  83,  75,  70,  63,  59,
  54,  52,  50,  48,  46,  46,  48,  50,  52,  54,
  59,  63,  70,  75,  83,  91, 100, 109, 120, 133,
 145, 156, 169, 184, 200, 216, 232, 251, 264, 265 },
{ 268, 266, 262, 240, 224, 209, 193, 180, 166, 152,
 139, 130, 119, 108, 100,  92,  85,  79,  72,  68,
  64,  61,  58,  57,  56,  56,  57,  58,  61,  64,
  68,  72,  79,  85,  92, 100, 108, 119, 130, 139,
 152, 166, 180, 193, 209, 224, 240, 262, 266, 268 },
{ 270, 269, 267, 252, 234, 218, 203, 187, 176, 162,
 151, 138, 127, 119, 109, 102,  95,  87,  82,  78,
  73,  71,  69,  66,  65,  65,  66,  69,  71,  73,
  78,  82,  87,  95, 102, 109, 119, 127, 138, 151,
 162, 176, 187, 203, 218, 234, 252, 267, 269, 270 },
{ 274, 273, 272, 271, 244, 229, 214, 199, 186, 172,
 160, 150, 138, 130, 120, 112, 106,  97,  94,  88,
  84,  81,  80,  77,  76,  76,  77,  80,  81,  84,
  88,  94,  97, 106, 112, 120, 130, 138, 150, 160,
 172, 186, 199, 214, 229, 244, 271, 272, 273, 274 },
{ 279, 277, 276, 275, 256, 239, 223, 211, 197, 182,
 170, 160, 151, 139, 133, 123, 116, 110, 104,  98,
  96,  93,  90,  89,  86,  86,  89,  90,  93,  96,
  98, 104, 110, 116, 123, 133, 139, 151, 160, 170,
 182, 197, 211, 223, 239, 256, 275, 276, 277, 279 },
{ 286, 285, 283, 281, 278, 253, 237, 221, 208, 196,
 182, 172, 162, 152, 145, 136, 128, 122, 117, 111,
 107, 105, 103, 101,  99,  99, 101, 103, 105, 107,
 111, 117, 122, 128, 136, 145, 152, 162, 172, 182,
 196, 208, 221, 237, 253, 278, 281, 283, 285, 286 },
{ 294, 292, 290, 289, 284, 280, 250, 235, 220, 208,
```

```
  197, 186, 176, 166, 156, 147, 141, 135, 131, 124,
  121, 118, 115, 114, 113, 113, 114, 115, 118, 121,
  124, 131, 135, 141, 147, 156, 166, 176, 186, 197,
  208, 220, 235, 250, 280, 284, 289, 290, 292, 294 },
{ 300, 299, 297, 295, 291, 287, 282, 248, 235, 221,
  211, 199, 187, 180, 169, 163, 154, 148, 143, 137,
  134, 132, 129, 126, 125, 125, 126, 129, 132, 134,
  137, 143, 148, 154, 163, 169, 180, 187, 199, 211,
  221, 235, 248, 282, 287, 291, 295, 297, 299, 300 },
{ 306, 304, 303, 301, 296, 293, 288, 282, 250, 237,
  223, 214, 203, 193, 184, 177, 168, 164, 158, 153,
  149, 146, 144, 142, 140, 140, 142, 144, 146, 149,
  153, 158, 164, 168, 177, 184, 193, 203, 214, 223,
  237, 250, 282, 288, 293, 296, 301, 303, 304, 306 },
{ 311, 310, 308, 305, 302, 298, 293, 287, 280, 253,
  239, 229, 218, 209, 200, 192, 185, 179, 173, 167,
  165, 161, 159, 157, 155, 155, 157, 159, 161, 165,
  167, 173, 179, 185, 192, 200, 209, 218, 229, 239,
  253, 280, 287, 293, 298, 302, 305, 308, 310, 311 },
{ 315, 314, 312, 309, 307, 302, 296, 291, 284, 278,
  256, 244, 234, 224, 216, 207, 201, 195, 188, 183,
  181, 178, 175, 174, 171, 171, 174, 175, 178, 181,
  183, 188, 195, 201, 207, 216, 224, 234, 244, 256,
  278, 284, 291, 296, 302, 307, 309, 312, 314, 315 },
{ 319, 317, 316, 313, 309, 305, 301, 295, 289, 281,
  275, 271, 252, 240, 232, 225, 217, 212, 204, 202,
  198, 194, 191, 190, 189, 189, 190, 191, 194, 198,
  202, 204, 212, 217, 225, 232, 240, 252, 271, 275,
  281, 289, 295, 301, 305, 309, 313, 316, 317, 319 },
{ 321, 320, 318, 316, 312, 308, 303, 297, 290, 283,
  276, 272, 267, 262, 251, 242, 236, 230, 222, 219,
  215, 213, 210, 206, 205, 205, 206, 210, 213, 215,
  219, 222, 230, 236, 242, 251, 262, 267, 272, 276,
  283, 290, 297, 303, 308, 312, 316, 318, 320, 321 },
{ 323, 322, 320, 317, 314, 310, 304, 299, 292, 285,
  277, 273, 269, 266, 264, 260, 255, 247, 241, 238,
  233, 231, 228, 227, 226, 226, 227, 228, 231, 233,
  238, 241, 247, 255, 260, 264, 266, 269, 273, 277,
  285, 292, 299, 304, 310, 314, 317, 320, 322, 323 },
{ 324, 323, 321, 319, 315, 311, 306, 300, 294, 286,
  279, 274, 270, 268, 265, 263, 261, 259, 258, 257,
  254, 249, 246, 245, 243, 243, 245, 246, 249, 254,
  257, 258, 259, 261, 263, 265, 268, 270, 274, 279,
  286, 294, 300, 306, 311, 315, 319, 321, 323, 324 },
    }
};

void    intePart(void);
void    alloPart(void);
void    readPart(void);
void    procPart(void);
void    writPart(void);

/*Start of main*/
void main(void)
{
    printf("---Dither 50*50 Program---\n\n");
        intePart();
    printf("Allocating MemoryÉ\n");
        alloPart();
    printf("Reading Image...    %30s\n",&name1);
        readPart();
    printf("Processing Image... %30s\n",&name1);
        procPart();
    printf("Writing Image...    %20s\n",name2);
        writPart();
    printf("Success! Goodbye\n");
}
```

```
/*Interface Part*/
void intePart(void){
    printf("Please Type The Filename Of Input Image : ");
    scanf("%s", name1);
    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("\n0=HT_Type4, 1=HT_Type5\n");
    printf("Please Type What KIND Of Dither Pattern : \n");
    scanf("%d", &kind);
    printf("Please Type What Size of Halftone Cell  : \n");
    scanf("%d" , &CellSize);
}

void alloPart(void)
{
    filein = (unsigned char *)malloc(sizeof(unsigned char)*xsize*ysize);
    if(filein == (unsigned char *)NULL){
        printf("Missing Memory...\n");
        exit(1);
        }
    fileout = (unsigned char *)malloc(sizeof(unsigned char)*xsize*ysize);
    if(fileout == (unsigned char *)NULL){
        printf("Missing Memory...\n");
        exit(1);
        }
}

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 procPart(void)
{
    int      x,y,z;
    long     i;
    double   sl,da;
    int      tmp;
    float    s,c;
    float    xr,yr;       /* coordinate after rotation */
    float    xrm;         /* maximum negative xr value after rotation */

    x = y = z = i = 0;
    if(kind>MAX){
        printf("KIND value was wrong...\n");
        exit(1);
        }

    bit = 1;                          /*Bit is fixed to 1*/

    tmp = pow( (double) 2.0 , (double) bit ) - 1.0;    /*tmp = Number of gra
y level*/

    printf("    Output Image Tones = %d tones\n",tmp+1);

    Angle= Angle*PI/180.0;
```

```
    s=sin(Angle), c=cos(Angle);
    xrm= ysize*s;
    for( y = 0 ; y < ysize ; y++){
        for( x = 0 ; x < xsize ; x++){
            xr = x*c - y*s;
            xr+=xrm ;
            yr =  x*s + y*c;
            da = 1-(double)filein[i]/255.0;                  /* 0 - 1.0 */
            sl = (double)(mat[kind][(int)yr%CellSize][(int)xr%CellSize])/32
4.0; /* -0.5 - +0.5 */
            da = floor(da-sl+1);              /* 0.5 - 1.5 */
            fileout[i++] = (char) (da*255.0);
        }
    }
}

void    writPart(void)
{
    long i;
    FILE    *fp;
    double  c;
    fp = fopen(name2,"wb");

    if(fp == (FILE *)NULL){
        printf("fileOpenError\n");
        exit(1);
        }

    for(i=0;i<xsize*ysize;i++){
        c = fileout[i];
        if( c < 0)
            c = 0 ;
        if( c > 255 )
            c = 255 ;
        fputc((int)c,fp);
    }
    fclose(fp);
}
```

VITA

Miss Juleeporn Kunlayajitkoson was born on July 4,1975, in Bangkok, Thailand. She receives her B.Sc. in Photographic and Printing Science from Department of Imaging and Printing Technology, Faculty of science, Chulalongkorn University. She began her master degree study in Imaging Technology, Department of Imaging and Printing Technology, Faculty of science, Chulalongkorn University since 1997.