CHAPTER 4

EXPERIMENT

4.1 Material

4.1.1 Paper

- plain laser paper 100 gsm
- Mitsubishi Paper for inkjet (gloss type) 120 gsm

4.1.2 Ink

- Process Toner for Canon Color Laser Copier 1120
- Process Inkjet inks for Canon Bubble jet BJC8500

4.2 Apparatus

4.2.1 Spectrophotometer

- Gretag Spectrolino Scan

4.2.2 Digital Color Printer

- Canon Color Laser Copier 1120
- Canon Bubble jet BJC8500

4.2.3 Personal Computer

- Pentium III series

4.2.4 Software

- MATLAB R12
- Adobe Photoshop version 6.0
- Microsoft Excel 97

4.3 Procedure

4.3.1 Equipment setup

Personal Computer is properly connected to spectrophotometer and digital color printer. The softwares and the drivers of all devices are installed.

4.3.2 LUT data creation

The *LUT data* is created by *Matlab* in *RGB* device color space. There are two sets of *LUT data*: 1.) 343-color patch, 7x7x7 evenly uniform divided in *RGB* device color space, 2.) 729-color patch, 9x9x9 evenly uniform divided in *RGB* device color space.

4.3.3 Printer calibration and color chart printing

The printer is calibrated regarding the manufacture specification. Then the *Input Signal* $[X_{lut}]_i$ are sent to print by *Adobe Photoshop* with default program parameters and without any color matching function as shown in Figure 4-1. The results are color chart which is correspond to each set of *Input Signal* $[X_{lut}]_i$.

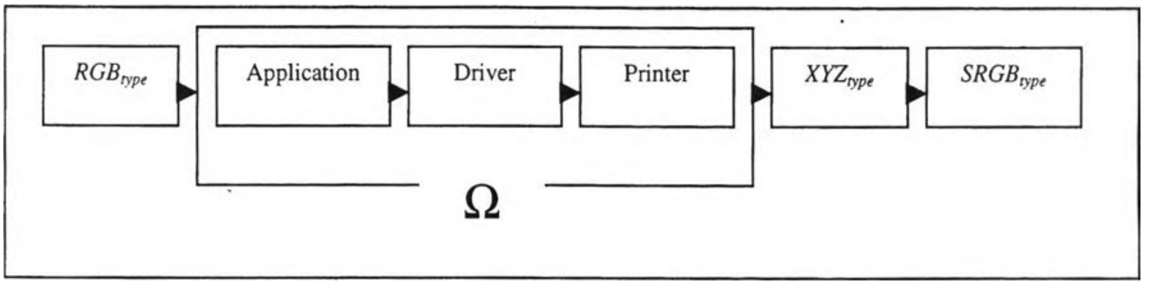

Figure 4-1 The schematic diagram of the *LUT data* generating

4.3.4 Color chart measuring

The printout of color chart is measured by spectrophotometer to obtain the *CIEXYZ*$_{D65}$ numerical values. Then they are converted to *sRGB* numerical values, by following coefficient of transformation:

$$\begin{bmatrix} X_{D65} \\ Y_{D65} \\ Z_{D65} \end{bmatrix} = \begin{bmatrix} 0.4124 & 0.3576 & 0.1805 \\ 0.2126 & 0.7152 & 0.0722 \\ 0.0193 & 0.1192 & 0.9505 \end{bmatrix} \begin{bmatrix} R_{sRGB} \\ G_{sRGB} \\ B_{sRGB} \end{bmatrix}$$

$$\begin{bmatrix} R_{sRGB} \\ G_{sRGB} \\ B_{sRGB} \end{bmatrix} = \begin{bmatrix} 3.2410 & -1.5374 & -0.4986 \\ -0.9692 & 1.8760 & 0.0416 \\ 0.0556 & -0.2040 & 1.0570 \end{bmatrix} \begin{bmatrix} X_{D65} \\ Y_{D65} \\ Z_{D65} \end{bmatrix} \qquad (4\text{-}1)$$

The measured values are stored in the LUT. And, each LUT is converted to be *Backward LUT data* (φ^{-1}).

4.3.5 Proposed method origination

The proposed method of this research is to apply the 1st, 2nd and 3rd order linear regression to the *Backward LUT data* (φ^{-1}) in *sub-divided color space*. The alternatives of partitioning color space are: tetrahedron divided by plane R+G+B=384 and whole space as shown below.

4.3.5.1 Order of Regression Model

- First Order 4 terms (3x4 coefficient matrix)

$$R_{RGB} = a_0+a_1R_1+a_2R_2+a_3R_3$$

$$G_{RGB} = b_0+b_1R_1+b_2R_2+b_3R_3$$

$$B_{RGB} = c_0+c_1R_1+c_2R_2+c_3R_3$$

(4-2)

- Second Order 11 terms (3x11 coefficient matrix)

$$R_{RGB} = a_0+a_1R_1+a_2R_2+a_3R_3+a_4R_4+a_5R_5+a_6R_6+a_7R_7+a_8R_8+a_9R_9$$

$$G_{RGB} = b_0+b_1R_1+b_2R_2+b_3R_3+b_4R_4+b_5R_5+b_6R_6+b_7R_7+b_8R_8+b_9R_9$$

$$B_{RGB} = c_0+c_1R_1+c_2R_2+c_3R_3+c_4R_4+c_5R_5+c_6R_6+c_7R_7+c_8R_8+c_9R_9$$

(4-3)

- Third Order 14 terms (3x14 coefficient matrix)

$$R_{RGB} = a_0+a_1R_1+a_2R_2+a_3R_3+a_4R_4+a_5R_5+a_6R_6+a_7R_7+a_8R_8+a_9R_9+a_{10}R_{10} +a_{12}R_{12}+a_{13}R_{13}$$

$$G_{RGB} = b_0+b_1R_1+b_2R_2+b_3R_3+b_4R_4+b_5R_5+b_6R_6+b_7R_7+b_8R_8+b_9R_9+b_{10}R_{10} +b_{12}R_{12} +b_{13}R_{13}$$

$$B_{RGB} = c_0+c_1R_1+c_2R_2+c_3R_3+c_4R_4+c_5R_5+c_6R_6+c_7R_7+c_8R_8+c_9R_9+c_{10}R_{10} +c_{12}R_{12} +c_{13}R_{13}$$

(4-4)

- Third Order 20 terms (3x20 coefficient matrix)

$$R_{RGB} = a_0+a_1R_1+a_2R_2+a_3R_3+a_4R_4+a_5R_5+a_6R_6+a_7R_7+a_8R_8+a_9R_9+a_{10}R_{10} +a_{12}R_{12} +a_{13}R_{13}+a_{14}R_{14}+a_{15}R_{15}+a_{16}R_{16}+a_{17}R_{17}+a_{18}R_{18}+a_{19}R_{19}$$

$$G_{RGB} = b_0+b_1R_1+b_2R_2+b_3R_3+b_4R_4+b_5R_5+b_6R_6+b_7R_7+b_8R_8+b_9R_9+b_{10}R_{10} +b_{12}R_{12} +b_{13}R_{13}+b_{14}R_{14}+b_{15}R_{15}+b_{16}R_{16}+b_{17}R_{17}+b_{18}R_{18}+b_{19}R_{19}$$

$$B_{RGB} = c_0+c_1R_1+c_2R_2+c_3R_3+c_4R_4+c_5R_5+c_6R_6+c_7R_7+c_8R_8+c_9R_9+c_{10}R_{10} +c_{12}R_{12} +c_{13}R_{13}+c_{14}R_{14}+c_{15}R_{15}+c_{16}R_{16}+c_{17}R_{17}+c_{18}R_{18}+c_{19}R_{19}$$

(4-5)

where; R_i is a function of $[Y_{lut,sRGB}]_i$ that a combination of three parameters as follow:

$$R_1= R_{sRGB}$$

$$R_2= G_{sRGB}$$

$$R_3= B_{sRGB}$$

$R_4 = R_{sRGB} . G_{sRGB}$

$R_5 = G_{sRGB} . B_{sRGB}$

$R_6 = B_{sRGB} . R_{sRGB}$

$R_7 = (R_{sRGB})^2$

$R_8 = (G_{sRGB})^2$

$R_9 = (B_{sRGB})^2$

$R_{10} = R_{sRGB} . G_{sRGB} . B_{sRGB}$

$R_{11} = (R_{sRGB})^3$

$R_{12} = (G_{sRGB})^3$

$R_{13} = (B_{sRGB})^3$

$R_{14} = (R_{sRGB})^2 . G_{sRGB}$

$R_{15} = (G_{sRGB})^2 . B_{sRGB}$

$R_{16} = (B_{sRGB})^2 . R_{sRGB}$

$R_{17} = R_{sRGB} . (G_{sRGB})^2$

$R_{18} = G_{sRGB} . (B_{sRGB})^2$

$R_{19} = B_{sRGB} . (R_{sRGB})^2$

4.3.5.2 Partition Method

- Whole space

This method uses all of the *LUT data* to calculate the coefficient. The *Coefficient Partition* and *Target Partition* are the same boundary. The *Overlapping Pratition* is not exist.

- Tetrahedral method divided by plan of $R+G+B = 383$

The $sRGB$ color space is divided into tetrahedral *sub-space* and divided again by the plane of equation $R+G+B = 383$.

Coefficient Partition is follows the condition below.

Section 1

$R_{sRGB} > (G_{sRGB} - 25),\ G_{sRGB} > (B_{sRGB} - 25)$ *and* $R+G+B > 383$

Section 2

$R_{sRGB} > (G_{sRGB} - 25),\ G_{sRGB} > (B_{sRGB} - 25)$ *and* $R+G+B < 384$

Section 3

$R_{sRGB} > (B_{sRGB} - 25),\ B_{sRGB} > (G_{sRGB} - 25)$ *and* $R+G+B > 383$

Section 4

$R_{sRGB} > (B_{sRGB} - 25),\ B_{sRGB} > (G_{sRGB} - 25)$ *and* $R+G+B < 384$

Section 5

$G_{sRGB} > (R_{sRGB} - 25),\ R_{sRGB} > (B_{sRGB} - 25)$ *and* $R+G+B > 383$

Section 6

$G_{sRGB} > (R_{sRGB} - 25),\ R_{sRGB} > (B_{sRGB} - 25)$ *and* $R+G+B < 384$

Section 7

$G_{sRGB} > (B_{sRGB} - 25),\ B_{sRGB} > (R_{sRGB} - 25)$ *and* $R+G+B > 383$

Section 8

$G_{sRGB} > (B_{sRGB} - 25),\ B_{sRGB} > (R_{sRGB} - 25)$ *and* $R+G+B < 384$

Section 9.

$B_{sRGB} > (R_{sRGB} - 25),\ R_{sRGB} > (G_{sRGB} - 25)$ *and* $R+G+B > 383$

Section 10

$B_{sRGB} > (R_{sRGB} - 25), R_{sRGB} > (G_{sRGB} - 25)$ and $R+G+B < 384$

Section 11

$B_{sRGB} > (G_{sRGB} - 25), G_{sRGB} > (R_{sRGB} - 25)$ and $R+G+B > 383$

Section 12

$B_{sRGB} > (G_{sRGB} - 25), G_{sRGB} > (R_{sRGB} - 25)$ and $R+G+B < 384$

And, *Target Partition* is follow the condition below.

Section 1

$R_{sRGB} > G_{sRGB} > B_{sRGB}$ and $R+G+B > 383$

Section 2

$R_{sRGB} > G_{sRGB} > B_{sRGB}$ and $R+G+B < 384$

Section 3

$R_{sRGB} > B_{sRGB} > G_{sRGB}$ and $R+G+B > 383$

Section 4

$R_{sRGB} > B_{sRGB} > G_{sRGB}$ and $R+G+B < 384$

Section 5

$G_{sRGB} > R_{sRGB} > B_{sRGB}$ and $R+G+B > 383$

Section 6

$G_{sRGB} > R_{sRGB} > B_{sRGB}$ and $R+G+B < 384$

Section 7

$G_{sRGB} > B_{sRGB} > R_{sRGB}$ and $R+G+B > 383$

Section 8

$G_{sRGB} > B_{sRGB} > R_{sRGB}$ and $R+G+B < 384$

Section 9.

$B_{sRGB} > R_{sRGB} > G_{sRGB}$ *and* $R+G+B > 383$

Section 10

$B_{sRGB} > R_{sRGB} > G_{sRGB}$ *and* $R+G+B < 384$

Section 11

$B_{sRGB} > G_{sRGB} > R_{sRGB}$ *and* $R+G+B > 383$

Section 12

$B_{sRGB} > G_{sRGB} > R_{sRGB}$ *and* $R+G+B < 384$

The *Overlapping Partition*, in this case, is 25 unit for each section. Then, the overlapping boundary of each pair of partition is 50 unit. *Matlab Program 01* is used to simulates those methods to retrieve each coefficient.

4.3.6 Proposed analysis method

The *Testing data* uses to test the performance of each algorithm, is applied to each algorithm which is also done by *Matlab Program 01.* Figure 4-2 shows the schematic diagram of the evaluation process.

The printout of those *Testing data* are measured by spectrophotometer to obtain the *CIELAB* numerical values.

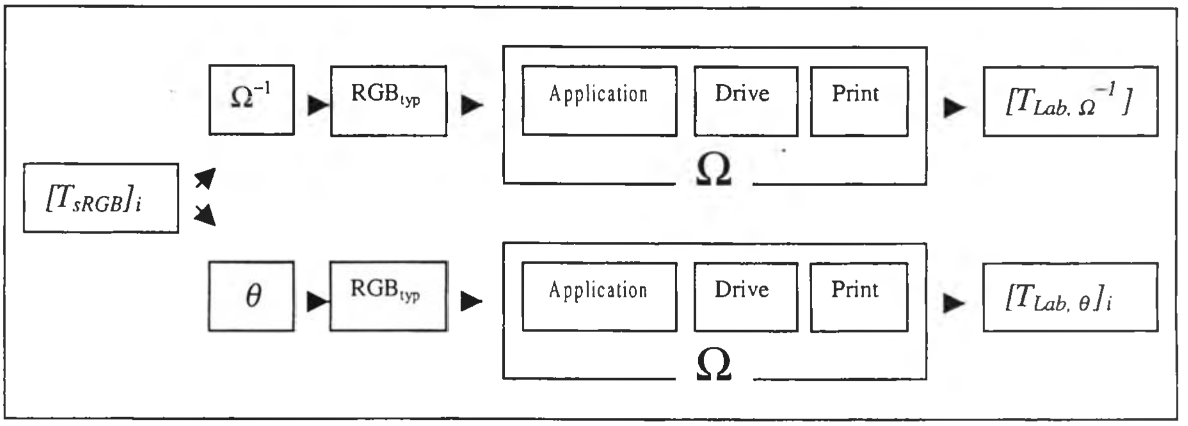

Figure 4-2 The methodology of analysis

4.3.6.1 Proposed method analysis

The Testing data in *sRGB* color space are converted to *CIELAB* color space to compare with the measured *CIELAB*.

The result is performed by the equation in XXX.

4.3.6.2 Testing data

T_{uni} are 14x14x14 data which is evenly sampling of whole *sRGB* color space. Then, they are croped by color gamut of printer, denoted as:

$$[T_{sRGB\text{-}uni}]_i = [\, T_{R\text{-}uni},\ T_{G\text{-}uni},\ T_{B\text{-}uni}\,]_i \qquad (4\text{-}6)$$

T_{lut} are domain of signal in backward *LUT data*, denoted as:

$$[T_{sRGB\text{-}lut}]_i = [\, T_{R\text{-}lut},\ T_{G\text{-}lut},\ T_{B\text{-}lut}\,]_i \qquad (4\text{-}7)$$

T_{glo} are global signal testing data, denoted as:

$$[T_{sRGB\text{-}glo}]_i = [\, T_{R\text{-}glo},\, T_{G\text{-}glo},\, T_{B\text{-}glo} \,]_i \qquad (4\text{-}8)$$

The response of testing data by Ω^{-1}, denoted as:

$$[T_{Lab\text{-}uni,\, \varphi-1}]_i = [\, L_{uni,\, \varphi-1},\, a_{uni,\, \varphi-1},\, b_{uni,\, \varphi-1} \,]_i$$

$$[T_{Lab\text{-}lut,\, \varphi-1}]_i = [\, L_{lut,\, \varphi-1},\, a_{lut,\, \varphi-1},\, b_{lut,\, \varphi-1} \,]_i \qquad (4\text{-}9)$$

$$[T_{Lab\text{-}glo,\, \varphi-1}]_i = [\, L_{glo,\, \varphi-1},\, a_{glo,\, \varphi-1},\, b_{glo,\, \varphi-1} \,]_i$$

The approximated value of testing data by θ, denoted as:

$$[T_{Lab\text{-}uni,\, \theta}]_i = [\, L_{uni,\, \theta},\, a_{uni,\, \theta},\, b_{uni,\, \theta} \,]_i$$

$$[T_{Lab\text{-}lut,\, \theta}]_i = [\, L_{lut,\, \theta},\, a_{lut,\, \theta},\, b_{lut,\, \theta} \,]_i \qquad (4\text{-}10)$$

$$[T_{Lab\text{-}glo,\, \theta}]_i = [\, L_{glo,\, \theta},\, a_{glo,\, \theta},\, b_{glo,\, \theta} \,]_i$$