CHAPTER 1

INTRODUCTION

The characterization of a color output device such as a digital color printer defines the relationship between the device color space and a device-independent color space, typically based on CIE colorimetry. This relationship defines a (forward) printer model. Several approaches to printer modeling exist in the literature. They may be divided into two main groups:

1.) Physical models. Such models are based on knowledge of the physical or chemical behavior of the printing system, and are thus inherently dependent on the technology used (ink jet, dye Sublimation, etc.). An important example of physical models for halftone devices is the Neugebauer model, which treats the printed color as an additive mixture of the tristimulus values of the paper, the primary colors, and any overlap of primary colors.

2.) Empirical models. Such models do not explicitly require knowledge of the physical properties of the printer as they rely only on the measurement of a large number of color samples, used either to optimize a set of linear equations based on regression algorithms, or to build lookup-tables for 3D interpolation. Simple regression models have not been found very successful in printer modeling but the lookup-table.

However, both these groups of printer models have to be inverted to be of practical use for image reproduction, since what we typically need is to transform images colorimetrically defined in a given color space into the color space specify to the printer. The solution to this inverse problem is difficult to find. Iterated optimization algorithms are often needed to determine the device color coordinates, which reproduce a given color defined in a device-independent color space, as proposed.

The proposed method is in category of empirical model that is versatile. It may be applied to printers using different printing technologies, and even to other types of image reproduction devices, such as monitors. In comparison, state-of-the-art physical printer models are limited to one printing technology. Furthermore, the determination of the inverse transformation with physical models requires very extensive computation with non-linear optimization techniques, which preferred to avoid.

The proposed characterization technique based on an empirical model provides a practical tool to transform colors between any two-color spaces, for example between scanner RGB and printer CMY device space. In a color management application, it is preferred to connect the device-dependent color representations to some device-independent color space.

The sRGB color space is chosen for this purpose since it is used as a communication standard. Thus the characterization technique provides the transformation between any color point in sRGB color space and the corresponding printer values, which treated as RGB model, are needed to reproduce the given color.

The three-dimensional 3D look-up table (LUT) with interpolation is a relatively new development in color space transformation. It consists of three parts: partition, find, and interpolation. Partition is process that divides the domain of the source space and populates it with sample point to build the lookup table. In general, the table is built by an equal-step sampling along each axis of source space. The advantage of this arrangement is that simplicity supplies the information about which cell is next to which. Hence, the only need is information of the starting point and the interval for each axis.

Generally, patches at the lattice points of the source space are made, and the destination color specifications of these patches are measured. The corresponding values from the source and destination spaces are tabulated into a look-up table. Non-lattice points are interpolated by using the nearest points, which is the step of finding the necessary points to calculate. There are many interpolation techniques to find the correspond value of non-lattice point. For example, the geometry interpolation, such as Prism, Pyramid, and Tetrahedral, or the Regression method including its 1st, 2nd and higher order.

Basically, the 3D interpolation is the multiple applications of the linear interpolation. The interpolated value is linearly proportional to the ratio of the distance between non-lattice distance and its interval. For the 3D interpolation, it's derived by applying seven time of the linear interpolation according to their nearest eight points.

Regression methods is an estimate the mean value of a response variable y or predicting some future value of y based on knowledge of a set of related independent variables, such as a set of known values of $\{(x_1,y_1), (x_2,y_2), (x_3,y_3),\ldots, (x_n, y_n)\}$.

The models used to relate a dependent variable y to the independent variables x are called regression models or linear statistical models because they express the mean value of y for given values of $x_1, x_2, x_3,\ldots, x_n$ as a linear function of a set of unknown parameters.

The set of known values obtained from measure of color samples in destination space. Then, regression is performed to selected points, with known color specifications in both source and destination spaces, for deriving the coefficients of the polynomial. The only requirement is that the number of points should be higher than the number of polynomial terms; otherwise, there will be no unique solutions to the simultaneous equations because there are more unknown variables than equation. The procedure to solve the simultaneous equations, to obtain the coefficients of the polynomial, is matrix algebra method. Then, the result is coefficient matrix.

Another constituent is number of data, or color samples, that use to derive the coefficient matrix. There is difference of accuracy, to approximate the result, between the use of coefficient matrix obtain from whole of data and portion of data around the interested point. In geometric viewpoint, this is the method of divide data into sub-space then derive the coefficient matrices from each sub-space because the data can arranged itself as axis to form the space. Hence, there are several alternatives to partition the data space.

The proposed technique is combination of 3D-partition method with regression model. The regression model is applied to a small lattice cell instead of the entire color space. They have benefit to combine these techniques together because:

- Like the trilinear interpolation, there is no need to find the position of the interpolation point within the cube.
- There is no need of a uniform sampling; it can apply to any 3D structure, such as distorted hexahedral.
- It can accommodate any mathematical expression, such as square-root, logarithm, and exponential terms.

- It can have any number of terms in the equation as long as the number does not exceed the number of vertices in the cube.

In this research, It is expected that this combination could extremely achieve the high accuracy of color transformation.

1.1 Objective

To elucidate the effect of partition methods and linear regression model on accuracy of color transformation between color spaces.

1.2 Scope of the Research

This research cover a new method to improve the accuracy of color transformation using coefficient matrices optimized in sub-divided color space.

The coefficient matrices obtained from 1st, 2nd and 3rd order of linear regression model while the partition methods are tetrahedral divided by a plane of R+G+B=383, and cubic without partition.

1.3 Content of the Thesis

Chapter 2 deals with the overview of the theoretical considerations and literature reviews. Chapter 3 explains the proposed new overlapping technique, which it is the important algorithm to achieve high accuracy color transformation.

This also explain the structure of the experiment, the concept of least square, the concept of partition and the concept of combination method as well as the concept of an evaluation the algorithms which used in the experiment.

In the Chapter 4, the description on materials under study, the experiment procedures and apparatuses are described.

Chapter 5 contains the results and discussion on this research. Finally, the results are concluded in chapter 6 also with some suggestion.