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# Performance Comparison of Colour Correction and Colour Grading Algorithm for Medical Imaging Applications

(Perbandingan Prestasi Algoritma Pembetulan Warna dan Penggredan Warna untuk Aplikasi Pengimejan Perubatan)

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ABSTRACT

*Different types of image acquisition devices render different measure of colour depending on the specification of devices; even a same device will give different values of colours rendered, taking at certain duration of times. Most of the researches nowadays have attempted to solve these limitations and the researches of colour correction algorithm has been evolved recently. Colour correction algorithm has been widely used in various fields such as food industry, medical imaging, forensic cyber applications, film industries etc. In medical imaging, researchers have considered colour correction as an essential part in their pre-processing step prior to diagnosis. There are various statistical methods in colour correction and colour grading algorithm being implemented nowadays and finding the best algorithm with high accuracy is non-trivial. This paper presents comparative analyses of colour correction techniques that combine colour correction and colour grading algorithm using conventional gamma correction, polynomial regression, and proposed polynomial regression with modified gamma Look-up Table (pgLUT). It has been observed that our proposed pgLUT colour correction algorithm outperformed the conventional methods by 16.5%.*

*Keywords: Medical image colour correction; colour grading; Gamma Correction; Polynomial Regression; look-up tables; comparative image analysis*

ABSTRAK

*Jenis peranti pemerolehan gambar yang berbeza memberikan ukuran warna yang berbeza bergantung kepada spesifikasi peranti; malah peranti yang sama akan memberikan nilai warna yang berbeza, yang diambil pada jangka masa tertentu. Sebilangan besar penyelidikan pada masa kini telah mencuba untuk menyelesaikan masalah ini dan penyelidikan algoritma pembetulan warna telah berkembang baru-baru ini. Algoritma pembetulan warna telah banyak digunakan dalam pelbagai bidang seperti industri makanan, pengimejan perubatan, aplikasi siber forensik, industri filem dan lain-lain. Dalam kaedah pengimejan perubatan, para penyelidik menganggap pembetulan warna sebagai proses yang penting iaitu sebagai langkah pra-pemprosesan sebelum diagnosis. Sekarang, terdapat pelbagai kaedah statistik di dalam pembetulan warna gambar menggunakan algoritma penggredan warna dan mencari algoritma terbaik dengan ketepatan yang tinggi adalah mencabar. Kajian ini menyajikan analisis perbandingan teknik pembetulan warna yang menggabungkan pembetulan warna dan algoritma penggredan warna melalui kaedah pembetulan gamma secara konvensional, regresi polinomial, dan regresi polinomial bersama kombinasi Jadual Pencarian Gamma yang diubah* *(pgLUT). Daripada kajian ini, telah diperhatikan bahawa algoritma pembetulan warna bersama pgLUT yang dicadangkan mengatasi ketepatan pembetulan gamma secara konvensional iaitu sebanyak 16.5%.*

*Kata kunci: Pembetulan warna; penggredan warna; pengimejan perubatan; pembetulan gamma; regresi polinomial; jadual carian; analisis perbandingan.*

## INTRODUCTION

The statistical concepts of regression analyses are very important in colour calibration fields corresponding in fitting a model to noisy data (pixels data in image) or to explore the relationships between predictors and outcome variables. Colour information and its consistency is one of the most important aspects especially in medical imaging fields. Regression analysis is one of the various methods to determine the colour correction co-efficient between the target values and the feature values.

Medical imaging involving the use of camera, inserted in human organs have been conducted since its first introduction in 1853 (Spaner et al. 1997). Digital images obtained from cameras such as endoscopy, colonoscopy, gastro endoscopy, and laryngoscopy provide perception in medical diagnosis (Constantinou et al. 2020). For example, colonoscopy is an endoscopic examination by guiding the telescope in humans' bowel to investigate suspicious lesions of cancer (Rex et al. 2015), postal polypectomy, post cancer surveillance, iron deficiency anaemia, surveillance in bowel disease, and abnormal radiographic studies (Robinson et al. 2019). Physicians are only able to make diagnosis based on the quantitative colour tissue displayed on-screen, but most of the times the condition on-screen illuminated by poor lighting, unstable and sudden change in illumination thus produced both low contrast and quality images (Rani 2014; Wang, W. et al. 2019). In order to make this possible, colour standardization procedures have been proposed earlier to assist physicians in differentiating between normal and abnormal tissues (Yokoi et al. 2006).

Many researches have been conducted to improve image acquisition by implementing colour correction methods in efforts to produce accurate, versatile, and reproducible results (YongXia et al. 2019). Commonly used methods such as non-linear gamma correction and polynomial regression have been introduced in the medical technology. The non-linear gamma correction method improves image luminance with moderately good performance despite its simplicity. Several authors proposed gamma correction method in their image enhancement approaches such as in (Koutsouris 2020; Liang et al. 2009; Neophytou et al. 2006), however the method is time consuming during the selection of gamma parameter (Veluchamy & Subramani 2019)HE results in over-enhancement and intensity saturation effect in most cases. In this paper, an effective image contrast enhancement method called an Adaptive Gamma Correction with Weighted Histogram Distribution (AGCWHD). Other works enhance the method by introducing adaptive gamma correction methods using median, minimum and maximum values of cumulative histogram, gamma correction with weighting distribution, and dynamic gamma correction factor based on statistical information (Anjaiah & Sampath, K. 2013; Huang et al. 2013; Karuppanagounder & Palanisamy 2014; Rani 2014) we first perform Discrete Wavelet Transform (DWT). Furthermore, (Zhou et al. 2019) introduced methods known as Triple Dynamic Clipped Histogram Equalization (TDCHE) that keeps the relationship between controlling rate of increase, maintaining mean brightness, and maintaining average information content to stay balanced.

On the other hand, polynomial regression approximates complicated image pattern through continuous improved coefficients based on truth colour checker (Luo 2001; Xie et al. 2020). There have been works that proposed its application in human's retinal shading estimation, tongue diagnosis, and potential skin cancer imaging (Haeghen et al. 2000; Liu et al. 2020; Wang, X. & Zhang 2010).

In this paper, we proposed a hybrid adaptive gamma correction with polynomial regression method to get the advantage of both. We combined the benefits of improved luminance image with dynamic image enhancement to observe the quality of improvement over their traditional methods.

## METHODOLOGY

### COLOUR CORRECTION: POLYNOMIAL REGRESSION

Regression analysis allows prediction or estimation of the value of one variable (the response variables, dependent) from one or more predictor variable (often called regressor, independent, input features). Simple linear regression predicted, over a single value independent variable, as shown in Figure 1, while multiple linear regression predicted two or more continuous independent variables, . The regression line in blue colour fits the predicted value which is always asymmetric; that is the equation predicting from will almost always be different from the equation predicting from . The dissimilarities between the predicted and observed values are always referred as regression residuals and represent the errors of prediction. The most common relationship of all pairs of observation (*x,y*) is:

$$Y_i = a + bX_i + e_i \tag{1}$$

where the regression parameter, a is the intercept on the y-axis and parameter, b is the slope of the regression line. The random error is assumed to be uncorrelated with constant variance and zero mean. Because of less computational demand, the conventional least square method has been applied widely in many applications where it achieves optimum result when the underlying error distribution is Gaussian. Regrettably, this method becomes erratic if the noise has non-zero means components and if outliers (isolated samples or observations) are present in the data.

Polynomial regression analysis is also concerned with estimating a regression equation that best estimate, Y but from some optimal combination of independent variables. Despite lower execution time that can be an ideal solution to the online colour correction scheme, polynomial regression offers flexible optimization through its continuous variables and degree of transformation while maintaining low and tolerable error rate.

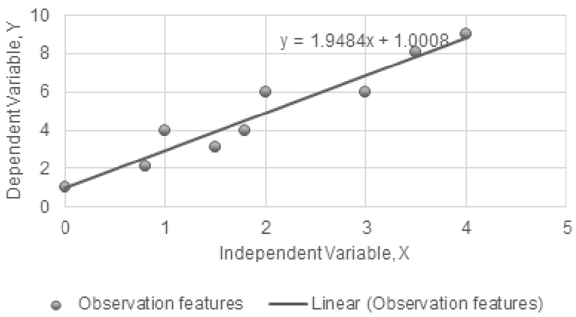


FIGURE 1. Example of hypothetical scatterplot shows the regression lines estimated

The equation of a polynomial or device independent representation can be viewed as a general transformation from camera view perspective depends on the degree of transformation. By referring to Equation (1), if we adopted the 5th polynomial models used in camera characterization and 24 colour patches of *Munsell* colour checker as reference, the non-linear transformation equation may look like:

$$\begin{aligned} SR_i &= a_{11}R_i + a_{12}G_i + a_{13}B_i \\ &\quad + a_{14}R_i\,G_i\,B_i + a_{15} \\ SG_i &= a_{21}R_i + a_{22}G_i + a_{23}B_i \\ &\quad + a_{24}R_i\,G_i\,B_i + a_{25} \\ SB_i &= a_{31}R_i + a_{32}G_i + a_{33}B_i + \\ & a_{34}R_i\,G_i\,B_i + a_{35} \end{aligned}$$

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Where $i$=1,2,3…….24

Note that, the SRGB value is the ground truth value from *Munsell* or *X-rite* Colour Checker that can be determined via standard industrial camera or the booklet reference by representative dealer whereas the RGBs values are the features pixels. The aim of every correction algorithm is to improve the regression coefficients ( $a_{11}, a_{12}, a_{13}$ …) using many optimization techniques (exhaustive or non-exhaustive) so that colour reproducibility of the distorted image can be improved as close as its ground truth value using reference colour checker. Most of the techniques in single or multiple linear regressions are often fitted by the Ordinary Least Square (OLS) approach. It is efficient under the assumptions that the errors have finite variance and are homoscedastic meaning that the $E[\varepsilon i^2/x_i]$ does not depend on *i* (the input features or predictor). Unfortunately, up to certain degrees of transformation, this method tends to over fit the data.

## COLOUR GRADING: CONVENTIONAL GAMMA CORRECTION AND ENHANCED GAMMA CORRECTION WITH LOOK UP TABLE (LUT)

Many researchers have implemented the conventional gamma correction along with their proposed colour correction methods. Gamma correction is a non-linear operation and is useful to code and decode the luminance of an image. Pixels with low intensities of an image (where gamma, $\gamma < 1$) can be brightened well using gamma correction and some preferred detail can be highlighted by using this algorithm. The process used to correct this power-law response phenomena is called gamma correction or gamma adjustment. Gamma can be any value between 0 and infinity. If gamma is 1 (the default), the mapping is linear. If gamma is less than 1, the mapping is weighted toward higher (brighter) output values. If gamma is greater than 1, the mapping is weighted toward lower (darker) output values.

Conventional Power Law transformations in gamma correction have the basis form:

$$V_{out} = V_{in}^{\gamma} \tag{3}$$

Moreover, gamma correction using LUT has been developed to test its performance along with proposed colour correction. The LUT can be expressed as:

$$Look - \text{Up tables}: \left[ \text{Maximum Intensity x} \left[ \frac{0:\text{Maximum Intensity}}{\text{Maximum Intensity}} \right]^{\gamma} \right] \quad (4)$$

## RESULTS AND DISCUSSION

### COLOUR CORRECTION: POLYNOMIAL REGRESSION

To examine the effectiveness of the polynomial regression algorithm with various degree transformation for colour correction, several experiments have been performed to observe their performances using 24 patches *X-rite* colour checker distorted image with its ground truth value on MATLAB platform. Then, the resulted image will be validated using colour reproduction index, as in Equation (5) to measure the colour error. The resulted image after $n^{th}$ polynomial colour correction is shown in Figure 2. It has been observed that, polynomial degree 3 outperformed other polynomial degrees in calibrating the distorted image.

(a) (b)

FIGURE 2. X-rite colour checker 24 patches, (a) colour distorted image (b) colour correction using Polynomial 3

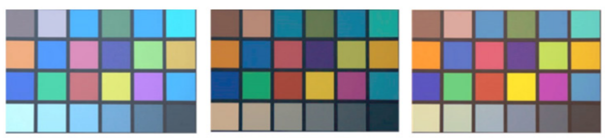
### COLOUR CORRECTION AND COLOUR GRADING: HYBRID TECHNIQUES

Further sequential experiments have been conducted to investigate the effect of colour grading as well as colour correction techniques using similar colour distorted image. The proposed colour correction using polynomial regression technique has been tested in hybrid with two techniques of gamma correction: conventional gamma correction and modified gamma correction with Look-Up Tables (LUT). The LUT formation and selection of this gamma value is very crucial as this can affect the performance of colour grading algorithm. Usually, the gamma, γ is chosen as 0.45. In our case, γ is chosen as 0.9 for optimum results in both hybrid techniques. By using colour reproduction index as in Equation (5), we have measured the colour error of resulted images to foresee the performance of proposed colour correction algorithm and other existing methods. In Figure 3(a), the colour error is recorded as the highest at 4.45 by using colour grading technique (gamma correction) solely. In contrast, by using hybrid techniques of colour correction (polynomial regression) and colour grading (conventional gamma correction), the colour error is significantly reduced to 0.85 as can be seen in Figure 3(b). Furthermore, by using our proposed techniques of colour correction (polynomial regression) and improved colour grading techniques (modified gamma LUT correction) (pgLUT), the colour error is reduced to 0.32 as can be seen in Figure 3(c). The comparative analysis in terms of colour error is given in Table 1.

TABLE 1. Performance comparison of proposed algorithm and other methods

| Techniques | Colour Error (24 patches) | Improved Colour Percentage |
|---|---|---|
| Distorted Image | 3.22 | 0 % |
| Using conventional gamma correction only | 4.45 | -38.2% |
| Using polynomial regression and conventional gamma | 0.85 | 73.6% |
| Using proposed polynomial regression with modified gamma LUT (pgLUT) | 0.32 | 90.1% |

Figure 3 shows the resulted images using our proposed algorithm and other conventional methods. As a conclusion, the experimental results interpret insight studies of using hybrid colour correction techniques on various medical imaging applications.



(a) (b) (c)

FIGURE 3. Colour correction results using (a) Conventional gamma correction (b) Polynomial regression and conventional gamma correction (c) Proposed polynomial regression with modified gamma LUT (pgLUT) correction

## CONCLUSION

In general, quality of image can be improved using colour correction, colour constancy, colour grading, or any hybrid colour correction techniques. The combination of colour correction and enhanced colour grading techniques (polynomial regression with modified gamma LUT) (pgLUT) is observed to perform better than other conventional colour correction algorithms. This result suggested any distorted images in medical imaging fields can be improved or corrected to promote higher colour reproducibility, hence enabling high quality research information for diagnosis, prognosis, and treatment options. As a conclusion, the proposed method using hybrid colour correction algorithm provides significant studies towards developing a conclusive diagnostic framework in a well-equipped health facility. Future study will be implementing and analysing the performance of this proposed hybrid colour correction technique using real-world medical images such as tongue diagnosis imaging, magnetic resonance imaging (MRI), ultrasound, and ct scan imaging.

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## DECLARATION OF COMPETING INTEREST

None

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