

## Estimated Spectral Reflectances of Jati Belanda Leaf Using Fourier Transformation

Dhieka Avrilia Lantana<sup>1</sup>, Yeni Herdiyeni<sup>1,3</sup>, Irmanida Batubara<sup>2,3</sup>

<sup>1</sup>Department of Computer Science, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University, Bogor 16680, Indonesia

<sup>2</sup>Department of Chemistry, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University, Bogor 16680, Indonesia

<sup>3</sup>Biopharmaca Research Center

\*Corresponding author, e-mail: dhieka.avrilia.lantana12@apps.ipb.ac.id, yenierdiyeni@gmail.com, ime@ipb.ac.id

### Abstract

This research proposes new method to estimate spectral reflectances of Jati Belanda (*Guazuma ulmifolia*) leaf based on digital image color. Jati Belanda is a medicinal plant containing antioxidant compounds. Spectral reflectances can be used to estimate chemical compounds but the tools to obtain spectral reflectances is very expensive. To estimate the Jati Belanda leaf reflectance values based on digital image color, we used Fourier Transformation. The estimated spectral reflectances are evaluated using root mean square error (RMSE) and goodness-of-fit coefficient (GFC). According to the experiment, dataset used is 276 leaves of medicinal plants and the best polynomial transformation is 3<sup>rd</sup> order with RMSE value 4,83 and GFC value 0.96. The future work could estimate the amount of chemical compounds in Jati Belanda Leaf using estimated spectral reflectances. Estimated spectral reflectances is an important part of estimated the amount of chemical compounds.

**Keywords:** polynomial transformation model, spectral reflectance, jati belanda, Fourier transformation

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### 1. Introduction

Herbal medicines are widely used by people to cure disease and maintain their health because the price is cheap and have little side effects [1]. One of the famous medicinal plants in Indonesia is Jati Belanda (*Guazuma ulmifolia*). Jati Belanda leaf contains chlorophyll and carotenoids. It is well known that chlorophyll and carotenoids show strong antioxidant properties [2, 3]. To maintain the quality of herbal medicines, quality control is needed. One method of quality control is to look spectral reflectance [4]. Some of antioxidant compounds, chlorophyll and carotenoids, has color. The color could be seen by spectral reflectance to control quality of Jati Belanda as a antioxidant.

Reflectance is the light reflected by the leaves, while absorption is the light absorbed by the leaves. The amount of active compounds on leaves effect on the value of reflectance and absorption. The leaves have good quality if the reflectance is small because they contain many active compounds so a lot of light is absorbed [5]. Measurement of spectral reflectances usually using a tools that called spectrophotometer. The use of spectrophotometer have some disadvantages such as price is expensive, difficult to operate and poor mobility. Therefore we need rapid and accurate techniques. To solve the problem, other techniques are needed to conduct quality control of medicinal plants by using digital image processing. Image processing is done by looking at the spectral reflectances from image that is taken by using a digital camera. Image processing offers an alternative that is faster, simple and nondestructive with approach to color techniques [6].

Reflectance estimation has been done by using Wiener Estimation [4], [6-7], Principle Component Analysis (PCA) [8-10], Fourier [9, 10] and Wavelet [9, 11]. One of the method, Fourier Transformation, show good and stable performace in all experiments according to [10]. In this research, Fourier Transformation is used for other alternatives as a method of reflectance estimation in medicinal plants leaf. Fourier Transformation has been widely used in image processing. Fourier Transformation is an algorithm for transform time domain into frequency

domain. Fourier Transformation will decompose a signal into its constituent sinusoidal components [12]. Polynomial transformation introduced by [13] was combined in reflectance estimation to establish the best fit in spectral reflectances. Output camera containing RGB values can be extended to higher order polynomial by adding and combining cross-products such as  $RG$ ,  $GB$ ,  $RB$ ,  $R^2$ .

## 2. Research Method

### 2.1. Proposed Techniques

The research methodology can be seen in Figure 1. The method consists of data acquisition, preprocessing, estimating the spectra reflectance, evaluating the result and determining the best model.

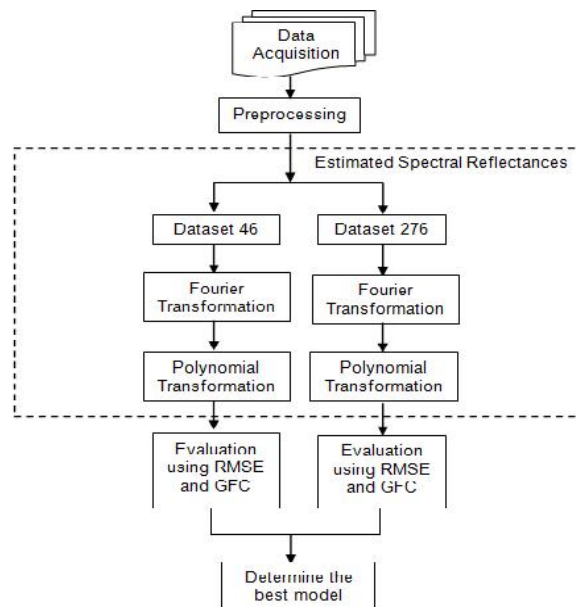


Figure 1. Research Method

### 2.2. Data Acquisition

This research use data from 46 leaves of medicinal plants (consist of young leaves and old leaves) as training set, 10 leaves of Jati Belanda plants as test. Data were taken from Garden of Biofarmaka Research Center Bogor Agricultural University. Spectral reflectances were measured for each leaf in the visibility range 400-700 nm. Each spectral reflectance consists of 515 values. Reflectance values were taken at the bottom of the veins as much as 6 points. Figure 2 shows the measurement of spectral reflectance using spectrophotometer.

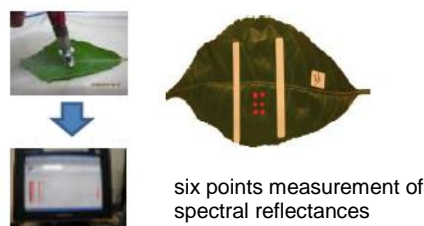


Figure 2. The Measurement of Spectral Reflectances using Spectrophotometer

After leaves were measured using spectrophotometer, each leaf is placed in a box that has a white background to capture image. The lighting in the box is using a Tungsten lamp at 15 watts. Image acquisition distance is set at 50 cm and 90° angle shots of the light source. It is because in order to capture the behavior of picture was same with the behavior of measurement by using spectrophotometer. There are two datasets used in this research, 46 leaves of medicinal plants and 276 leaves of medicinal plants. In dataset 46 leaves of medicinal plants, 6 point that measured using spectrophotometer are averaged to produce a single value. The mean value is used as the training set to estimate the value of reflectance. In dataset 276 leaves of medicinal plants, 6 points is used as the training set

### 2.3. Preprocessing

Preprocessing performed on image of leaf. Each image of leaf was crop in the same area with spectral reflectances retrieval by 100x100 pixels. Cropping is done in order to capture area of RGB value equal to the spectral reflectance retrieval.

### 2.3. Estimated Spectra Reflectance

The estimated spectral reflectances are done by using color of Red, Green and Blue from image. The image was obtained from digital camera. In linear model, reflectance reconstruction ( $\hat{r}$ ) can be approximated by a linear combination of a small number of basis function [14]. Linear model to estimate the spectral reflectances is using equation that conduct in [9]. The equation can be written as:

$$\hat{r} \approx B(S^T B)^{-1}d \quad (1)$$

Where:

- $\hat{r}$  = Reconstructed Spectral Reflectances
- $B$  = Basis Function
- $S$  = Spectral sensitivity
- $d$  = The camera output

Matrix  $S$  can be determined by following equation:

$$S = d^T r \quad (2)$$

Where  $d$  is camera output while  $r$  is original spectral reflectances that measure by spectrophotometer. Basis function could be compute using Fourier Transformation while the camera output could be increase by polynomial model.

### 2.4. Fourier Transformation

Fourier Transformation is the most important transformations in the field of signal processing, especially in image processing. It transforms a function from time or spatial domain into frequency domain [12]. Fourier Transformation was named by its inventor, Joseph Fourier. Fourier Transformation decompose a signal into a sinusoidal or waves in various frequencies whose the summation of waves is equivalent to the original wave [12]. If the value is discrete values, it can be used as a Discrete Fourier Transformation ( $F(u)$ ).

$$F(u) = \sum_{x=0}^{N-1} f(x)e^{-i\frac{2\pi ux}{N}} \quad (3)$$

Fourier Transformation inverse ( $f(x)$ ):

$$f(x) = \frac{1}{N} \sum_{u=0}^{N-1} F(u)e^{i\frac{2\pi ux}{N}} \quad (4)$$

in this case,

$i$  = imaginer =  $\sqrt{-1}$

$u$  = variable frequency

Both *Fourier Transformation* and *Fourier Transformation inverse* was called pair of *Fourier Transformation*. In Fourier Transformation, there is energy that called Power Spectrum ( $|F(u)|$ ). The highest power spectrum in certain frequency shows that frequency has important information. Power spectrum is obtained by Equation (3).

$$|F(u)| = \sqrt{R^2(u) + I^2(u)} \quad (5)$$

Where  $R(u)$  is real number and  $I(u)$  is imaginary number from the Fourier Transformation. The phase is expressed by following equation:

$$\theta(u) = \tan^{-1} \left[ \frac{I(u)}{R(u)} \right] \quad (6)$$

For each dataset, a DFT was performed using the CVDFFT function available in OpenCV.

### 2.5. The Polynomial Transformation Model

In this research, the polynomial transformation model for estimated spectra reflectances was used. The use of polynomial transformation model is to enhance reconstructed spectral reflectances. Polynomial transformation that used in this research can be seen in Table 1 according to [13].

Table 1. Polynomial Transformation

Orde	Terms	Polynomial Transformation
1	3	R G B
2	7	R G B R <sup>2</sup> G <sup>2</sup> B <sup>2</sup> RGB
3	10	R G B R <sup>2</sup> G <sup>2</sup> B <sup>2</sup> RG RB GB RGB

### 2.6. Evaluation using RMSE and GFC

In order to define dataset and the best order of the polynomial as training set, some evaluation were used to measure error and fitness. To evaluate reflectance estimation, we use two evaluations: Goodness-of-Fit Coefficient (GFC) and the root-mean-square-error (RMSE) [10]. GFC is used to see the similarity between the pattern of the spectral reflectances reconstruction with the spectral reflectances original. GFC value can be calculated using following equation:

$$GFC = \frac{|\sum_j R_m(\lambda_j) R_r(\lambda_j)|}{\left( \left[ \sum_j [R_m(\lambda_j)]^2 \right]^{\frac{1}{2}} \left[ \sum_j [R_r(\lambda_j)]^2 \right]^{\frac{1}{2}} \right)} \quad (7)$$

Where:

$R_m(\lambda_j)$  = Original Spectral reflectances (measured by spectral device)

$R_r(\lambda_j)$  = Reconstructed Spectral reflectances

RMSE can be determined by using Equation 8. GFC and RMSE were used to determine the dataset and polynomial model to be used as a model estimation.

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (s(i) - \tilde{s}(i))^2}{n}} \quad (8)$$

Where:

$s$  = Original spectral reflectances

$\tilde{s}$  = Reconstructed spectral reflectances

$n$  = Number of wavelength

## 3. Results and Analysis

The main goal of this research was to find a way to approximate the spectral reflectances of Jati Belanda leaf based on digital image color. The experiments in this research

performed on two dataset. They are 46 leaves of medicinal plants (called dataset 46) and 276 leave of medicinal plants (called dataset 276). For testing dataset and polynomial transformation model, we use 10 leaves of Jati belanda as a test set. The selection of dataset and the polynomial transformation are determined based on the value of RMSE and GFC. RMSE and GFC are a parameter to determine the goodness of the dataset and the polynomial that will be used to estimate the spectral reflectances. RMSE closer to 0 indicates that the model is useful for reflectances estimation. GFC value closer to 1 shows that the model is good for estimation.

Figure 3 shows the RMSE for dataset 46 and dataset 276. According to the RMSE values, RMSE values of dataset 46 has larger value than dataset 276. In general it can be concluded that dataset 276 performs better than dataset 46 as training set for spectral reflectance reconstruction. This is due to the dataset 276 has more information than dataset 46. Polynomial transformation model could enhance the spectral reflectance reconstruction in dataset 276. Dataset 276 using 3<sup>th</sup> order performs better and gets the smallest scores in term of RMSE.

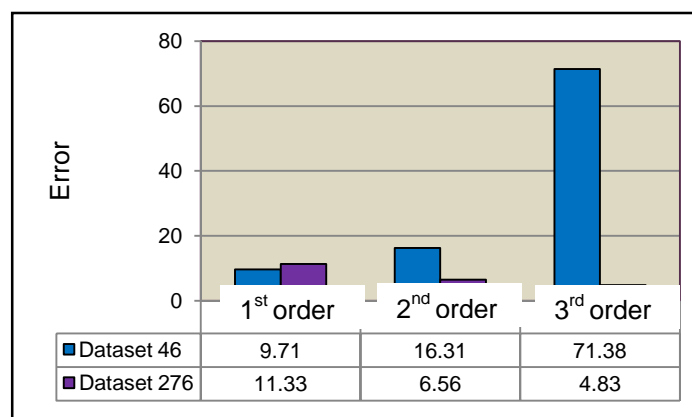


Figure 3. RMSE of dataset 46 and dataset 276 in Terms of Polynomial Transformation Model

Figure 4 shows GFC values for dataset 46 and dataset 276. Based on Figure 2, dataset 46 using 2<sup>th</sup> order have the highest value of GFC. However, the RMSE value of dataset 46 using 2<sup>th</sup> order can not be use as training set because the RMSE values was very large. While reconstruction of spectral reflectances using dataset 276 with 3<sup>th</sup> order gave high value of GFC 0.96 with the smallest RMSE values. According to evaluation using RMSE and GFC, dataset 276 using 3<sup>th</sup> order was chosen because it has the smallest RMSE values and high GFC values.

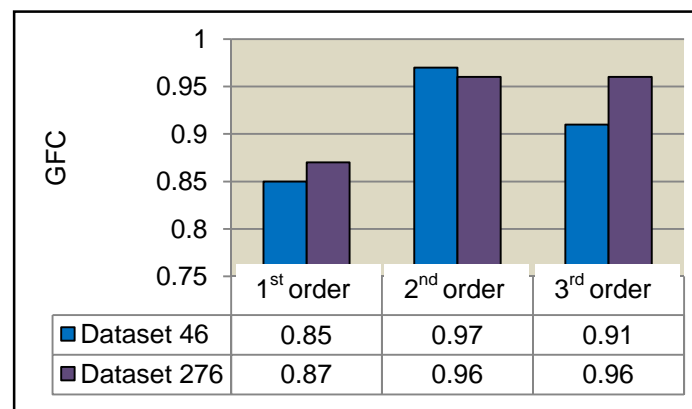


Figure 4. GFC of dataset 46 and dataset 276 in Terms of Polynomial Transformation Model

Figure 5 shows the visual comparison between reconstructed spectral reflectances of Jati Belanda leaf using dataset 276 with 3<sup>th</sup> order and original spectral reflectances of Jati Belanda leaf. Based on Figure 5, the reconstructed spectral reflectances between 460 nm – 700 nm have a good estimation. But at a wavelength of 410 nm - 450 nm, the reconstructed spectral reflectances slightly different from the original spectral reflectances. It is important to note the difference between reconstructed spectral reflectances and original spectral reflectances occurs at the blue or dark colors. This is due to that no data in training set 276 that has color at wavelength of 410 nm – 450 nm.

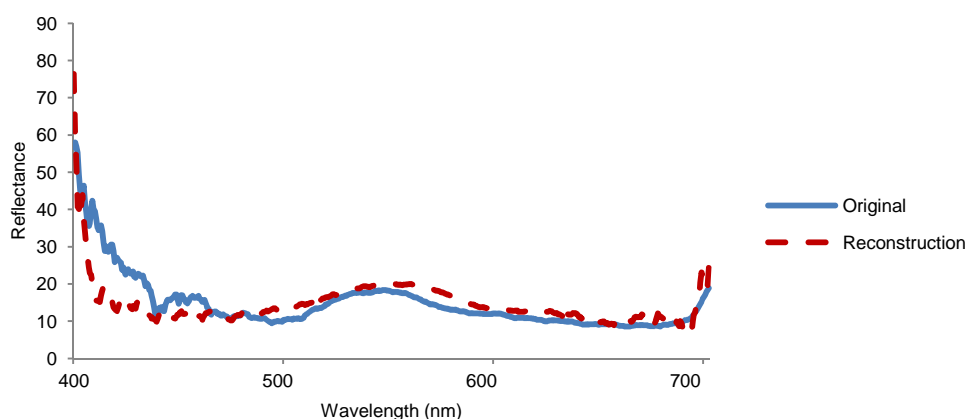


Figure 5. Visual Comparison between Spectral Reflectance Reconstruction using dataset 276 with 3<sup>rd</sup> order (dashed line) and Spectral Reflectance Original (solid line)

#### 4. Conclusion

Fourier Transformation was used as a method to estimate the reflectance of Jati Belanda leaf from the image. The use of 276 dataset using 3<sup>rd</sup> order as a training set performs better to estimate spectral reflectances. The RMSE is 4.83 and GFC is 0.96 of this model. The future work will concern about compounds estimation using the best method for reflectance estimation in medicinal plants leaf.

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