Developing Wood Identification System by Local Binary Pattern and Hough Transform Method

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Abstract. The aim of this paper is to develop the wood identification system using two methods, called, Local Binary Pattern (LBP) and Hough Transform (HT). Here, 12 (twelve) varieties of wood species form Indonesia will be used as the data sets. The wood species are taken from wood anatomy laboratory, Puslitbang Hasil Hutan (P3HH). Here, the classification method of this research uses Euclidean Distance (ED) to determine the distance of two images of wood. From the classification results, using LBP method is shown better than HT. The weakness of HT method in this paper is HT method can only detecting the circle shape rather than arbitrary shape. By using LBP method, 6 of 12 species are 100% accurate detected. Beside, using HT method, only one species (Cratoxylon formosum) has accuracy 90%.

1. Introduction

Tropical rain forest in Southeast Asia has more than 15000 different plant species, which consists of around 3000 wood species categories. The most income of Southeast Asia countries come from the export of wood production activity. Generally, wood is used for roof truss, furniture or a knick knacks as a souvenir. Indeed, the price of furniture or souvenir depends on production of wood material[1]. Therefore, the identification of wood is needed to determine the utilization of a wood species in the industry. Moreover, the identification of wood is urgently needed for government as bioforensics to against illegal logging [2].

Wood identification system can be an important system to minimize fraud in the market, where the wood is traded. For instance, several sellers can mixing the non quality woods and sell them with the high price. Nowadays, the identification process of wood is from its anatomy structures (macroscopic approach) [3]. However, in Indonesia, wood identification can be done by macroscopic and microscopic approach. In microscopic approach, the identification is through
the detail pattern of slice of small wood sample. For instance, see Figure 1 for the slice of wood image Ficus Callosa.

Several wood samples in Indonesia can be found in the wood anatomy laboratory, Puslitbang Hasil Hutan (P3HH). This association has various libraries and wood collections of Xylarium Bogoriense 1915 which have been collected from all parts of Indonesia since 1914. The traditional microscopic wood identification in laboratory is solved manually which is time consuming. Therefore, Puslitbang and The Indonesian Institute of Sciences (LIPI) work together in order to create the Computer Vision method for identifying wood species.

Hence, the goal of this paper is to develop wood identification system using two methods which are called Local Binary Pattern (LBP) and Hough Transform (HT). Here, 12 wood samples originated form Indonesia will be used to develop wood identification system. Moreover, for classification purpose, the Euclidean Distance (ED) will be elaborated.

This paper is organized as follows, in Section 2, several related works and methods are briefly elaborated. In Section 3, the methodology of this research is explained. Here, the entity relationship diagram (ERD) of the proposed system is given. Moreover, the results of this research, accuracy of LBP and HT method is described in Section 4. Certainly, this paper is concluded in last section, Section 5.

2. Related Works and Methods
2.1. Computer vision and its applications

Computer vision is a branch of computer science which study about how computer identifies an observed object, or how computer can extract the information from an image to solving a problem. Several references for studying the computer vision can be seen in [4, 5, 6, 7, 8]. Some applications of computer vision can be seen in Figure 2.
Figure 2 shows some applications of computer vision methods. For example in [7], the detection of lung cancer is elaborated using wavelet transformation and artificial neural network (ANN) method. Moreover, in the reference [8], the detection of licence plate number is discussed using probability tracking algorithm.

The study about computer vision in wood identification has been available in some references (see [9, 10, 11] for examples) for several last decades. However recently, the research about wood identification system is not popular. Specially in Indonesia, this computer-aided wood identification system is not available. Although, this system is very important to minimize time consuming in laboratory for identifying the species of wood.

2.2. Wood anatomy
Wood has special characteristics even in similar or different species. In order to develop the wood identification system, the information of specific wood anatomy, general characteristics, the nature and usefulness of the wood should be investigated.

The pattern of wood in microscopic level depends on the orientation of observation. There are three different orientation planes in the wood classification, which are called cross, radial and tangential section (see Figure 3 for more detail).

The explanation of the orientation planes of wood anatomy in Figure 3 is given as follow:

1. Radial section is a plane by cutting the wood according to the vertical axis of the stem. More precisely, logs cut through or parallel to the wooden radius and perpendicular to the growing circumference.

2. Tangential section is a plane when the tree is cleaved by an arbitrary plane parallel to the axis of the stem, but not through it and perpendicular to one of the radius.

3. Cross section is a plane created by cutting logs perpendicular to the vertical axis of the stem. The vertical axis is the exact line through the center of the circle and perpendicular to the plane of the latitude.

Using cross section cutting technique, then parenchyma of wood can be easily identified [12]. Parenchyma is a functional tissue in plants and animals which can describe the information about morphology and metabolism of its species [13, 14]. Therefore in this research, the cross section cutting technique is used to collect wood samples.

2.3. Detection and classification methods
Here, the brief description of two detection methods (LBP and HT) and one classification method (ED) will be elaborated.
2.3.1. Local Binary Pattern (LBP) The words ”Local Binary Pattern” describe the LBP operator which is create the threshold for a neighborhood from gray value of the center pixel to a binary pattern\cite{15, 16}. Following the notation in \cite{17}, let a monochrome image is denoted by $I(x, y)$ and $g_c$ is the gray value of pixel at arbitrary point $(x, y)$, thus $g_c := I(x_c, y_c)$. Moreover, if $P$ is the number of circular neighborhood sampling points on radius $R$ at point $(x, y)$, then $g_i$ denotes gray value of sampling points with $i \in M = \{0, 1, \cdots, P - 1\}$. Then, some notations can be defined as follows,

$$\begin{align*}
g_i := I(x_i, y_i), & \quad i \in M, \\
x_i := x + R\cos(2\pi i / P), & \\
y_i := y - R\sin(2\pi i / P). & \quad (3)
\end{align*}$$

See Figure 4 for an example of circular neighborhood sampling points where $(P, R) = (8, 1)$.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure4.png}
\caption{Neighborhood sampling points on circular $(P, R) = (8, 1)$. The number of neighbor cells is start form 0 to $P - 1$. The position of these numbers is started from the left top of neighbor and then the rest is placed in clock-wise direction.}
\end{figure}

Moreover, according to Ojala et al.\cite{15}, the basic local binary pattern operator are defined as follow,

$$LBP_{P,R}(x_c, y_c) = \sum_{i \in M} 2^i \times \delta(g_i - g_c), \quad (4)$$

$$\delta(z) = \begin{cases} 0, & \text{if } z < 0, \\ 1, & \text{otherwise.} \end{cases} \quad (5)$$

Figure 5 shows the example of process to compute in $3 \times 3$ pixels with the circular (8, 1). In Figure 5, the value of center pixel $g_c$ is 54. Then, by (5), the value of each neighborhood sampling points is determined. Furthermore using (4), multiplying each value of pixels by $2^i$ where $i \in \{0, 1, \cdots, 7\}$ and sum it all up, thus $LBP_{8,1} = 2^2 + 2^3 + 2^4 + 2^5 = 60$ is obtained.

2.3.2. Hough Transform (HT) Seeing the example characteristic data of wood sample as in Figure 1, picture of wood sample is full of circle patterns. Therefore, the identification of wood samples can be done by looking the characteristic of circles in the picture.

Research about circle finding using Hough Transform (HT) has been available in some references (see \cite{18, 19, 20} for examples). In order to detect circles, HT method uses a constraint equation for each feature points of pixels in a image.

Let the center of a circle lies on coordinate $(x_c, y_c)$ and it has a radius $r$, then the position of the edge points $(x, y)$ should satisfy by the following constraint equation:

$$(x - x_c)^2 + (y - y_c)^2 = r^2. \quad (6)$$
Indeed, this equation demonstrates for any given edge point \((x_i, y_i)\), then this point could be a candidate on any circle which lies on the surface of a right circular cone \((x_c, y_c, r)\) [19].

2.3.3. Euclidean Distance (ED)  In order to identify a cross section slice image of wood, then the classification method which is called Euclidean Distance (ED) for LBP and HT method should be given.

- ED for LBP
  Some LBP matrix results from several images in one species are averaged into one image as a reference image. Let \(I = (x, y)\) and \(\bar{I} = (\bar{x}, \bar{y})\) are a test an a reference image, then the distance of test image to reference image is given as,
  \[
  ||I(x, y) - \bar{I}(\bar{x}, \bar{y})||_{LBP} = \left( \frac{1}{N} \sum_{i} (g_i - \bar{g}_i)^2 \right)^{1/2},
  \]
  where, \(N\) is the number of pixels, \(g_i\) and \(\bar{g}_i\) are the value of \(i\)-th pixel in \(I = (x, y)\) and \(\bar{I} = (\bar{x}, \bar{y})\) respectively.

- ED for HT
  In order to calculate ED of a test image in HT method, the information of pixel sizes (PS), mean diameter of circles (MD), and standard deviation of circles (SD) is important. Let \(I = (x, y)\) and \(\bar{I} = (\bar{x}, \bar{y})\) are a test an a reference image, then the distance of test image to reference image is given as,
  \[
  ||I(x, y) - \bar{I}(\bar{x}, \bar{y})||_{HT} = \left( \frac{1}{M} \sum_{i} (PS_i - \bar{PS}_i)^2 + (MD_i - \bar{MD}_i)^2 + (SD_i - \bar{SD}_i)^2 \right)^{1/2},
  \]
  where, \(M\) is the number of circles, \(PS_i\) and \(\bar{PS}_i\) are the pixel sizes of \(i\)-th circles in \(I = (x, y)\) and \(\bar{I} = (\bar{x}, \bar{y})\) respectively. Similar to \(PS_i\), \(MD_i\) and \(SD_i\) are mean diameter and standard deviation of \(i\)-th circles in \(I = (x, y)\) respectively. Moreover, \(\bar{MD}_i\) and \(\bar{SD}_i\) are mean diameter and standard deviation of \(i\)-th circles in \(\bar{I} = (\bar{x}, \bar{y})\) respectively.

3. Research Methodology

3.1. Data Preparation

In this research, wood data is taken using microscope digital camera, Dino-Lite Pro AM4111 with a high-quality 1.3-megapixel image sensor. The detail of its specifications is given as follow:
10x-50x, 220x Variable Magnification.
1.3MP Color Resolution.
8 LEDS.
Max Refresh Rate: 30fps.
Multiple File Formats.
USB 2.0 Output.

As mentioned in Introduction, the wood samples are taken from Puslitbang Hasil Hutan (P3HH) association, Indonesia. Raw image of wood samples are obtained directly through the connection between digital microscope and laptop (see Figure 6). Here, three images for two times magnification (50× and 200×) are taken from one wood sample.

Figure 6. The collection of wood samples in Puslitbang Hasil Hutan (P3HH) (left). The configuration of digital microscope which is connected to the laptop [21].

In this research, 12 (twelve) samples of wood species are used. The samples were taken arbitrary in Puslitbang depend on the quality of the wood. The list of chosen wood samples can be seen in Table 1. For simplicity, each wood samples is given a code to refer the name of sample in this paper. In the Table 1, it can be seen clearly that each images has different circle pattern. This pattern describes the characteristic of wood, which can be used to identification process.

3.2. Entity Relationship Diagram (ERD)
In this research, wood identification system is build based on the entity relationship diagram (ERD) as shown in Figure 7. The explanations for each process are described as follows:

- **Image Capturing**: Image is taken from a slice of wood sample by a microscope device. Here 50 times magnification image of wood sample is used. Additionally, three times photo shoots are taken for each wood samples.

- **Image Cropping**: In order to obtain many images for validating HT method, each image from microscope device is cropped into 8 parts. Thus, for one species wood sample has 24 (3 × 8) images. The cropping technique can be seen in Figure 8. Meanwhile, for LBP method the cropping technique is not used.

- **Selection of training and testing data**: The collected images are divided into two categorizes, training and testing data. In HT, 20 images are used for training and the rest is used for testing data. Moreover, in LBP, 3 images from first capturing is used as training and testing data.

- **LBP/HT**: Here two methods (LBP and HT) are elaborated using the training data.
Table 1. Twelve wood slice pictures by cross section cutting technique.

| Code  | Name & Image   | Code  | Name & Image   |
|-------|----------------|-------|----------------|
| WS01  | *Acacia auriculiformis* | WS02  | *Actinodaphne glabra* |
| WS03  | *Cratoxylon formosum*   | WS04  | *Dillenia obovata*   |
| WS05  | *Diospyros pilosanthera* | WS06  | *Durio kutjensis*   |
| WS07  | *Durio oxleyanus*       | WS08  | *Elasteriopermum tapos* |
| WS09  | *Fagraea elliptica*     | WS10  | *Ficus callosa*     |
| WS11  | *Litsea robusta*        | WS12  | *Macaranga pruinosa* |
Figure 7. The Entity Relationship Diagram (ERD) of wood identification system.

Figure 8. Cropping technique for validation HT method. Here, 8 (eight) regions are used for one wood sample. Thus, for one species of wood sample has 24 \((3 \times 8)\) images which can be used as data training and testing in HT method.

- **Pattern Extraction**: The result from two methods produces a pattern for one wood species, which brings the information about each characteristics of wood species samples.

- **Euclidean distance**: After the pattern is obtained, then the testing data is used to validate each models by computing the distance between one testing image to patterns (here, twelve patterns for each models are used). The euclidean distance for LBP and HT model are computed as (7) and (8) respectively.

- **Identification**: Since some distances of between twelve patterns and one testing image are computed, then the identification of testing image can be done by selecting the smallest distance.

- **Result of Accuracy**: Finally in this research, the accuracy of two methods is given. Here, the accuracy using LBP method is presented in table of confusion matrix.
4. Result and discussion
4.1. Pattern extraction
As elaborated in Section 3 Methodology, each method (LBP and HT) produces a pattern for identification process. Here, LBP method gives an histogram for each wood species. One histogram for one wood species is obtained from the matrix of LBP. This matrix is calculated by $LBP_{8,1}$ using Eqs. (4-5). The example histogram result of Black Eboni Tree ($Diospyros pilosanthera$) wood sample can be seen in Figure 9 (left).

![Figure 9](image_url)

*Figure 9. The example of pattern extraction form two methods (LBP and HT) using Black Eboni Tree ($Diospyros pilosanthera$) wood sample. LBP model produce histogram information (left). Meanwhile, HT model produce circle information (right) from the original image (middle).*

In contrast to LBP method, HT method yields several circle patterns from an image. Each picture of wood species has different information of circles. Circle pattern on image of Black Eboni Tree ($Diospyros pilosanthera$) wood sample can be seen in Figure 9. Meanwhile, the result of HT method for finding circle in image of *Fagraea elliptica* and *Macaranga pruinosa* can be seen in Figures 10(a)-(b) and Figures 10(c)-(d) respectively. Moreover, 11(a)-(b) and Figures 11(c)-(d) show the results of HT method for detecting circle pattern in image *Durio kutjensis* and *Durio oxleyanus* respectively.

The detected circles on an image can be extracted into several information for identifying wood species. In this research, information obtained includes pixel sizes (PS), mean diameter of circles (MD), and standard deviation of circles (SD).

![Figure 10](image_url)

*Figure 10. The original and HT result of *Fagraea elliptica* (a-b) and *Macaranga pruinosa* (c-d).*

It can be seen clearly that the radius of circles in each pictures (Figures 10-11) is shown varied. However, HT is not very robust method to find the circle. In Figures 10(b) and 10(d), several black circles in original image are not able well detected.
Figure 11. The original and HT result of *Durio kutjensis* (a-b) and *Durio oxleyanus* (c-d).

Nevertheless, HT method is an acceptable method for finding circle pattern in image. Several papers discuss about improving HT method, such that this method can be used to detect circles and ellipses very well. Please see the references [22, 23, 24] for detail about improving HT method.

4.2. Accuracy measurement

The accuracy for LBP and HT method is described in Table 2 and Table 3 respectively. In Table 2, first row and column describe code of wood species as given in Table 1. The number (1, 2, 3) in the table describes the total of identified and not identified wood samples from the system. For instance, WS01 in the second row has 3 identified wood samples, since number 3 is located at column WS01. Meanwhile, WS02 in the third row has 2 identified and 1 not identified wood samples, since number 2 is given in column WS02 and number 1 is filled in column WS03. Experiment result using LBP method in Table 2 shows wood species WS01, WS05, WS07, WS10, WS11 and WS12 have 100% accuracy. Meanwhile, wood species WS03, WS06 and WS09 have lowest accuracy, i.e. 33%.

Table 2. The accuracy in confusion matrix of wood identification system using LBP method.

| WS  | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | **Accuracy LBP** |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|-----------------|
| 01  | 3  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 100%            |
| 02  | -  | 2  | 1  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 66%             |
| 03  | -  | 1  | 1  | -  | -  | 1  | -  | 1  | -  | -  | -  | -  | 33%             |
| 04  | -  | 1  | -  | 2  | -  | -  | -  | -  | -  | -  | -  | -  | 66%             |
| 05  | -  | -  | -  | 3  | -  | -  | -  | -  | -  | -  | -  | -  | 100%            |
| 06  | -  | 1  | -  | -  | 1  | -  | 1  | -  | -  | -  | -  | -  | 33%             |
| 07  | -  | -  | -  | -  | 3  | -  | -  | -  | -  | -  | -  | -  | 100%            |
| 08  | -  | -  | -  | 1  | -  | -  | 2  | -  | -  | -  | -  | -  | 66%             |
| 09  | -  | 1  | -  | -  | 1  | -  | 1  | -  | -  | -  | -  | -  | 33%             |
| 10  | -  | -  | -  | -  | -  | -  | -  | 3  | -  | -  | -  | -  | 100%            |
| 11  | -  | -  | -  | -  | -  | -  | -  | -  | 3  | -  | -  | -  | 100%            |
| 12  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 3  | -  | -  | 100%            |

In opposition to LBP method, the accuracy of HT method is obtained by several trials using testing data as explained in Section 3, Research and Methodology. Here, each trials uses a random part of cropping images as a testing data. Unfortunately from Table 3, wood sample
of wood code WS05 (*Diospyros pilosanthera*) is difficult to detect which has 0% accuracy. Comparing using LBP, detection of wood WS05 is 100% accurate.

The weakness of HT method is several types of wood species have very close circle patterns. Thus occasionally, system using HT fails to identify wood sample in accurately. Indeed this method needs some improvements such that the patterns are not only in circle shape, but also other patterns can be obtained such as ellipse, oval, etc. Therefore, the difference between two images can be clarified.

| Code   | Accuracy HT          |         |         |         |         |         |         |
|--------|----------------------|---------|---------|---------|---------|---------|---------|
|        | Trial 1   | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Avg     |
| WS01   | 25%       | 25%     | 50%     | 25%     | 25%     | 30%     |
| WS02   | 50%       | 25%     | 0%      | 50%     | 0%      | 25%     |
| WS03   | 100%      | 75%     | 100%    | 75%     | 100%    | 90%     |
| WS04   | 50%       | 75%     | 75%     | 75%     | 75%     | 70%     |
| WS05   | 0%        | 0%      | 0%      | 0%      | 0%      | 0%      |
| WS06   | 50%       | 50%     | 50%     | 25%     | 75%     | 50%     |
| WS07   | 75%       | 25%     | 75%     | 75%     | 0%      | 50%     |
| WS08   | 0%        | 25%     | 0%      | 0%      | 0%      | 5%      |
| WS09   | 0%        | 50%     | 0%      | 50%     | 25%     | 25%     |
| WS10   | 75%       | 0%      | 0%      | 25%     | 25%     | 25%     |
| WS11   | 0%        | 50%     | 50%     | 25%     | 25%     | 30%     |
| WS12   | 25%       | 50%     | 25%     | 0%      | 25%     | 25%     |

Overall from Table 2 and Table 3, wood identification system using LBP method is better than using HT method. However, if the HT method is modified such that it can detect any kind of shapes besides circles, then the accuracy is expected to be better. Beside, the segmentation process can be considered in preprocessing level for this method. Moreover, the difficulty to obtain many data of wood samples still becomes challenging for this research. Further, this research will be developed using more variations of wood species to measure the robustness of identification system.

5. Conclusion

The wood identification system using Local Binary Pattern (LBP) and Hough Transform (HT) is elaborated. Generally, two methods are shown able to identify the wood species very well. Comparing these two methods, using LBP method is shown better than HT method. Using LBP method, the highest accuracy is 100% obtained. Meanwhile, using HT method, 90% accuracy is gained. Indeed, the weakness of HT method in this research only focus on circle pattern rather than on other shape of patterns. Fortunately, this method can be improved such as applying segmentation process in preprocessing thus the increasing of accuracy can be expected.

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