Tree Crown Density Analysis from Hyperspectral Image

Rina Syazwani Zulkafli, SAA Shukor*

School of Mechatronic Engineering, Universiti Malaysia Perlis, 02600 Perlis, Malaysia

*Corresponding author: shazmin@unimap.edu.my

Abstract. A study was conducted to investigate whether reflectance data of hyperspectral image of an area could be used to extract related physical features to produce mapping of vegetation density. This paper explains on estimating percentage of vegetation coverage based on Normalized Difference Vegetation Index (NDVI). Image segmentation based on thresholding was used to separate different features of the land entities like soil, water and road. From here, NDVI values can be integrated for further segmenting the vegetation features. The colour segmentation method is then able to classify the vegetation according to their density level, which can be used to determine tree crown density. Test conducted towards a hyperspectral image shows that different density level can be extracted, where it contains about 7.5% high level tree crown density, 1.8% medium crown density and 5% low. More tests need to be conducted in order to proof the workability of the developed algorithm in analysing hyperspectral images from tree crown density mapping.

1. Introduction

Forest inventory is an activity that deals with trees and information obtained in a specific circumstance land area. This activity is not new and was carried out since the late 18th century using traditional method [1]. There are several reasons which makes forest inventory important, which includes structural development about the forest management, like evaluating the raw material of wood and acquiring number of individual trees. Apart from that, forest inventory activity would define spatial distribution of urban forest, and can be used to distinguish species composition. An optimal harvesting schedule can also be planned if a large-scale inventory is carried out.

In the early stage, the main method used in forest inventories was totally enumeration. However, they need a long period of time and energy to accomplish the inventories since some of the area is inaccessible. Sometimes, the interested area cannot be estimated completely since the area may be steep and at the same time, they may be facing the threat of wild animals. Furthermore, this method cannot provide complete coverage of large areas.

Due to this limitation, researchers have developed new method to estimate the timber information that can reduce the time consumed and even more effective than the manual method, which is based on image analysis. This would allow foresters or researchers to interpret the image into some valuable information regarding to the electromagnetic radiation from the Earth’s surface. This modern method offers increases in speed of analysis, high precision results and high timeliness of forest inventory. Remote sensing has been a valuable source of information in providing suitable images for mapping and monitoring forest activities [2].

Among the available approaches in remote sensing that support forest inventory is through hyperspectral imaging. Hyperspectral is the technology of extracting information from Earth’s surface through radiance obtained either from airborne or spaceborne sensors [3]. The image produces by the
sensor contains spectral bands due to its wavelength, which is suitable in extracting spatial-based information, like what is being done in this project. Hyperspectral images have been used for various applications in forestry and agriculture, such as for tree species recognition [4] and detection of plant disease and stress [5] [6].

One of the important studies in forest inventory is tree crown density. Data of forest / vegetation area taken from airborne, which is less complex to be collected compared to terrestrial / land, can be used to map tree crown density, which can be used to estimate tree volume, canopy structure and improve tree species classification [7].

This paper concentrates on the work of extracting and evaluating the density level of tree crown from a hyperspectral image. Due to the important role of segmentation in image processing, especially in this case of determining and mapping tree density, several methods of segmentation are tested. The selected methods are then being compared to determine the best in segmenting and extracting the image feature, i.e. tree crown density. Feature extraction results will classify the level of crown density (low, medium or high). In addition, the total pixels for all levels and percentage of tree crown density will also be calculated. To assist the usage of the algorithm in the future, a suitable Graphical User Interface (GUI) is also developed.

Several studies have been performed in image segmentation. Researchers in [8] stated that segmentation can be categorized into three classes, feature thresholding or clustering, edge detection and region extraction, while in [9], there are six segmentation methods which include histogram-based method, neural network-based segmentation, region-based method and clustering. Segmentation in image processing can be defined as a process of assigning a label to every pixel in an image of certain characteristics. The characteristics can be either with respect to colour, intensity or texture. For this project, three methods of segmentation will be tested which are threshold NDVI, k-means clustering and polygon Region of Interest (poly ROI), due to their mostly usage in image processing.

According to [10], thresholding can be classified into two schemes which are global (uses only one threshold for the entire image) and local (threshold that is used to an image that had been partitioned into several subregions) [11]. Meanwhile, the Normalized Difference Vegetation Index (NDVI) is a numerical index that uses the visible and near-infrared bands to analyse remote sensing measurement and used to determine whether the region of interest that being observed contains green vegetation or not. NDVI was first used in 1974 by [12]. Since the characteristic of plants across the electromagnetic spectrum can be obtained, the NDVI information can be extracted by focusing on the satellite bands that are most sensitive to vegetation information. The bigger the difference between near-infrared and red reflectance, the more vegetation there has to be. Theoretically, NDVI values are represented in value ranging from -1 to 1 and negative values always represent water, concrete, paved road and built-up area, values around zero represent soil and values over 0.6 always represent dense green vegetation.

K-means clustering, which is part of clustering-based image segmentation, has been used by many researchers [9] [10]. It works by to partitioning the image into various cluster based on the similarities features such as colour or texture. The algorithm divides the image into k-cluster based on the similarity between the pixels in the cluster. However, they discovered that this method encounters great difficulties when computing the number of clusters that are present in the future space or extracting the suitable feature.

Polygonal Region of Interest (Poly ROI) is refers to a special region in an image that is of particular interest or importance to the user. Poly ROI always deals with two regions which are region of interest and background region. The selected sample region is then being matched with the entire pixels in the image. The region that holds the same features with the selected sample region will be extracted together [13].

2. Methodology

Figure 1 shows the process flow conducted in this project. The first and foremost is to acquire the digital image from a source. As in this project, the image is captured by a sensor and digitized into...
Figure 1. Process flow of the work, from data collection (image acquisition) to the suitable Graphical User Interface (GUI) development in producing tree crown density analysis of an area.

The respective hyperspectral image was acquired on 20th September 2014 from the Landsat 8 platform and Operational Land Imager (OLI) sensor image. The raw imagery does not need any atmospheric correction since the sky is clear. The image obtained is in the form of visible green, red and near-infrared (NIR) bands images. Figure 3 shows the respective hyperspectral image in their bands used in this study.
The images were then enhanced using histogram manipulation for intensity transformation. This is to allow modification towards original image histogram so that the image contrast is improved. Next, all the images are combined together into an RGB colour image. Then, vegetation area will be determined using NDVI as shown in Equation (1), which calculated by dividing the difference in the near-infrared (NIR) and red colour bands by sum of the NIR and red colour bands for each pixel in the image.

\[
NDVI = \frac{(NIR - RED)}{(NIR + RED)}
\]

where:
NIR = Near-Infrared
RED = Red visible

As been discussed earlier, k-means clustering and poly ROI could also be used to segment the image, however upon testing, their results were not as accurate as of thresholding NDVI. Figure 4 shows the results of these processes. As can be seen from this figure, the results of thresholding NDVI shows the best compared to the other segmentation methods.
After thresholding, the image will be converted to grayscale image. As the grayscale image stored 256 different intensities, hence, the pixel can be divided into several ranges and can be used in the next step which is feature extraction. Feature extraction is always required as it can pull out the relevant information from the image. The information is then will be used in the classification stage of image processing data. Therefore, it is important to extract the exact information so that they can be classified correctly. In this project, the feature used as the input is colour ranges. This feature will distinguish the level of vegetation density into low, medium or high. The total area will be calculated and displayed.

A Graphical User Interface (GUI) is also designed in this project to allow better accessibility. It will serve as a better tool in providing a fast result and can demonstrate the overall functionality of the algorithm. User needs to choose the respective three images (green, red and NIR bands) needed to produce an RGB image which will be shown. Next, the NDVI segmented image will be generated and the features according to the level of tree crown density will be calculated and shown.

3. Results and Discussion

Figure 5 shows the respective GUIs for tree crown density analysis of the data used in this project, while Table 1 summarizes the results. It can be seen that for high density level, the total pixels is 12073 with 7.5456 %, 2934 pixels (1.8338%) for medium density and 8082 pixels (5.0513%) for low density tree crown. A total coverage area of 14.4307% representing vegetation / forestry site shows that it does not represents the majority of the area, hence proved by the desert-type location (refer to Figure 2). High value of density indicates that the tree has a large amount of leaf material available for photosynthesis and has growing conditions that enable full and symmetrical growth. While, low density level value may indicates poor amounts of foliage, a thin crown, or missing section of crown or may result from stresses such as insect and disease or any other environmental factors such as drought, wind, competition or soil compaction [14]. Thus, it can concluded that in this area, the total tree crown with high-density level has the highest distribution, followed by the tree crown with low-density level and lastly, the tree crown with medium-density level. From here, further processing like tree species recognition can be done.
Figure 5. GUI calculating and mapping tree crown density

Table 1. Summary of results representing the tree crown density of the study area

| Tree Crown Density | Total Pixel | Percentage Area |
|--------------------|-------------|-----------------|
| High               | 12073       | 7.5456%         |
| Medium             | 2934        | 1.8338%         |
| Low                | 8082        | 5.0513%         |

4. Conclusion

This project has shown the capability of remote sensing, specifically hyperspectral image in extracting and classifying information regarding tree crown density. Standard image processing approaches are needed and due to its importance, several dominant methods in image segmentation has been used and tested. From here, it has been proven that threshold NDVI gives the best segmentation results in vegetation area arrangement. Further tests are required to prove the workability of the overall methods in analysing tree crown density.

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