Machine vision analysis of harvested forestry sites using high resolution UAV data

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Abstract*—The development of algorithms for building photo mosaics and 3D surface models over post-harvest forestry sites using high-resolution imagery captured by a low-flying UAV, is presented. The proposed system contains three databases with different resolution and height of shooting from forests and agricultural lands including: 1) Sentinel 2A/2B (resolution of 10, 20, and 60 m with 13 bands), 2) Airbus multispectral imagery dataset (resolution of 1.5 m with 4 bands), and 3) Multispectral imagery by SENSEFLY'S UAV (resolution of 11 cm with 4 bands). The proposed system conducts NDVI remote sensing on Airbus and SENSEFLY'S UAV multispectral imagery dataset as only one set of images are available. However, the proposed method uses sentinel 2A and 2B dataset form Trairao, Brazil. The result of the accuracy indicates that the accuracy of system is above 97.81%. However, the average accuracy of the proposed methods was found to be 98.13%. The precision of the classifier was found to be 97.75%. The response time of the system is tested, and it was found that the mode response time for this system is below 15 seconds. The mean value for the response time was found to be 7.56 seconds. The results indicate that the accuracy of the proposed algorithm can be maintained at 95% under 18% cloud coverage. The accuracy of system under 3% cloud coverage was found to be slightly lower than the average accuracy of proposed method under 0% cloud coverage. The accuracy drops by 0.40% from 0 to 3 percent cloud coverage. The average efficiency of system for cloud masking of 3%, 6%, 9%, 12%, 15% and 18% was found as 97.80%, 96.95%, 96.55%, 96.35%, and 95.85%, respectively.

Keywords— ***Photo mosaics, sentinel, mode response, cloud coverage, post-harvest forestry.***

I. INTRODUCTION

Nowadays, Technology has been the most important thing and useful in our daily life, it is not only in our daily live also it makes human more capable of doing hilarious and genius as well Tech may link to techniques ranging from simple stone to complex gene editing which has appeared since the 1980s. New understanding has allowed humans to produce fresh stuff and conversely many science efforts are made possible by techniques that help people travel to locations they have not been able to achieve before.

Machine learning is a method of data analysis that automates analytical models' construction [1]. This is a subdivision of AI based on the principle that systems will memorize from information collected, identify problems, and solve problems with limited human intervention. Machine learning today is not like machine learning from the past because of fresh computing techniques. This was created out of recognition of pattern, therefore the principle that devices could discover to perform specific functions without programming; scientists interested in artificial intelligence wanted to see if machines can learn from information. The algorithmic side of artificial intelligence is essential since as systems are subject to fresh information, they can modify separately. They gain knowledge from prior computations to generate reliable, repeatable choices and results. It is also not a new research, and one which has gained new traction. Although there have been many computer vision algorithms for a few years, the ability to apply complex mathematical calculations automatically to large volume data is the recent development [2]. Therefore, this work has used the machine learning image processing and computer vision as well to be capable of processing the image that taken from the drone of the harvested forestry site.

The image processing has always been a method of able to perform those image operations in order to gain or obtain valuable information from an enhanced image. A kind of signal processing wherein information would be a picture and output could be picture as well as feature or characteristics associated along with the picture. Image processing is one of the fast-growing technologies now and it still forms the core research area within the engineering and computer science disciplines [3].

Selection of harvesting system is the most complex when trees' stands become too thick, the risks to forest health rise. Removing the trees at greater risk and leaving the trees with greater potential enhances the forest's quality and personality. The partially open canopy enables enough light to boost the health and vigour of the individual tree and enables the growth of seedlings. Eventually the young trees substitute the older trees because the older trees either die or are harvested. Therefore, in this project the achievement is to use the technology to help or make it easier to find the required trees that need to be harvested [4].

It is critical maintaining forests very healthy and fruitful by researching into remote sensing instruments monitoring of physiological stress from abiotic or biotic variables. The significant study focused on forest health assessment using manned aircraft and remotely sensed data from the satellite. Unmanned aerial vehicles (UAVs) can provide fresh instruments for enhanced surveillance of forest health by offering elevated temporal and spatial resolution information [5]. The high-resolution pictures of unmanned aerial vehicles (UAVs) can be utilized in a cost-effective way to describe the state of forests at periodic times [6]. It is recommended to use aerial log detection technique, but rather to detect fallen logs in open forest stands with a high proportion of log visibility and straightness.

The UAV-Based Thermal Imagery the research has been done for optimization of feature findings [7]. The conventional system may lead to bad results, especially when it is mapping extremely complicated 3D frameworks of data sets with extremely low comparison between and inside images. To solve it, the alignment of three steps processes were implemented and tested: camera pre-calibration, Heat image correction for tiny air temperature modifications and enhanced assessment of an original image location through RGB (visual) image alignment.

Another work presented on harvesting contractor production and costs in forest plantations of Argentina, Brazil, and Uruguay. Harvesting contractor production over the past few decades, wood manufacturing of the forest plantations in South America has expanded significantly. This study created logging contractors operating in Corrientes (Argentina) functions and manufacturing costs as well in some countries around Argentina that share some stations and information were collected between 2008 and 2012 [8]. Different variables can affect the techniques of timber harvesting, for instance, stand features, ground conditions, and distance from extraction, weather, forestry treatments, and social concerns. It was proposed the multiple criteria analysis is an effective method to help gardeners plan which scheme to qualify based on their operational requirements [9].

Researchers [10] proposed of strategy for the development of a smart NDVI camera system for outdoor plant detection. It uses the embedded system of process control, mapping, and sophisticated imaging cameras with agriculture. It became an aspect of precision farming that promotes the conservation of fertilizer, pesticides, and machine time. The NDVI facilitates plant discrimination in a digital camera from soil pixels and can be used quantitatively to acquire data about the plant's chlorophyll activity. It also highlighted in another research that there are two ways to acquire the images of the plant leaf. The first way is to capture images using the external camera, it has been used iball web camera and the second way is to capture the image from the email, etc. The image input is converted to space of colour [11].

In summary, it has been used many methods such as remote sensing which sense the colour of the plant to recognize which tree needed to be harvest as well the harvested timber has three method, which one of the most expansive and taking long process to do is electing a single tree among the other which is the main intention of this work. Different software and algorithms have been used in terms of recognizing the plant health monitoring to be the right one to be harvested.

II. Block Diagram and Operation of the Proposed System

Machine vision in scanning harvested sites is designed and implemented to avoid human participation in the long process. Today's technology enables to perform a high-quality scanning skills and very accurate results with a short period time. The drone with high camera quality is needed as the main component, the drone will be utilized as tool to get the input data for the program which are the pictures of the site that need to be harvested, and by taking these pictures du to SD card that will be attach in the camera at the drone and prepared to be ready in the MATLAB software to get image processed and computer vision.

Fig. 1 and 2 are showing system block diagrams, starting with setting up the drone to be ready for the mission by checking its battery as well marking out the site by using GBS and enable camera once it is in great condition will be ready for starting the scanning or picturing the site, after it is done picturing the data will be transferring to MATLAB program via SD card that attach to the drone camera. All the data will be processed and analysed by MATLAB software, it gives the user two options to the date to be analysed whether with Neural Network method or Normalized Difference Vegetation (NDVI) method, therefore the output depending on the user's choice.

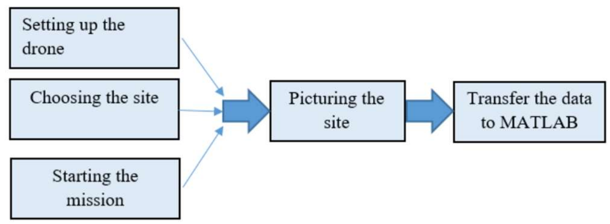

Fig. 1. General Block diagram

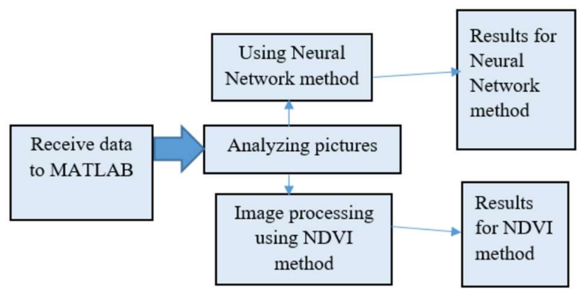

Fig. 2. Block diagram for MATLAB Platform

Fig. 3 shows the complete system flow chart. It gives an idea in the system technique.

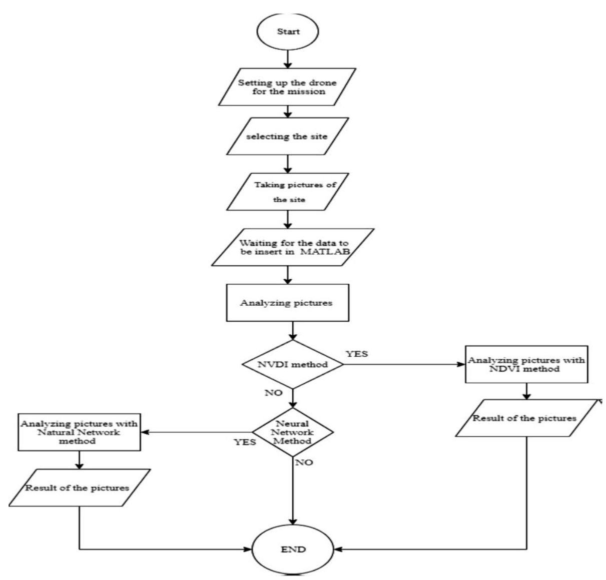

Fig. 3. System Flow chart

Step 1: setting up the UAV, battery condition and enable the camera.
Step 2: selecting the site and point it at the drone map.
Step 3: scanning or picturing the site chosen.
Step 4: inserting the data to MATLAB using SD card.
Step 5: Analyzing the data in MATLAB software.
Step 6: User choose which method to process with whether Neural Network or Normalized Difference Vegetation (NDVI) method.
Step 8: results will show what plant needs to be harvested.

The main features of the system are the difference in NDVI (DNDVI) and the NDVI of the new and old samples. The proposed system will apply regression by computing the mean of the NDVI data for old and new samples. The next step is to apply the classes for the output NDVI image. The classes and features are explained further with machine learning algorithm. The data will be classified, and the classes will be labelled on the NDVI output image.

Random forest algorithm is used in this project due to its simplicity and high accuracy when the number of input variables are less. To detect whether a land was first forest space or not, the NDVI is used as one of the inputs for the Random forest.

The first feature: In this algorithm, the difference between the NDVI value of forest is used as critical and strong indicator. The difference in NDVI can be found by comparing the NDVI of forest for two different time (old and new). For this comparison, the NDVI of the same pixel is considered. The comparison can show regions that have changed with respect to the threshold value of NDVI. This indicator can determine the region of interests (ROI).

Fig. 4. Concept Design

The second feature: The second indicator in this algorithm is soil region with value of NDVI in range of 0 to 0.25. This can help to determine soil region from forest, watery area, building, and rocks. In case of changes in NDVI value for those area with NDVI value of above 0, the second feature can determine whether the forest have been harvested.

This project used various software for development. MATLAB software was used for simulation while SNAP software was used to view, render, resample, mask, and prepare the database bands for image processing.

Sentinel Application Platform (SNAP): Satellite images are mostly covered with cloud that result in low access to land. Therefore, cloud masking is required. This requires resampling the database in SNAP application that is a free tool for sentinel satellites as shown in Fig. 5.

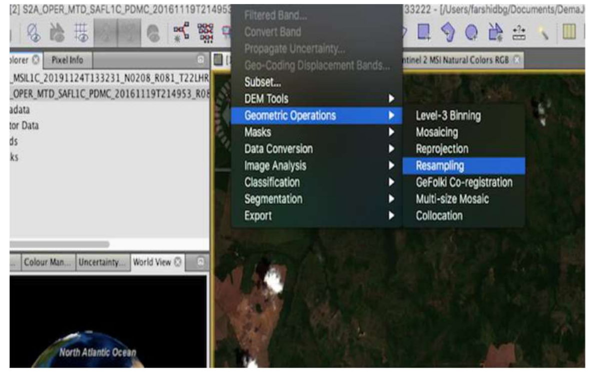

Fig. 5. Resampling of sentinel 2A multispectral image

The process requires to open the main sentinel dataset (usually called manifest with ".safe" format or ".xlm" format. The resampling process requires to apply cloud masking using the landcover mask as shown in the Fig. 6.

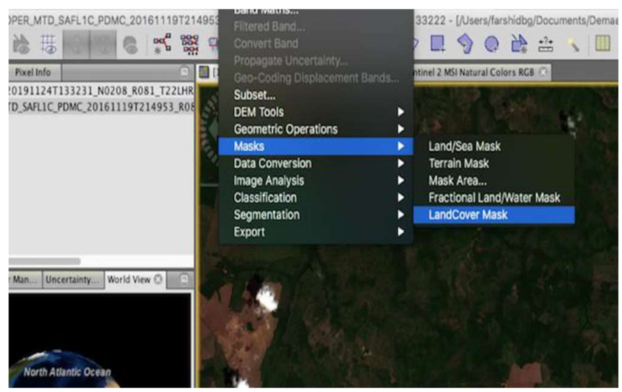

Fig. 6. Landcover mask of sentinel 2A multispectral image

To access to NIR and RED bands, the dataset of the multispectral data shall be run by SNAP application. Each band exists under the view folder inside the bands folder. Red band is B4 with wavelength of 665nm while there are 4 NIR bands exists in the sentinel 2A dataset.

However, as the resolution of RED band is 10 m, Band 8 will be selected which has the same resolution with wavelength of 842nm. Once the selected band is opened, the band can be saved in form of ".TFF" file. The ".TFF" file can be further accessed in MATLAB for image processing.

The program divides into two main parts, including: 1) NDVI 2) Random Forest algorithm.

NDVI: NDVI required two bands of the multispectral imagery including Red and NIR. In the first step, the NIR and Red bands are read. As the sentinel image is very large image usually, it is required to prepare portion of the video only. In the next step, the NDVI equation is applied with the aid of NIR and Red bands. It is requiring determining a threshold value to extract the healthy vegetation (pixels) from the rest of image. The result will be plotted on a separate figure as shown in Fig. 7.

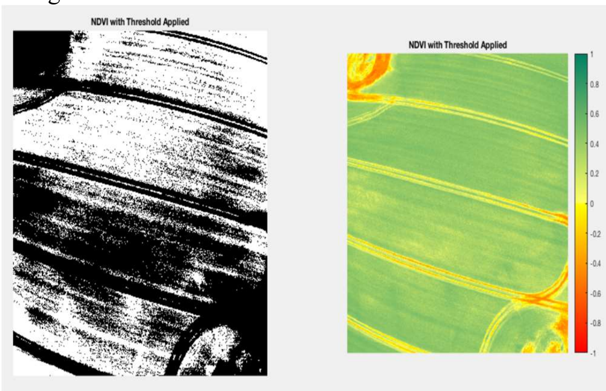

Fig. 7. Result of NDVI test

Random Forest algorithm: The first step is to train the dataset. This requires reading the NDVI of both the old and new dataset and apply NDVI for both. The process is similar to the. NDVI as explained earlier. To find the difference between the NDVI, the NDVI of the new is subtracted from the new dataset using the algorithm shown in Fig. 8.

```
% Call index of training & testing sets
DNDVI = NDVI_22 - NDVI_29;
figure('Position',[100 800 1400 400])
A3 = axes('Position',[0.025 0.1 0.4 0.8]);
imagesc(NDVI_22,[0 1])
title('NDVI 22 May 2018')
colorbar, set(gca,'FontSize',14)
colormap(A3,jet)
axis square tight, axis off
A4 = axes('Position',[0.325 0.1 0.4 0.8]);
imagesc(NDVI_29,[0 1])
title('NDVI 29 May 2018')
colorbar, set(gca,'FontSize',14)
colormap(A4,jet)
axis square tight, axis off
A5 = axes('Position',[0.625 0.1 0.4 0.8]);
imagesc(DNDVI,[-0.2 0.2])
title('Difference NDVI 22 - 29 May 2018')
colormap(A5,'Jet'), colorbar
set(gca,'FontSize',14)
axis square tight, axis off
```

Fig. 8. Computing DNDVI of old and new dataset

Once the data is computed from DNDVI, the data is trained with two features in the random forest algorithm.

III. Performance Testing and Simulation Results

The overall performance of the developed system has been evaluated by conducting various simulations of accuracy, response time, and efficiency of remote sensing of the system.

A. Accuracy of classifier

This test will determine the accuracy of the purposed random forest method to detects harvested forest spaces. For this test, sentinel 2A data of forest areas in form Trairao, Brazil is used where the harvested forest spaces will be detected. As there is only one sample for the forest for two different (similar months – November) time, the sample images retaken by the pixel value of 200 to 200. As the resolution of each pixel is 10 meters (B4 and B8 have resolution of 10 meter), the total scanning area would be 2000 square meter. The accuracy is calculated using the below formula:

Accuracy = Total number of correct classification / Total number of predictions

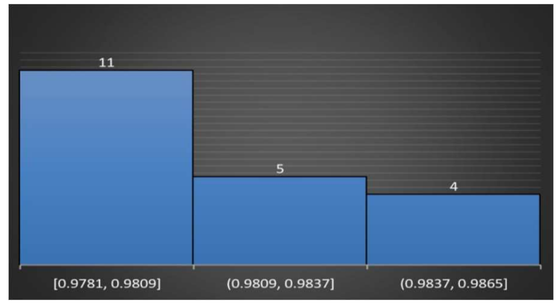

Fig. 9. Histogram of accuracy percentage for 20 samples

The accuracy test shown in the Fig. 9 The result of the accuracy indicates that the accuracy of system is above 97.81%. However, the average accuracy of the proposed methods was found to be 98.13%. The true positive index of the proposed system is above 37000 out of 4000 pixels in each sample image with land size of 4km square. The precision of the classifier was found to be 97.75%.

B. Response time for classifier

This test will determine the response time of the purposed method to determine the decision regarding the harvested forest spaces. In this test, 30 samples with different land coverage size will be tested with the proposed system. The decision can take different response time based on the size of the land being scanned and the difference between the NDVI between the samples as the main features of the classifier. In this test, 30 sample images with different land size are used with the range of scanning area would be from 4 – 80 km^2.

The response time of the system is tested, and it was found that the mode response time for this system is below 15 seconds as shown in the Fig. 10.

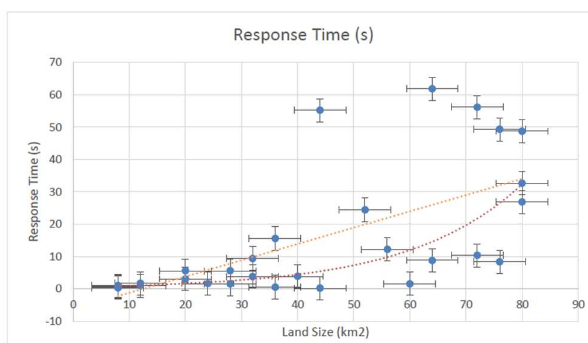

Fig. 10. Response time of proposed harvesting forest space detector

The mean value for the response time was found to be 7.56 seconds. The result indicates that the land size can influence on the response time and increase it but it is not the only elements. The next elements that is highly effective is the amount of soil discovered in the land that is the main element to trigger the second layer of the classifier. For example, when the size of the land is 64 km2, the response time is 61.85s which is higher than when the size of the land is 72,76, and 80. However, by quick look at the harvested area, it was found that that 14.32 km2 out of 64 km2 was spotted by classifier in the first stage as the harvested area to discover.

C. Efficiency of remote sensing with presence of cloud

The aim of this test is to determine how cloud masking in this project can affect the result of system. In this test, 5 different cloud masking is conducted over 5 samples images. The cloud coverage requires the proposed system to predict land pixels that are not visible by Red and NIR band. Under this test, cloud masking of 3%, 6%, 9%, 12%, 15% and 18% will be considered and created via SNAP software. For this test, total of 5 sample images are considered with 5 different cloud masking for each making 25 samples.

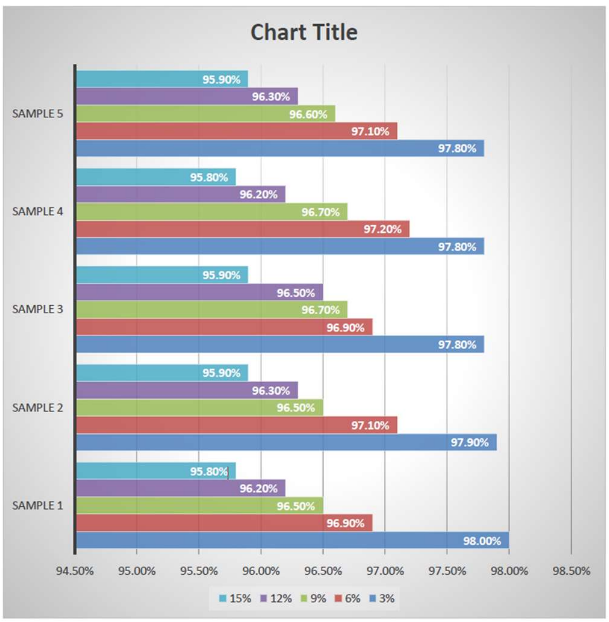

Fig. 11. Efficiency of remote sensing with presence of cloud

As per the analysis of Fig. 11, cloud coverage can reduce the performance of purposed method proportionally. This is due to the unknown pixels that are abundant with very low NDVI value for classifier to predict. However, the proposed method decides based and predicts based on neighboring pixels regarding soil and forest classification. The amount of noise resulted due to cloud, however, can reduce the accuracy of system in higher degree where the system makes various wrong decision. The results indicate that the accuracy of the proposed algorithm can be maintained at 95% under 18% cloud coverage. The accuracy of system under 3% cloud coverage was found to be slightly lower than the average accuracy of proposed method under 0% cloud coverage. The accuracy drops by 0.40% from 0 to 3 percent cloud coverage. The average efficiency of system for cloud masking of 3%, 6%, 9%, 12%, 15% and 18% was found as 97.80%, 96.95%, 96.55%, 96.35%, and 95.85%, respectively.

IV. Conclusion

The algorithms for building photo mosaics and 3D surface models using high-resolution imaginary for harvested forestry sites are developed using three databases with different resolution and height of shooting from forests and agricultural lands. The accuracy of 97.81% and above has observed and the precision of the classifier was found to be 97.75%. It also observed that the accuracy of the proposed algorithm can be maintained at 95% under 18% cloud coverage. The response time of the system is below 15 seconds, which indicates the system utilization is good. The mean value for the response time was found to be 7.56 seconds. The average efficiency of system for cloud masking for different cloud conditions are analyzed and found an average of 96% efficiency produced by the system.

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