Low-Cost Applications of Drones in Seed-Plantation and Plant-Health Analysis

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ABSTRACT

The goal of this paper is to present low-cost applications of drones in forestry and agriculture. The first objective of this paper is to prepare a simple low-cost assembly which uses a conical flask to store seeds and an open-close shutter mechanism for good distribution of seeds all over the farm using drones. The drone considerably decreases human efforts and increases the seed distribution efficiency. The second goal of this paper is to present a low-cost single-camera system to analyze plant health status using NDVI analysis. Normalized Difference Vegetation Index is a spectral band calculation that uses the visible (RGB) and Near-Infrared (NIR) bands of the electromagnetic spectrum. Leaf cells have evolved to re-emit solar radiation in the near-infrared spectral region and to absorb solar radiation in the visible spectral region. Comparing the amount of reflected red light to that of the Near-Infrared light can suggest what proportion of the sunlight was being absorbed by the plants. This method can be used to avoid the crop-loss due to various reasons such as weeds, pest infestations, lack of nutrients and many more. All the available resources for monitoring plant health are extremely costly. Not all the farmers can afford the use of the technology. Hence our goal is to make low-cost equipments so that farmers can make use of the technology at a much affordable price.

Keywords*: Infrared, NDVI (Normalized Differential Vegetative Index), NIR (Near Infra-Red), Nutrients, Plant Stress Level.*

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1. INTRODUCTION

The applications of drones are expanding with each passing minute and agriculture is no exception. The technology of unmanned aircrafts can be used for collecting valuable information in the agriculture sector, which can be used to avoid damage caused by pest infestation.

The factor that makes drones the best option for this purpose is the cost effectiveness of these unmanned devices. The cheaper cost as compared to airplanes and helicopters makes UAVs the optimum choice for carrying out valuable research which can help in the enhancement of production. It has been predicted that the agriculture sector will be responsible for nearly 80 percent of the commercial market for drones[1]. This is because drones can be that defining piece of technology which enables farmers to make better decisions regarding the management of their farms.

Precision agriculture technologies provide an opportunity to evaluate plant communities using light reflectance. Agriculture defines the success of a plant as productivity per unit of land area. Environmental stresses impose limitations on plants ability to achieve maximum yield. Inadequate fertility can reduce the growth and production. The consequence of stressful growing conditions is a decline in leaf chlorophyll concentrations, a decrease in incident light absorbance, and a reduction in overall plant productivity.

Planting trees in remote forest locations is a slow, laborious process that still relies on humans with shovels to do all the work. It can be drastically modernized by employing drones to plant seeds, spray for invasive species, and monitor the tree growth process. Forests are important for mitigating the effects of climate change, acting as carbon sinks that absorb as much as 30 percent of annual CO_2 emissions. Loaded with a batch of seeds, the drones can fly to specified sites and fire a seed into the ground. Besides speeding up the process while drastically reducing the costs, drones replace human effort with modern reliable technology.

On the other hand, the use of vegetative indices has allowed users to relate differences in reflectance of incident light at various wavelengths to changes in canopy characteristics. There are numerous indices, all derived from ratios based on the reflectance of incident light at specific wavelengths. The normalized difference vegetative index (NDVI) has gained wide acceptance based on its ease of use, only requiring two wavelengths, and the plant characteristics it has been correlated too. NDVI has been used to evaluate plant nitrogen status, chlorophyll content, green leaf biomass and grain yield. Spectral information has

ISSN: 2321-8169
707 –713

been used to evaluate micronutrient stress, detection of insect infestation, and disease infection of plants. An understanding of the physiochemical impacts of plant stress and their spectral responses, through the use of remote sensing, can allow producers to make decisions that are environmentally friendly, and economically feasible. On the field, an UAV equipped with multispectral camera allows us to determine the pest infestation of plants even before the leaves wilt. Using UAV's, the massive use of fertilizers can be reduced; Estimation of Chlorophyll content and plant nitrogen status, Leaf Area Index (LAI): Total photosynthetic tissue per unit ground surface, crop yield estimation can be predicted[2].

2. SEED SOWING DRONE

A simple low cost drone which can be designed and made at home using scrap materials very easily. The drone consists of a conical flask to store the seeds to be spread, a support mechanism to support the whole system and a shutter mechanism to open and close the opening of conical flask and to equally distribute the seeds over the farm.

2.1 ASSEMBLY AND WORKING

Seeds are poured in the conical flask through the opening. The opening and closing of the opening is done using a shutter. The shutter is operated or rotated using a servo motor. An L-shaped bracket is attached to the servo motor. An Arduino Uno board is attached to the servo motor which gives the input program for servo motor. This program decides the angle of rotation and the rotation speed(rpm) of the motor shaft. For our purpose, an angle of 90-120 degrees is used. The Arduino Uno board is connected to a battery which is the input power source.

Fig-1: Assembly of Seed Sowing Drone

Fig-2: Working of Seed Sowing Drone

It can be seen from fig.2, as the shutter opens the nozzle, seeds are sprayed via a guiding mechanism which increases the seed distribution efficiency. The angle of rotation set for this shutter mechanism is kept 90 degrees. It can be varied as per the drone speed and the speed of the servo motor so as to achieve maximum distribution of seeds.

3. PLANT HEALTH ANALYSIS -NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

NDVI is acronym for Normalized Difference Vegetation Index. It's used to better define the vitality and photosynthetic activity of plants. The NDVI is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum. It is adopted to analyze remote sensing measurements and assesses whether the target being observed contains live green vegetation or not.

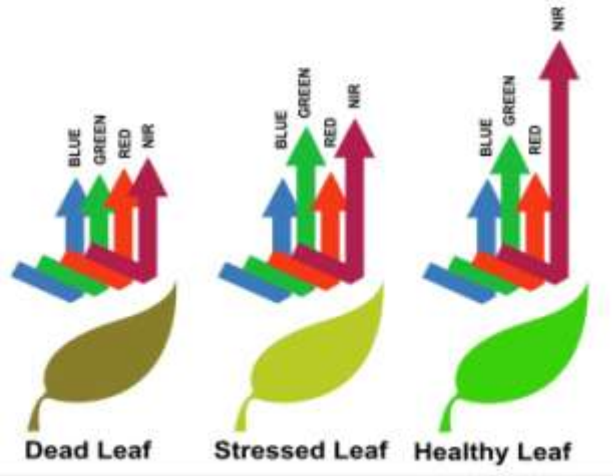

Fig-3: Vegetation Reflectance

In the Fig. 3, NIR indicates the reflectance in the near-infrared region and RED indicates the reflectance of red region in the electromagnetic spectrum[3]. Healthy vegetation reflects more light in the NIR region and absorbs most of the light in the visible red region. Whereas, stressed vegetation reflects less sunlight in the NIR region and absorbs more sunlight in the red region than that of the healthy vegetation. Theoretically, NDVI values are represented as a ratio ranging in value from -1 to 1 but in practice extreme negative values represent water, values around zero represent bare oil and values over 0.6 represent dense green vegetation.

3.1 CHLOROPHYLL ABSORPTION SPECTRUM

The NDVI concept is best understood by the Chlorophyll absorption and reflectance spectra. Chlorophyll in plants absorbs maximum of blue and red radiant energy incident on it. We can choose either red or blue filter for our NDVI calculation. Since red filter provides best contrast for our NDVI image, we choose red for our NDVI calculation[4].

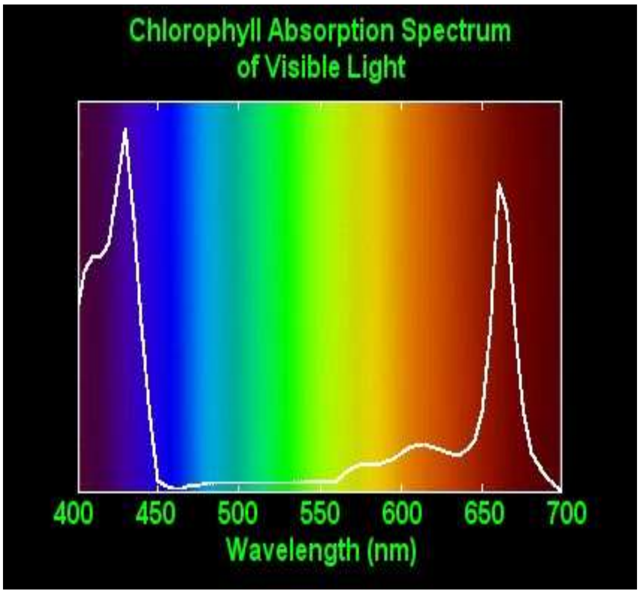

Fig-4: Chlorophyll Absorption Spectrum of Visible Light

3.2 VEGETATION REFLECTANCE SPECTRUM

About 50-70% of near-infrared spectrum is reflected and only about 1-5% of red spectrum is reflected by the green vegetation[4]. Higher the NIR reflectance and lower the red reflectance, healthier is the vegetation. As shown in fig.5 we can see that plants reflect most of the radiant energy in green and NIR spectra of the electromagnetic spectrum.

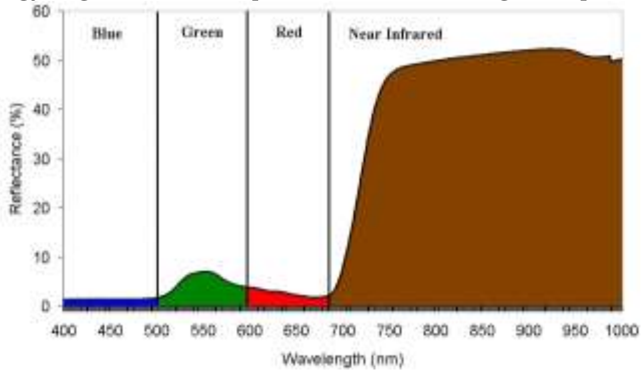

Fig-5: Graph of Reflectance Vs Wavelength of light

3.3 CAMERA MODIFICATION

3.3.1 MOBIUS ACTION CAMERA

The Mobius action camera is one of the most sophisticated mini cameras. One of the biggest advantages of this camera is that it is light weight and has manual time-lapse setting. It allows us to take a picture after a fixed interval of time. By mounting this camera on UAV, it can take pictures after a fixed preset interval of time which can be modified as required.

3.3.2 CAMERA HACKING (REPLACING THE IR-BLOCK FILTER)

Human eye consists of three cones red, green and blue and everything we see is a combination of colors formed by a combination of various intensities corresponding to the each color. We do not see infra-red rays with the naked eyes and so allowing the NIR rays to enter the camera makes the images noisy as far as the human seeing mechanism is concerned. For this reason, Our traditional digital cameras have an inbuilt NIR block filter which blocks all the incoming radiation in NIR region. Fig.6 shows the dismantled view of our Mobius action cam. We first broke down the IR-block filter which is a very tedious task since it's very small in size and the lens is just below it and if the lens gets even a single scratch the camera gives blurry images. We then cut a piece of Wratten-25a filter and placed it just after the lens where the IR-block filter was originally fitted as shown in fig.6. The camera was reassembled after replacing the filters and focus was adjusted using the Allen-screw to get good images.

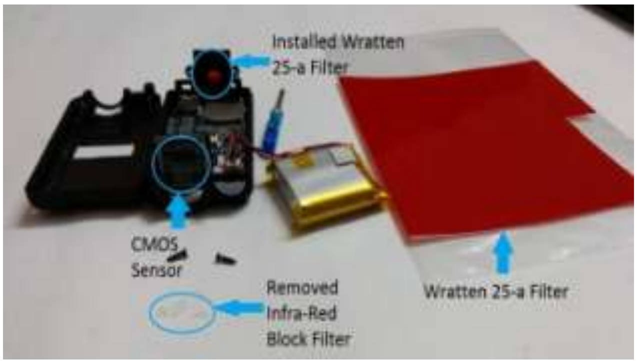

Fig-6: Camera Hacking

Our normal digital camera has 3 channels- red, green and blue. Since the available infra-red cameras are extremely costly, we can use our own converted camera which captures the NIR rays reflected from the plants. For this purpose, we remove the inbuilt infra-red filter and replace it with a dual-band-pass filter which allows the wavelengths corresponding to red and near-infra red (NIR) to pass. The blue channel captures the near-infra red (NIR) and the red channel captures the wavelengths corresponding to the red region of the electromagnetic spectrum. As shown in the fig.5, the Wratten-25a allows only the red and NIR regions of the electromagnetic spectrum to pass through it [5].

 ISSN: 2321-8169
707 –713

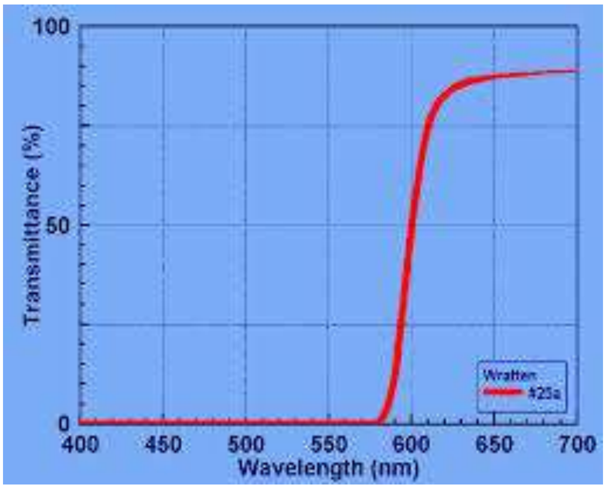

Fig-7: Transmittance characteristics of Wratten-25a

3.3.3 CAMERA CALIBRATION

The leaked NIR in the red channel can be tackled by Ned Horning's Calibration Plugin added to the software Image-J which is a Scientific Image Processing Software [6]. We can subtract the required amount of NIR from the red channel to get good enough results for our analysis

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3.3.4 NDVI ANALYSIS

Using the Ned Horning's NDVI lookup tables, we convert the raw image into an output NDVI image on a scale from -1 to +1 using Image-J. Experimentation needs to be done to get a good contrast by adjusting the white balance settings, as well as by modifying the traditional NDVI formula in a way such that it doesn't affect the core concept behind NDVI.

4. EXPERIMENTS

4.1 DETECTING WILT LEAVES

We performed our first experiment on a set of leaves just to make sure whether the camera hacking was perfectly done-

a. We arranged 7 leaves, 3 of them affected due to water-loss and heat and remaining green and healthy and placed them alternately.
b. The image was taken using our modified camera.
c. After post-processing and conversion using Image-J, the output result in the form of an NDVI image is obtained as shown in fig.9.

The traditional formula used for NDVI calculation is:

$$NDVI = (NIR-RED)/(NIR+RED)$$

We could not get a good contrast using the traditional NDVI formula. So we had to try out different formulas without affecting the significance of the NDVI and modify the formula to obtain a better contrast[7].

By trial and error method, we got the best contrast using this Modified NDVI formula-

$$NDVI = (NIR-RED) / (NIR+0.8*RED).$$

Fig-8: Raw Image 1

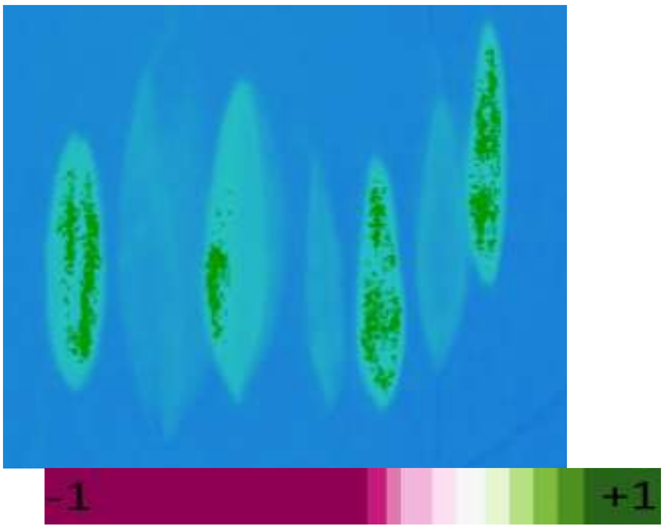

Fig-9: NDVI image 1

International Conference on Ideas, Impact and Innovation in Mechanical Engineering (ICIIIME 2017) ISSN: 2321-8169
Volume: 5 Issue: 6 707 –713

Fig.8 and Fig.9 represent the raw image and the NDVI output respectively. We can clearly see the difference in shades. The results are explained in section 5.

4.2 LOCATING THE AFFECTED AREAS OF A DISEASED PLANT

Second experiment was performed with an aim to detect the diseased plant and differentiate between the healthy and affected areas of the diseased plant. The input image and the NDVI output are as shown below -

Fig-10: Raw Image 2

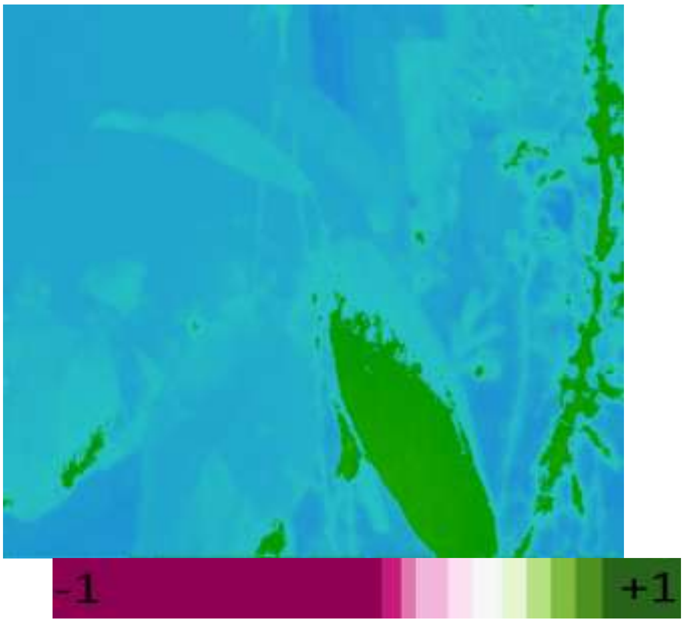

Fig-11: NDVI image 2

Fig.9 and fig.10 represent the raw image and the NDVI output respectively.Here also the unaffected part appears green and the affected part has a white tinge. The results are explained later in section 5.

4.3 WEED DETECTION

This experiment for performed in order detect the weeds growing in the plant region which might potentially affect the plants.

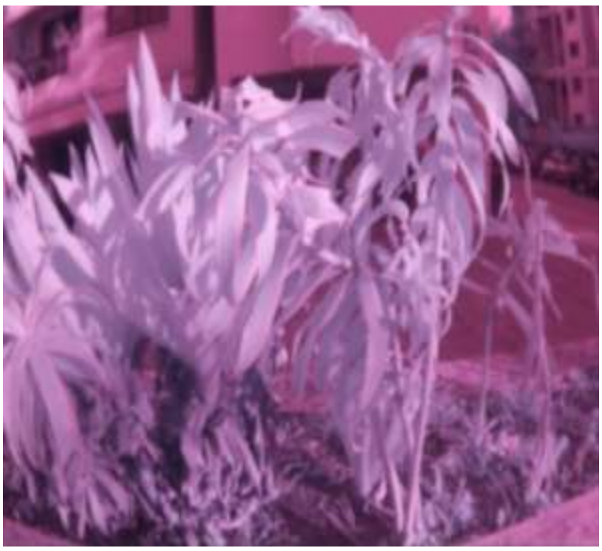

Fig-12: Raw Image 3

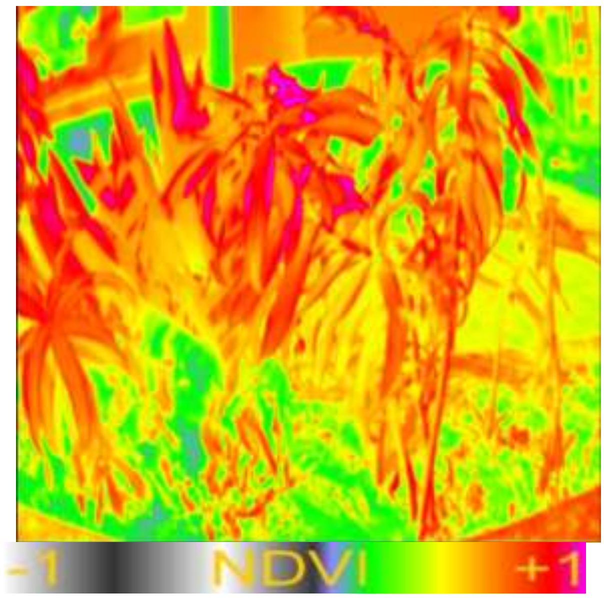

Fig-13: NDVI image 3

Fig.12 and Fig.13 represent the Raw Image and the NDVI output respectively. The weeds appear green, which according to the lookup table used for this experiment have lower NDVI values than the red region indicating higher NDVI values.The results are explained later in section 5.

5. RESULTS

Experiment 4.1

According to NDVI output obtained, a clear difference is seen in shades between the green leaves and wilt leaves in the stretched NDVI images. Healthy leaves appear much greener and wilt leaves appear faded in the image.

Experiment 4.2

The NDVI image clearly differentiates the affected parts of the diseased plant from the parts that are yet to be affected. Thus corrective measures can be taken to save the plant from getting entirely damaged.

Experiment 4.3

This experiment demonstrates that NDVI analysis can be used for detecting weeds which can potentially damage the plants. The weeds reflect much less portion of the sun- light in the NIR region as compared to that of the healthy green vegetation and thus the NDVI values of the weeds are lower than that of the healthy green vegetation.

6. CONCLUSION

Any digital camera can modified to detect green vegetation and to do some basic plant analysis by replacing the NIR-block filter with the red pass filter. Mobius action camera costs about 10 times less than the commercially available cameras used for plant health analysis which is a huge triumph of the modified single-camera system thereby making it easily affordable for the traditional farmers which was the major goal of our project. From the performed experiments, we can conclude that the clear contrast in colours is obtained from NDVI outputs of the respective images. Thus with reasonable accuracy, we can use the modified single-camera system for analyzing the green vegetation and performing plant health analysis.

ACKNOWLEDGEMENT

We would like to express our special thanks of gratitude to Prof.Joglekar as well as our Head of the Department Dr.A.P.Pandhare who gave us the golden opportunity to do this wonderful project on the topic 'Low-Cost Applications of Drones in Seed-Plantation and Plant Health Analysis'. We would also like to thank Navstik Labs and Bharat Rohan Team for their support and encouragement. We would also like to thank Mr.Adwait Datar and Mr.Pushkar Sevekar for their help in finalizing this project within the limited time frame.

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