Definition of Management Zones through Image Processing for Precision Agriculture

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Abstract—**The continuous growth of the world population results in ever growing demands on food production, however the amount of area available to expand farming activities gets smaller every day. This is the chief motivator for techniques to help farmers improve the efficiency of their crops. This paper proposes the utilization of aerial images of plantations, captured by unmanned aerial vehicles (UAV), in order to monitor the plant's health, the vitality of the vegetation is calculated using well-known methods such as Normalized Difference Vegetation Index (NDVI). However, alone this data is not enough because the farmer cannot decide which actions and where he should take, for that reason the management zones are needed. The vigor zones are calculated utilizing a classification algorithm to divide the crop in a prefixed number of regions, grouping those with similar aspects, which allows the producer to decide how he will act in each zone.**

1. Introduction

The continuous growth of the World population keeps pushing up the food production requirements. On the other hard the amount of area available to expand farming activities gets smaller every day, e.g. more land is claimed for housing, growing concern with indigenous rights and wild life protection, etc. This is the chief motivator for techniques to help farmers improve the efficiency of their crops [1].

One concept created to help improve the productivity is precision agriculture (PA). According to [2] it consists in the application of geospatial techniques and sensors, such as aerial images and GPS, to identify crop variations and use different approaches to treat them.

The variation of management over space according to [3] is proven to be effective in increasing field yields. One reason for that is due wrong amount of crop management, more or less, of inputs is applied the crop productivity decreases.

In addition PA not only improves the crop productivity, but it also reduces the use of agriculture supplements e.g. fertilizers, pesticides, nematicides which result in the reduction of cost and overall environmental loading [4].

In order to deploy PA it is necessary to use tools which provide information about the crop enabling the identification of variations in the plantation.

For that reason the use of unmanned aerial vehicles (UAV) to capture information through image is being widely explored, as can be seen in [2] [5] [6] [7]. This technology is advantageous because it is easy to use, has various applications, it is totally portable, and cost effective.

UAVs remotely sensed data enables cheap computation of Normalized Difference Vegetative Index (NDVI) of wide areas such as entire crops. NDVI information is a good measure to predict the planting yield variation [8]. Then with the NDVI it is possible to calculate site-specific management zones inside the crop area.

A management zone (MZ) is a region of the plantation that requires a specific treatment, the determination of a MZ is done by grouping the areas with similar characteristics, such as NDVI, into a bigger one.

Since there may be areas with the same characteristics but spatially disconnected, a management zone can appear in more than one region of the plantation. A single crop can be separated in many different MZ but usually it is divide in no more than 5 zones.

The definition of management zones is extremely useful for the farmer point of view since it serves as a tool for the precision agriculture, resulting in a higher productivity and a reduction in costs per hectare.

Due to the utility provide by the definition of management zones, and the ease of use of unmanned aerial vehicles remote sensing, this work proposes an algorithm to define these zones from digital images captured by [1]

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2. Related Work

The use of digital images to calculate management zones is already being studied, as can be seen in [9] where its taken in consideration five soil and landscape attributes, NDVI information, soil electrical conductivity, total nitrogen, organic matter and cation exchange capacity acquired for a coastal saline land. It summarizes the data using principal component analysis (PCA) to choose a smaller subgroup of attributes, resulting in 2 principal components (subgroups) which are used as input to a fuzzy c-means clustering algorithm to determine management zones.

Also in [10] a segmentation algorithm inspired by an image-processing region-merging algorithm is presented, the clustering is done by merging close regions with similar attributes, the spatial coordinates are only used to specify the neighborhood in which the search happens.

Thereby, it can be concluded that the use of clustering algorithms to determine management zones is already being explored and is verified to be effective. Therefore, it is a field that is worth researching.

This work proposes the use of a K-means [11] clustering algorithm in a NDVI digital image in order to cluster the areas with similar yielding characteristics and thus determine the different management zones, using only the index information. The K-means approach was opted due to its simplicity, and the possibility of using a search space different from the previous works which ni turn reduces the search space dimensions.

3. Methodology

This section describes the algorithm developed to generate the management zones from an image containing the Near-infrared spectrum, the flowchart is shown in fig. 1.

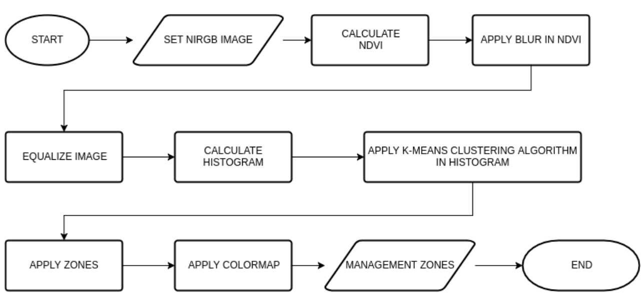

Figure 1. Algorithm Flowchart

The first step is to provide an image of the region that is going to be analyzed, it must contain a near-infrared and blue or red channels.

Following, the normalized difference vegetation index (NDVI), which indicates the vitality and green density of an area, is calculated following the eq. 1, if the red channel is available, or with eq. 2, if only the blue spectrum is present. The camera using in this study captures the NIR, Green and Blue frequencies. Therefore the second equation was utilized.

$$NDVI = \frac{NIR - Red}{NIR + Red} \tag{1}$$

$$NDVI = \frac{NIR - Blue}{NIR + Blue} \tag{2}$$

It was noted that the calculated NDVI presented many spatial discontinuities (noises), this may be caused by the presence of small gaps without plants, small areas with a great variation in the index, or even due to the discretization process when capturing the images. These outliers must be treated because when defining the management zones the objective is to spatially group zones with similar characteristics, and a small area with a lot of variation compared to its neighbors is not representative.

Thereby, to remove noise and smooth the NDVI a low-pass filter is applied, different kinds of filters have been tested including a Normalized box filter [12], a Gaussian filter [13] and a Median Filter [14].

Usually, the resulting image intensity values are not well distributed in all available range, which results in a difficulty distinguishing NDVI variations in the crop since these differences are usually small. Consequently, the management zones classification by the algorithm is impaired.

To address this issue the picture is equalized increasing the contrast and better distributing the intensity values.

The problem of management zones can be tackled in a variety of ways as presented earlier. In this work it is opted to explore a new venue. Namely, we were interested in investigating feature space remapping. This is a feasible idea since the management zones pose a hard segmentation problem. The same zone can occur in geographically disconnected regions on the field leading to segmented clusters. In doing feature remapping this issue can be circumvented.

In order to apply a feature remap the image histogram is computed and used as the new search space. This is also advantageous because it reduces the data dimensionality, minimizing the complexity of subsequent steps.

Once the histogram is computed the problem becomes a multi-scale thresholding since it is usual to seek out more than two management zones. Unfortunately it is complicated by a number external factors, such as lighting variations throughout the imaging time and varying climate conditions. Clustering is a very useful way to address the problem of multi-scale thresholding since the algorithm's mechanics decide naturally the fittest centroid to each of the desired segments.

The number of management zones, n, is a known variable served as input to the algorithm. The number of clusters is not an issue in this case, K-means is presented as a stable, efficient and well understood procedure.

Subsequently the image is transversed pixel by pixel and the NDVI value for each location is included in one of the sorted groups. The category in which each pixel will be inserted is chosen by the difference between the average group and current pixel intensity values. The class with smallest difference is selected.

It is important to emphasize that n can be interpreted as the number of management zones in the output image, and also that this parameter is set by the user. However, in real situations the number of zones is usually no greater than five.

The resulting image with the different zones is used to present to the farmer a picture of management zones of the area analyzed. For this reason the data must be intuitive and easy to read, therefore a color map is applied presenting each distinct zone with a different color.

4. Results and Discussion

In order to capture aerial images of the crop a UAV named sx2 (fig. 2) was used, when capturing the pictures the vehicle flies in an altitude between 100 and 150 meters, it's air speed must be at least 10 meters per second, ideally $15m/s$, and the ground speed should not exceed $15m/s$.

The UAV is completely autonomous and has autonomy to fly between 1 and 1.5 hour, it's flight path is set to cover all analyzed area. It is also configured that a snapshot of the plantations is taken every 2 seconds.

Figure 2. UAV utilized to capture crop images

The sensor, camera, used to take the pictures is a modified Canon S110 (fig. 3), originally it can only capture red, green and blue (RGB) frequencies, however to calculate the NDVI the near-infrared spectrum is needed. Therefore, the original optical filter is replaced for one that enables the perception of the near-infrared channel, resulting in a near-infrared, green and blue (NIRGB) image.

Figure 3. Canon S110

After all the individual pictures have been captured they must be tiled up into a single image that represents the whole area to be analyzed, this is the orthomosaic process [15]. For this purpose a 3rd party software is employed.

The output of this process, an orthomosaic image (such as fig. 4) is used as input in the algorithm presented in the last section (fig. 1).

Figure 4. Image to be processed

Following, sample images showing intermediary results are presented for each step of the proposed process.

The filtering step has the objective to reduce noise and smooth the image, in order to do that the filters mentioned in section 3 have been tested.

Using a median filter, the difference can be noticed comparing the figure before this process (fig. 5) and after (fig. 6).

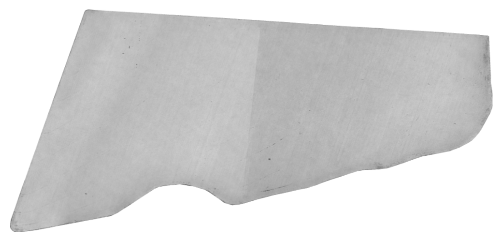

Figure 5. NDVI without filtering

Figure 6. NDVI after filtering

The equalization process is responsible to increase the image contrast, making it easier to perceive small NDVI variations. To exemplify the effect of this step the image histograms before and after equalizing are shown in fig. 7 and 8, respectively.

The output image after filtering and equalizing can be seen in fig. 9.

In case the algorithm is applied without filtering, equalizing and number of zones equals to five, it can be noted that it doesn't succeed classifying the different zones. As can be seen in the resulting image, fig. 10. The result is basically an homogeneous area.

However, if only the filtering step is ignored, number of zones equals to five, the algorithm finds a few different

Figure 7. Histogram without equalization

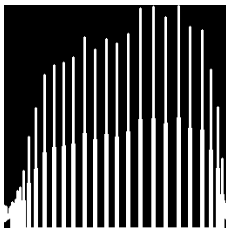

Figure 8. Histogram equalized

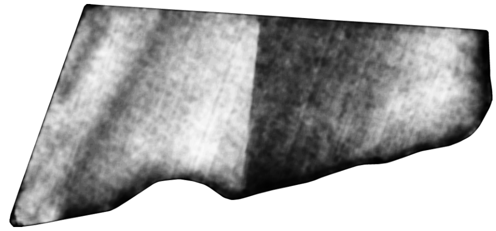

Figure 9. NDVI filtered and equalized

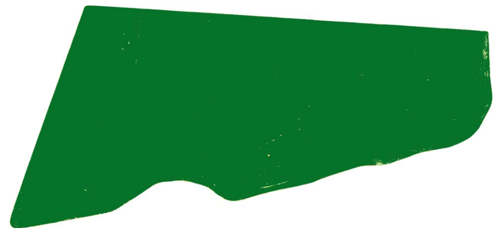

Figure 10. Management Zones without filtering and equalizing (n=5)

zones but it is not able to successfully spatially group them. Resulting in an image with scattered zones (fig. 11, which doesn't comply with reality.

Therefore, it is concluded that the equalizing and filtering step are necessary. The whole algorithm is applied, using a median digital-filter with kernel size of 35 pixels. The output, management zones, can be seen in the figures 12, 13, 14, for zones numbers equal to 3, 5 and 7, respectively. It can be noted that the different zones are well-defined and spatially clustered.

Although the results are apparently satisfactory there is no theoretic method to determine their quality. Therefore, the only way to validate the management zones calculated is through a specialist's opinion.

Considering that, this work was shown to some agronomists with practical experience determining management zones, and through their opinion this work was validated.

The full algorithm was executed in a machine with a CPU model Intel(R) Core(TM) i7-4700MQ CPU @ 2.40GHz, 16GB DDR3 memory, and it takes approximately 12 seconds to process an image with 4387x2021 pixels (17.1 MB) that covers about 160ha.

5. Conclusions

The definition of management zones in a crop is extremely important, because it assists the farmer to decide how much care each region of the plantation needs. With this information the producer can apply a varied input rate in each zone, thereby increasing the productivity and minimizing the costs per hectare.

Since the validation process is not well-defined being quite subjective, there is a need for a more scientific method to verify the quality of the results. This can be reached through soil and leaf analyses, or by comparing different management zones, using the same image input, created by several specialists and statistically correlate them.

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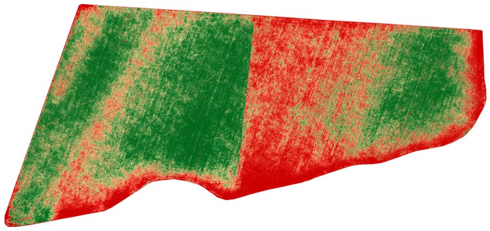

Figure 11. Management Zones without filtering (n=5)

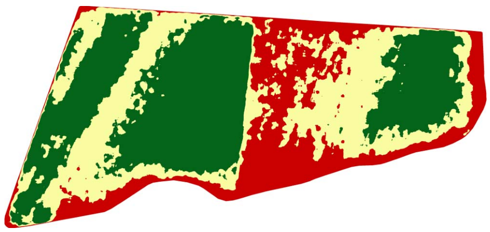

Figure 12. Management Zones with color map (n=3)

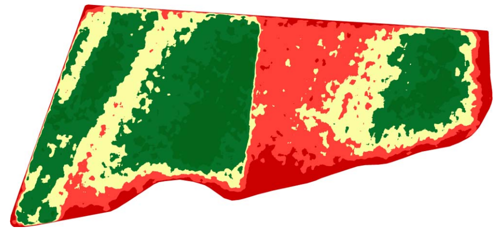

Figure 13. Management Zones with color map (n=5)

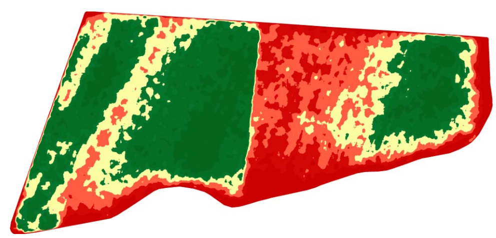

Figure 14. Management Zones with color map (n=7)

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