Texture Analysis for the Segmentation of Sugar Cane Multispectral Images

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Abstract. In this paper is presented an analysis of the impact of texture features for segmentation of multispectral aerial images of sugar cane. Currently there are no precise techniques to estimate objectively areas of fallen cane and this causes significant losses in crop productivity and industrialization. For the realization of this work was made an image dataset. To build this dataset was implemented a software from which were obtained labeled regions in the images related to this agronomic phenomenon and then were extracted some texture features and a typical agronomic index (NDVI). The features related to segmentation task were analyzed with classical techniques such as Principal Component Analysis and Decision Trees. The results obtained show good performance to distinguish normal sugar cane versus fallen sugar cane but not between different fallen sugar cane classes. However this approach was satisfactory to estimate the normal and fallen sugar cane areas and this increase the information quality available to support agronomic decisions.

Keywords: sugar cane; multiespectral images; texture features; principal components analysis; decision trees

1 Introduction

The cultivation of sugar cane in Argentina is found principally localized in the northwest region of the country (99 %), where represents, in agreement with [1], one of the most important productive activities, and in scarce extension in the littoral region (1 %). The productive systems present different technological levels according to the

adfa, p. 1, 2011.

system of crop used, with systems ranging from manual to fully mechanized. However, at present, over 70% of the total volume is harvested in a mechanized way. One of the most critical aspects of the process of harvesting sugar cane are the losses that are produced and are acceptable levels about 2,5%. The presence of fallen cane is one of the factors with biggest influence. Incidence of overturning superior to 20% produces increments in the losses that go from 4 to 6,4%, according to [2].

The presence of fallen sugar cane (CC) at the moment of harvesting brings important losses of product during the collection and in the sugar mill. In the phenomenon of CC take part random and unpredictable aspects. It is normal that the sugar cane plantation in a productive square reach an average height, but presents variations of this feature in different sectors of the field. This might be because of the different conditions of the earth that presents different levels of fertility, humidity, compressing, etc. On the other hand, each plant of the sugar cane plantation is constituted in a different way and they will manifest in unique form the different external stimulus.

When the plant is young and has developed under the best conditions, reaches certain height and for its own weight it begins to warp, moving close to break once its breakage tension is surpassed, product of the wind or environmental phenomena as the hail. The CC appears with great space heterogeneity.

Once produced the phenomenon, the earth can remain exposed or, on the contrary, can appear a product with green color because of the appearance of new green sheets, with phototropic growth. This adds heterogeneity to an external observation. The above mentioned factors make clear the great complexity of the phenomenon under study, which makes it difficult to analyze and quantify.

When strange matter called ‘trash’, that is not sugar cane, enters the sugar mill represents an important loss of efficiency in the process of manufacture of the sugar, as assure [3]. The challenge of industrial engineering is to explore the alternatives to control the harmful effects that these tailings or trash and the dust present in the cane have in the equipment, processes and operative performance of the factory. That is to say that the quality of the cane affects in direct form the industrial performance and the quality of the obtained sugar [4]. In turn, the quality of the raw material (cane) can be affected by changing aspects of the agriculture of the sugar cane, such as the introduction of new cultivars, climatic variations, the use of ripening chemists, changes in the cultural practices and in the systems of harvest or the appearance in the cultivations of illnesses or infections. As for the types of harvest, it is observed that the contents of trash and dust in cane harvested in mechanized way are appreciably lower that in the semi-mechanized, being more than 2 to 5,7 %. At the same time, the values of fiber (plant residues) rise from 14 to about 18% due to the presence of increased amount of plant parts with a less efficient harvesting [5]. This means that the industries pay to the producers a significant part of the weight of the trash of the entered raw material at the same price of the cane, because the form of sampling and analysis of this parameter is generally inadequate. To this must be incorporated the other additional costs produced by this strange product in the mill:

1. Abrasive wear in mills and a progressive loss of capacity to extract the cane juice.

2. Significant increase in the amount of "cachaza" and in the losses of sugar present in it.
3. Increased use of chemicals to treat the juices.
4. Increase of juice's color intensity and sugar's color intensity, thereby to avoid it the crystallization cycles must be reduced decreasing the manufacturing efficiency.
5. Wear on equipment, tubes and pumps.
6. Diminution of the calorific value of the sugarcane bagasse and consequently of the burning efficiency, with an increase of the boiler consumption and emissions.
7. Other.

To reduce to the minimum possible the percentage of trash in the sugarcane, several mills installed washing tables of cane, where they remove the content of dust by means of big quantities of water (about 3 m3 of water by ton. of cane). This supposes a saving of money, but adds problems like bigger costs for the required power, the water and the additional manual labor, added to the new discussions with the producers since some studies confirm that during washing it is lost a percentage of the performance of sugar extraction. Moreover, the technique requires availability of terrain to install settling tanks of sand and mud to reuse the water. A promising strategy to achieve the reduction of this impact takes root in achieving a bigger operative efficiency in the tasks of harvesting the cane, previous stage to the entrance to the factories, and fundamentally in sectors with broken cane that increases notably the percentage of trash. This is an area of intensive manual labor where for its particular properties, considers [5], it was no possible to introduce technological solutions to reduce its negative impact in the production.

At present, the quantization of the fallen cane in productive squares is an expensive and inefficient process. It requires sending evaluators to the terrain that must explore big surfaces to obtain a representative sampling that permit an estimation. The displacement around the field produces damage, requires many man hours of work and generates estimations with a high degree of uncertainty. In turn, the presence of space variations in the productivity of the cane is very wide, [6] determined variations until 50 tn/has. It is expected that this production pattern, as well as variations in the quality of the cane, be observed at diverse scales, in a similar way to other variables that influence in the production, as the properties of earth [7], making it difficult to establish a single sampling distance and has a negative impact on costs.

Other strategy is carrying out flights over the cultivations with specialists who estimate the percentage of fallen cane according to their experience and what is observed from the air. This strategy is subjective and dependent on the available specialists in each area of interest.

Keeping in mind these antecedents is evident that has not observed a report of some methodology with measurable certainty to decide the affected area, in order to help to plan a better way of harvesting and the associates costs.

With this goal in mind and in conjunction with the National Institute of Agricultural Technology of Argentina (INTA), the group has worked on a number of algorithms for processing high-resolution aerial photographs of sugarcane productive squares[8,9].

2 Materials

A set of images obtained for the National Institute of Agricultural Technology of Argentina (INTA) from a Sky Arrow 650TCNS ERA airplane , whose system of capture is composed of a Global Positioning System, a Geospatial MS4100 multi-spectral camera and a system of control and storage of data. The camera permits the acquisition of photograms in three bands of the electromagnetic spectrum: green (530-580 nm), red (650-685 nm) and near infrared (770-830 nm) with a resolution of 1920 x 1075 pixels. The GPS provides the position, altitude and height in synchronism with the acquisition of each photogram.

A flight was carried out on 5th May 2008, moment of the cultivation cycle where the presence of fallen cane is clearly evident. The flight was carried out in the solar midday to have homogeneous illumination in the surface. The flight plan was designed for an altitude of 1200 m, resulting a size of pixel of 0.7 m by side. There were obtained 540 photograms that were assembled by means of reconnaissance points in consecutive photograms generating a mosaic.

With the supervision of an agricultural engineer it was carried out the labelling of the images in the classes of interest, using the application Label Me [10] of the Massachusetts Institute of Technology (M.I.T.), which was in a local server to facilitate the access to the data and the incorporation to a pipeline of processing. The Fig. 1 shows the process of labeling which consisted in delimiting the images with polygons that contained representative portions of the cane classes: standing cane (CP), fallen in form of patch (CCP), fallen cane in big areas (CCA), fallen cane with phototropism (CCF) and areas of exposed ground (C).

From this stage resulted a dataset composed of 5678 samples or square images of 60x60 pixels.

With the red and near infrared channels was obtained the Normalized Difference Vegetation Index (NDVI) [11] of each image.

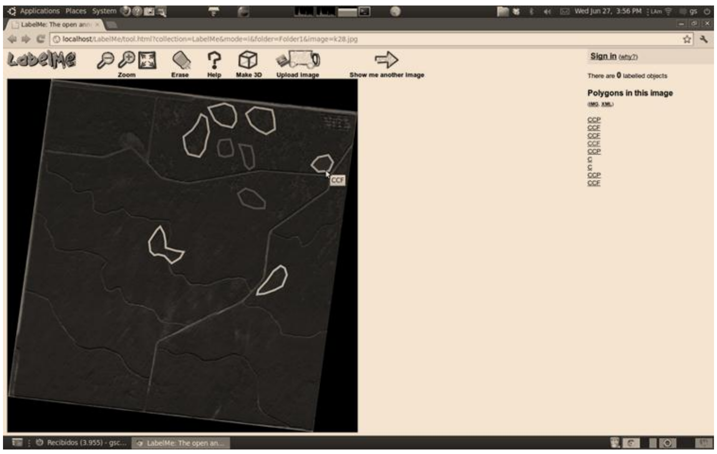

Fig. 1. Capture of screen of an example image and of the process of labeling with LabelMe.

3 Methodology and Results

3.1 Data analysis

Usually the methodologies used in the field of image analysis in agriculture when studying the state of the sugar cane are oriented to the use of photometric indices such as NDVI. On the other hand considering that this type of cultivation has more pronounced alterations in the spatial distribution compared to other crops suggests address the problem using texture characteristics of aerial images and evaluate their capability to describe it.

In this regard, it has been reported by [9] that the entropy, which is a common used texture feature in agriculture, provides insufficient information to distinguish the different states of the cane, so in this work is proposed to complete the set of texture features, incorporating other first-order statistics such as mean and standard deviation of the different channels of the image, in order to determine the relative contributions of each one in relation to the problem.

Before feature extraction, the three channels of the original images were preprocessed by applying the Cartoon+Texture image decomposition, proposed by [12]. For each image point, a decision is made of whether it belongs to the cartoon part or to the textural part. This decision is made by computing a local total variation of the image around the point, and comparing it to the local total variation after a low pass filter has been applied. This algorithm gave texture images with normalized brightness.

Then all images were processed with 11x11 pixel windows defining the following characteristics or indicators of interest applied to the windows:

- Entropy
- Standard Deviation
- Mean

Thus, each window was characterized by a set of 12 texture parameters, 3 for each channel in the image (Infrared, Red and Green) and 3 for the NDVI images.

As a first step, was carried out a Principal Components Analysis (PCA), which allowed to condense the information from a large set of correlated variables in fewer variables, without losing most of the variability present in the data set.

By applying PCA resulted that 96.6% of the variability in the data was explained by the first 3 principal components encountered. However it was observed that in the space generated by the main components only three classes were distinguished: CP, C and CC (which contains the types CCA, CCP and CCF).

In the Fig. 2 is shown the distribution of the types of cane in the Principal Components space.

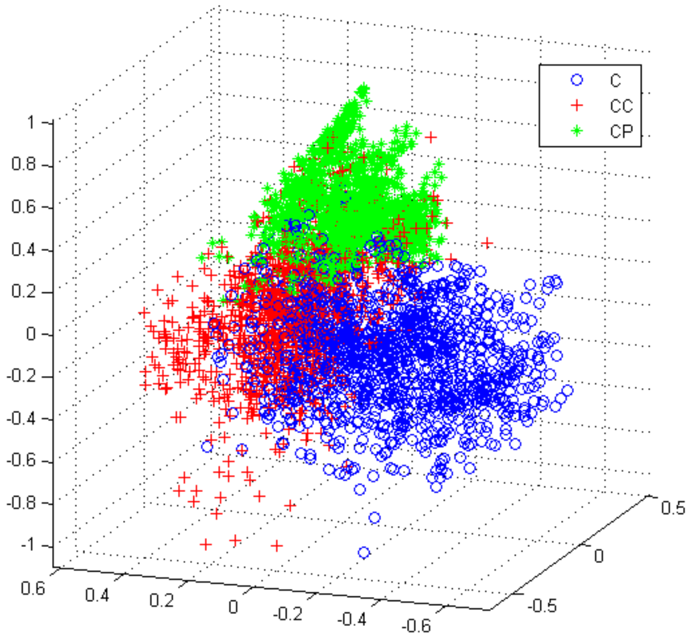

Fig. 2. Distribution of the types of cane in the Principal Components space.

Then all data was analyzed by Decision Trees, a prediction model based on inductive inference which identifies examples of one of several possible categories.

For this, data was normalized and clustered in Training groups and Test groups, picking up examples randomly from the groups CP, CC and C.

In the Fig. 3 is shown the percentage of success versus the level of pruning made to the original tree. Each curve corresponds to a different tree, obtained by subsampling the original data. It is also shown an average curve (red).

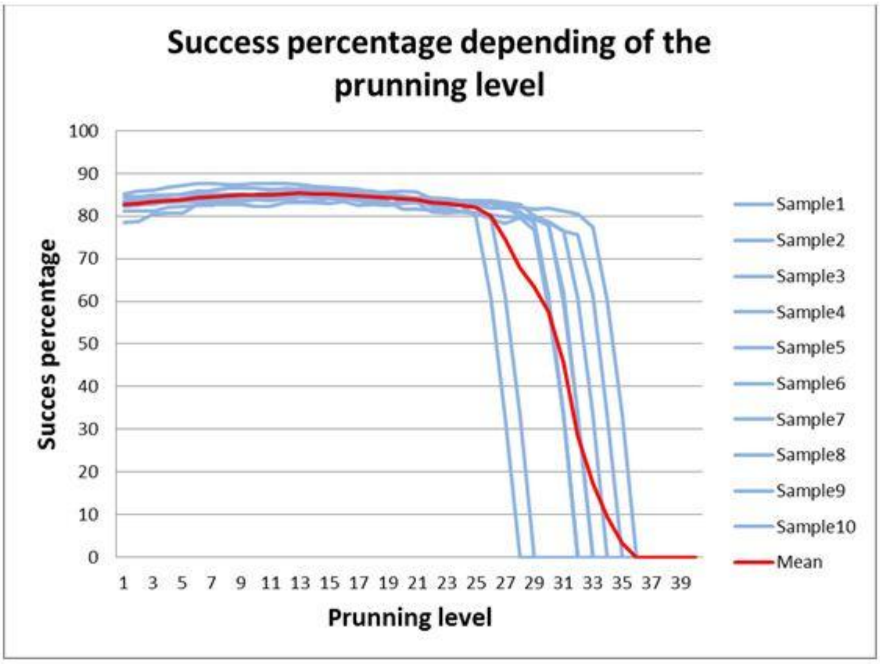

Fig. 3. Success percentage of ten different trees and mean curve.

For most cases, at a pruning of 25 levels was obtained the simplest tree with similar performance of the not pruned tree.

It also was studied the way that decision trees performed the identification. In general, root nodes were entropy and standard deviation of red channel. The following node was the mean of red channel and the third one was the mean of infrared channel. In some trees the fourth node identified a class but in others decided the entropy or standard deviation of infrared channel. The information of the green channel was the mean in the fifth node where also appeared the mean of the NDVI in others trees.

3.2 Proposed workflow

Figure 4 shows the summarized workflow diagram used for this approach. The images obtained by the INTA EEA Paraná were labeled and classified with the supervision of an agricultural engineer in order to build a Gold Standard and Test dataset. Next were built the NDVI images to obtain the photometric features and the three channels (infrared, red and green) of the original images were preprocessed to normalize the brightness. Afterward were obtained texture features to describe the sugarcane pattern in the aerial images. In this work texture features were analyzed with PCA and Decision Trees in order to evaluate their utility. Nevertheless, in future works, the objective is to build segmentation models by means of different machine learning methods.

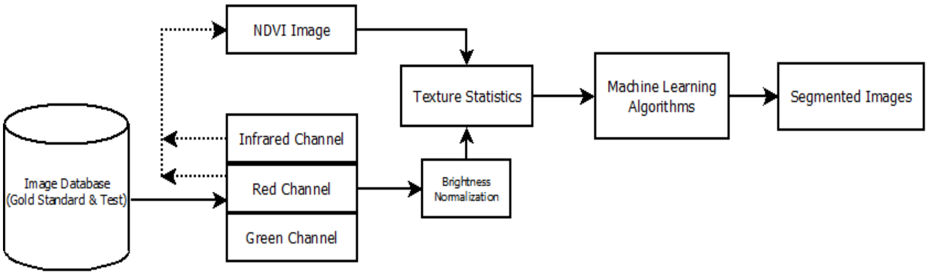

Fig. 4. Workflow Diagram

4 Conclusions

It was compiled a reference dataset and a database for the study of the cultivation of sugar cane in its different states.

PCA could distinguish between standing cane and fallen cane, but resulted insufficient to differentiate most of the fallen classes. The only CC that could be identified was the C class, which corresponds to the zone of lower fertility.

Another conclusion is that the most quantity of information is contained in the same channels considered by the NDVI indicator but from a geometric point of view. Then the information of the green channel and the variations of the NDVI were incorporated.

By the analysis carried out it was possible to measure and rank the importance of the incorporation of new descriptors in order to evaluate the state of cultivation. Furthermore it was noted that the approach of textures from the statistical viewpoint is insufficient for complete detection of fallen canes, so it must include spectral or multiscale approach to the problem.

As future work is planned to incorporate new descriptors in order to build a classifier oriented to the segmentation of the images.

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