A NOVEL METHOD FOR 2-D AGRICULTURAL SOIL ROUGHNESS CHARACTERIZATION BASED ON A LASER SCANNING TECHNIQUE

M. Barber[1], C. Pepe[1], P. Perna[1], F. Grings[1], J. Jacobo Berlles[2], M. Thibeault[3], H. Karszenbaum[1]

[1]Instituto de Astronomía y Física del Espacio (IAFE), Pabellon IAFE, Ciudad Universitaria (1428), Buenos Aires, Argentina.
[2]Departamento de Computación, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Pabellón II, Buenos Aires, Argentina.
[3]Comisión Nacional de Actividades Espaciales (CONAE), Paseo Colón 761 (1063), Buenos Aires, Argentina.

ABSTRACT

In this paper we present a laser profiler, whose main aim is the determination of agricultural soil roughness. Its working principle is based on the acquisition of an image of an object illuminated by a laser beam and on the use of 3D computer vision techniques to obtain the reconstruction of the scanned object. One of the most important purposes of this device is the attainment of the soil RMS height (s) and the correlation length (l) related to the autocorrelation function. These are fundamental inputs to derive soil moisture maps from soil backscattering data.

***Index Terms*— Profilers, soil roughness, rough surfaces**

1. INTRODUCTION

It is well documented that soil backscattering in the microwave regime depends mostly on soil roughness and soil permittivity [1]. Many agricultural applications require the retrieval of soil moisture at regional scales, in order to include soil moisture information into an ecoagricultural process model. One key step to derive soil moisture maps from soil backscattering maps at microwave regimes is to statistically quantify agricultural soil roughness. Up to date, only *in situ* measurements were able to success in this task.

Three main techniques for soil roughness measurement are discussed in the literature: meshboard profilers, needle-like profilers and laser profilers. Meshboard profilers are graduated boards able to measure soil roughness using graduated lines. Needle-like profilers are arrays of small parallel cylinders mounted over a board in such a way that the vertical displacements of the needles (related to the vertical profile of the soil) can be measured. Laser profilers discussed in the literature are flight-time laser altimeters, which measure soil profile by converting beam delay into beam flight distance. All these methods present different disadvantages, all discussed in [1]. The major drawback common to these methods is their inherent restriction to measure only 1-D profiles. This restriction is related to the fact that the most widely used electromagnetic interaction models used to calculate the soil backscattering at microwave regime (SPM, PO, GO, IEM) suppose that soil roughness can be characterized by a 1-D soil profile. This leads to theoretical derivations based on one of two autocorrelation functions (exponential, gaussian), that requires as an input the soil RMS height (s) and the correlation length (l_{corr}) related to the autocorrelation function (ρ). These values can be obtained from [2]

$$s = \sqrt{\frac{\sum_{i=1}^{N}\left(z_i - \bar{z}\right)^2}{N-1}} \tag{1}$$

where z_i is the height of the soil profile, $\bar{z}$ is the mean value and l_{corr} its correlation length which is given by

$$\rho(x') = \frac{\sum_{i=1}^{N+1-j} z_i z_{j+1-1}}{\sum_{i=1}^{N} z_i^2} \Rightarrow \rho(l_{corr}) = \frac{1}{e} \tag{2}$$

Recent investigations suggest that for some agricultural soils profiles related to specific agricultural techniques, these hypotheses may not be valid. Firstly, in smooth soils related to non-tillage methods, the assumption of a single autocorrelation function able to describe the whole soil profile was found false [3]. Secondly, most agricultural soil presents a non symmetrical 2-D profile, related to preferential plough directions and water leakage. So, it is not clear in which direction soil profile should be measured, and angular averaging leads to very imprecise parameter estimations, not related to intrinsic parameter variability but to an incorrect experimental design [1].

One way to increase the theoretical knowledge about real soil backscattering, is to measure the bi-dimensional soil profile of agricultural soils. In order to do this, in this paper we present a profiler based on a laser scanning technique, that intrinsically measure the 2-D soil profile [1]. This profiler is constructed around a laser beam that is diffracted using a small glass rod, in order to obtain a clear laser line over the soil. A mechanical base is used to move the laser base transversally, in order to scan a 2-D soil profile. On every step of the laser base, a camera takes a picture of the soil illuminated by the laser line. Then, an image processing technique is used to extract soil profile from soil images. In its prototype version, the scanner is able to scan an area of 1 m x 0.3 m.

In section 2 we describe the laser profiler device and the associated image processing techniques needed to derive profile information from photographic images. In section 3 we show some 3-D profiles measured on specific test sites. Finally, in the conclusions we analyze how this new technique could be able to close the gap between theoretical models and real soil backscattering.

2. DEVICE AND IMAGE PROCESSING TECHNIQUES

In this section the laser profiler is described. A laser, a glass rod and a digital camera are attached to a platform. This platform is placed at a distance of 30 cm over the ground. The laser beam is diffracted by the thin glass rod in order to obtain a laser plane, which intersects the soil and is seen as a line. This line breaks if there are elevations or depressions on the impact area. The images are taken by the digital camera (Logitech QuickCam Pro for Notebooks, 2 MP resolution), which is placed at a distance of 20 cm of the laser beam and 20 cm over the ground. The system described is supported by a rod connected to a motor that provides longitudinal movements (see Fig. 1) so as to obtain a 1 m x 0.3 m scannable area. All the components are mounted on a parallelepiped-shaped metal structure so that the profiler can be moved to the field work area.

A picture is taken and the complete system is moved 5 mm away from the original position. This process is repeated as many times as necessary until the complete surface is scanned. The pictures are saved and analized using the method described next.

The image processing techniques use projective geometry theory [4]. This is based on the fact that every point in R^2 has a dual in R^3, so that the coordinates in a picture (inhomogeneous coordinates) can be "generalized" into real spatial coordinates. Given the inhomogeneous coordinates *(x,y)*, the 3-D coordinates can be obtained from

$$X = (xd)/(f+y); Y = (yd)/(f+y); Z = (fd)/(f+y) \quad (3)$$

where d is the distance between the digital camera and the laser beam and f is the focal distance of the camera. This parameter and the principal point are obtained from the camera calibration process [5].

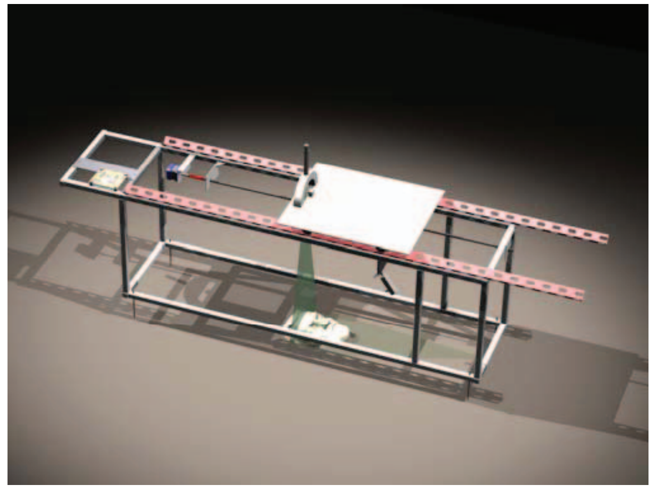

Figure 1: General view of the scanner. The different components of the device can be seen: a laser with its aperture system, a digital camera and a motor coupled to the rod, which allows the platform to move longitudinally.

The process to get the 3-D coordinates is the following: the image is processed with an image analysis tool in order to find the points of maximun intensity of the laser beam. Once these are found, (3) are solved for every picture and the 1-D profile of the surface can be reconstructed. This algorithm is repeated for every picture and the 1-D profiles are put together - considering the 5 mm separation between the positions of the camera when taking different pictures - in order to obtain the 3-D reconstruction. With this kind of reconstruction a 2-D value for *s* can be obtained taking, for example, the mean value between the value of *s* along one direction and the value of *s* along the direction perpedicular to the first one. With the same argument, two different correlation lenghts, for perpendicular directions, can be obtained.

3. RESULTS

We present in this section one of the reconstructions obtained by the device using the processes described above. We scanned a parcel of sand of 0.6 m x 0.3 m with the inscription "IAFE"' on it (see Fig. 2). The 3-D reconstruction is presented in Fig. 3 where all the coordinate scales are in cm. It can be seen that the non-written area is reconstructed as a perfect smooth one. The letters can be observed with clarity as well as the roughness around the letters, a consequence of the handwriting.

Figure 2: The picture shows a sand surface with the inscription “IAFE” on it.

Figure 3: 3-D reconstruction of the pattern of Fig. 2. All coordinate scales are in cm.

4. CONCLUSIONS

In this paper a novel scanning device was presented. Upon the base of a few components and the theoretical support of projective geometry, a portable profiler was developed. It allows getting the RMS height s and correlation length l_{corr} in 1 m x 0,3 m parcels with a 20-30% error in heights and 1-10% error in horizontal lengths. It is worth emphasizing the improvement in the accuracy of the device with respect to the standing devices which estimate the RMS height with a higher error and do not allow estimations for the correlation length. Other remarkable fact is that this device allows getting 2-D mean values for s y l, which is a very important improvement in the way this problem is treated at the present time

5. REFERENCES

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