MECH TECH 2016

ASSOCIAZIONE ITALIANA DI INGEGNERIA AGRARIA

Università di Sassari

Dipartimento Agraria

Mechanization and new technologies for the control and the sustainability of agricultural and forestry systems

PROCEEDINGS

Alghero, Italy, 29th May-1st June 2016
Ex Ospedale Santa Chiara, Bastioni Marco Polo, 77 – Alghero (SS)

www.mechtech2016.uniss.it

ISBN 979-12-200-1098-6

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Studies and development of a terrestrial mobile LiDAR scanning for canopy shape assessment

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Abstract

Remote sensing technologies are spreading rapidly such as combination of decision support tools for farm management. Between emerging solutions, LiDAR (Light Detection and Ranging) appears like more responsive to the specific and heterogeneous demands of the agricultural sector. In this context, and in the much more general precision agriculture domain, terrestrial LiDAR may become an effective aid to the characterization and analysis of plants growth. The knowledge of such parameter is one of the constraint for the sustainable management which takes into account the sito-specific requirements and variability (growth / yield / failed areas etc.) within the production units. To this end, some preliminary tests in an experimental olive grove located in Tuscany (Italy) conducted in collaboration with the Department of AeroespacialIngeniería y Mecánica de Fluidos, Área de IngenieríaAgroforestal the University of Seville, were carried out. First results, achieved by comparing digital LiDAR data versus volume measurements made manually or through photogrammetric analysis, have provided substantial results and an overview of the broad potential of this technology.

Keywords*VRT, scanner laser, precision agriculture, spraying*

Introduction

In the European Community the orchard cultivations (apples, pears, stoned fruits, nuts, top fruits, soft fruit citrus fruits, grapes, olives, wild fruits) cover an area of 1.29 million hectares (ha) (2012 EU). The most commons fruit trees are, in terms of scale apples, oranges, peaches, small citrus fruit trees, olive and grape. Inside the olive growing, in terms of number of farms specialised in the olive oil activity, the three main producers have approximately the same share of farms. Spain, however, produces 49% of the total by value, followed by Italy with 35% and Greece with 16%. Mediterranean countries produce 95 % of the total world olive oil production estimated to be 2.4 million tonnes per year. Olive production is a significant land use in the southern Member States of the EU with important environmental, social and economic considerations. The main areas of olive oil production are in Spain (2.4 million ha), followed by Italy (1.4 million ha), Greece (1 million ha) and, outside EU, Turkey (0.5 million ha). In this context, but at the same way for the others previously mentioned, might be found a broad diversity either on growth, shape, volumes either for the specific management such us planting layout, trellis systems, cultural practies etc. . Besides this, every cultivation characterized themselves for all much the same an inside variability. Therefore, the actuation of principles of BAT best agricultural practies, promoted by EU, must be oriented to solutions which support the farm companies activities. In this context precision agriculture could provide tool and knowledge to optimize the use of inputs and raw materials in the production processes. Many are the solutions developped to achieve essential parameters correlated to physiological and/or yield responses such us nutritional condition (Quebrajo et al., 2015), weed detection (Slaughter et al., 2008) Hydric stress (testi et al., 2008). At the same way, a lot of studies have been carried out in order to understand the chance and criticality to coupling this devices on vary types of carriers such us aerial and grounds units. Among themselves a significantly number have been focussed on characterization of canopy structure. This because crown properties have direct relationship on plant response (yield, quality, stress) but even in management strategies (applications of pesticides, nutrients etc.). Upon the devices actually investigated in precision agriculture techniques the sensor LiDAR (Light Detection And Ranging) better known as 2D laser scanner. The LiDAR, basically made by a laser sensor, measures the distance between it and a generic target without geographical positioning reference at the platform (terrestrial or aerial) where is coupled. The operating principle is based on the time of flight of a pulse i.e. the timeframe interval needed so that a ray of light (infrared region), generated by an emitter, hit a target and its reflections are intercepted by a receiver. The values, calculated through stabilized quartz clock, allow to achieve the distance of everyone points and schematize the relative coordinate (x,y,z). The overall results is the acquisition of millions points arranged in irregular clouds that individuates exactly the target shape. These features allow to achieve, in a stationary survey, a 2D modelling of the crown shape that might be enhanced if the LiDAR is conveyed by ground units in a direction perpendicular to the ground level (Palleja et al., 2010). The set of these characteristic, together the quick management, make it a usable tool in several operative contexts ranging from environmental monitoring, the architectural survey, civil engineering and today the agricultural sector. Nevertheless, to date, there are only limited knowledges which allow LiDAR data elaboration into prescription maps and/or specific rules for devices management in order to get a variable rate treatment. One example is the chance to varying plant protection products doses and volumes rates in relation to the target volume. The generalised usage of LiDAR technologies may potentially bring many advantages and more generally toward the increasing of the economic and environmental sustainability. On these considerations, the study focuses on the issues for the development and implementation of a ground monitoring system able to manage and process data generated by terrestrial laser scanner in order to estimate the crown volume of the plants.

Material and methods

To assess the LiDAR a preliminary assembly and field tests were carried out. The olive grove was located in San Casciano Val di Pesa (43°68' N; 11°14’) Tuscany, Italy at 250 m above sea level. The olive trees were planted in 1998 and the mains cultivar were Leccino, Frantoio, Moraiolo. The orchard density was 300 tree ha^{-1} with a planting layout of 6,5 m between the rows and 5 m on the lines which were oriented north-south. The training system was with a main trunk where from one to three branches branch off, with an average canopy diameter of 3.5 m, irregularly shaped and a height of 5 m. The plot was characterized by a slope of 14% along the north-south direction and the soil management foresaw permanent natural grassing cover.The preliminary trials involved two main stages:

- Crown volume assessment through manual measurements
- Crown volume assessment through laser measurements

Then the results were finally compared to evaluate the relationship among the two techniques. The manual measurements were performed using the tree silhouette method.

This assesses the crown volume by revolutionizing areas delimited on pictures captured through a photo camera from equidistant positioning around the vertical axis in the center of the tree. The pictures were taken in twenty fixed direction, every 18° around the entire tree circumference, centering the camera viewfinder at the middle height of the crown. In order to scale the snapshots, a topographic reference was placed in proximity the crown and furthermore, specific targets (scotch tape) were placed inside it. All of them have been dimensioned using as reference the height from the ground and the distance apart the tree's vertical axis. Next, pictures were elaborated in the image processing software ImageJ® (National Institutes of Health, Bethesda, MD, USA).

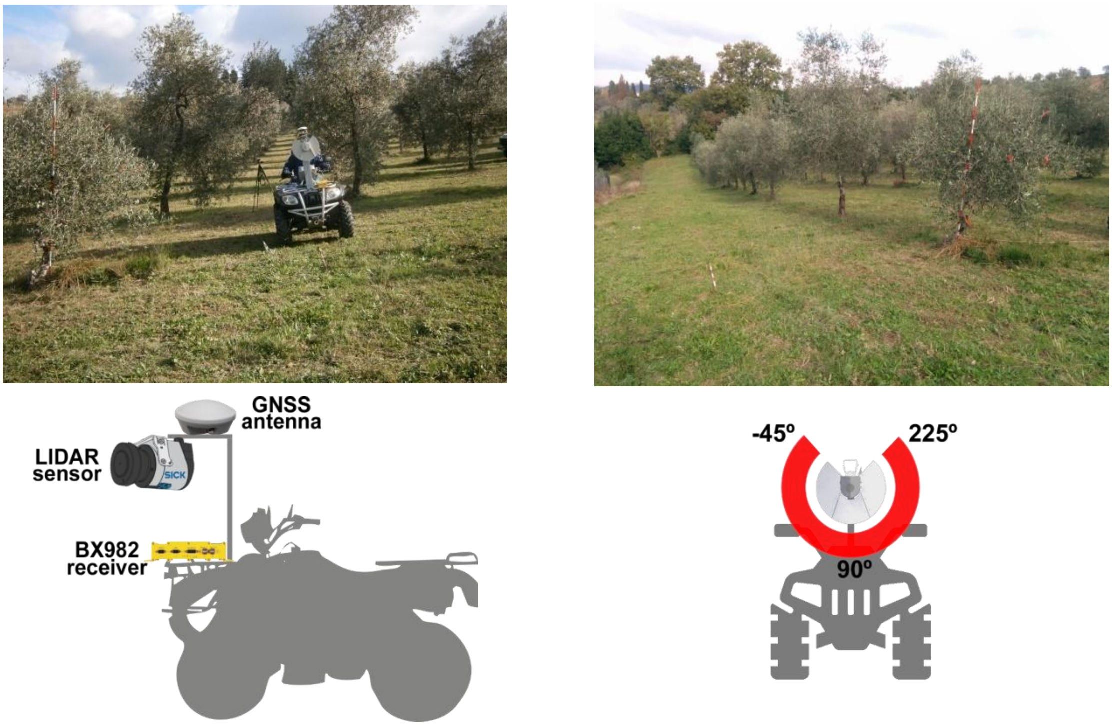

Figure 1. Study area and scheme of the monitoring yard

Laser measurement was made up of a SICK LMS-111 LiDAR (SICK AG, Germany) coupled with a RTX-GNSS receiver Trimble BX982. The whole system was carried by an ATV at constant forwarding speed of 1,5 km/h. The sensor, with a maximum scanning angle of 270°, was vertically and oriented to the ground to create a 2D point cloud in a plane, obtaining vertical slices of the crowns. The measurement configuration was set with 0.5° angular resolution. The main output data of the sensor per scan consisted of the angle values (α), the distance (ρ) to the objects and the reflectivity. The data acquisition interface was made by LMSscan Alpha V0.52 (University of Florence, Firenze, Italia) software. This is a Microsoft Visual Studio based software used to control the sensors and store data as text strings in a on-board computer. The output is a dataset (a text file (.csv)) with x-y-z vehicle coordinate (Latitude, Longitude, Altitude WGS84), time, forwarding speed, sampling frequency and the corresponding distance at relative angles. Then, after a pre-processing stage devoted to convert coordinate reference system and selection of cloud points (off-target and ground points), an application to calculate crown features based on Microsoft Visual Basic Application was developed. This is a multi-step app that allow the processing of these files to evaluate the volume enclosed by the surface scanned by the LiDAR and other linear parameters of interest for crown characterization (height, width, depth). To analyze the system a first test on a single olive tree was carried out. This was performed along on the four main directions (N-S, S-E, S-N, N-W) at the same distance (3,8 m) to the center tree axis. Afterwards the checking of positive results achieved on these step, we proceeded with some scanning test on the row.

Results and discussion

Manual measurements, performed using the tree silhouette method, have highlighted an average volume of 7.38 m3 with a standard deviation of 1.1 m3 while the laser measurements, to the same olive tree, were respectively 6.66 m3 and 6.25 m3 on two repetitions. Thus, the comparison between the two techniques provided a 9% difference in the first test and 15% in the second one, values that are in line with those achieved by comparing manual and electric methods (Miranda-Fuentes et al., 2015). Table 1 summarises all measured and calculated parameters achieved through LiDAR.

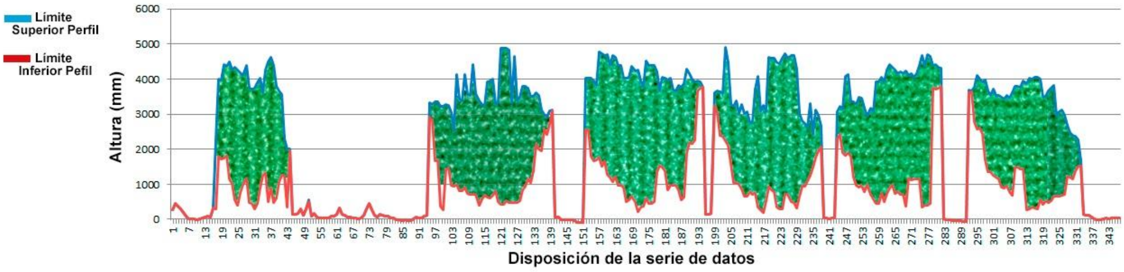

Figure 2.Trees crown profiles detected on the row with their upper and lower limits

	CrownVolume m³					
test	**Olive 1**	**Olive 2**	**Olive 3**	**Olive 4**	**Olive 5**	**Olive 6**
1	5.69	14.71	9.83	14.32	12.22	9.82
2	4.19	13.18	10.13	14.81	12.40	10.47
3	5.35	14.37	10.64	13.68	11.80	9.14
Mean	5.08	14.09	10.20	14.27	12.14	9.81
Std deviation	0.78	0.81	0.41	0.57	0.31	0.67

Table 1 Crown Volume achieved by laser scanner

Conclusion

The use of LiDAR technology appears a useful tool for the volume canopy assessment. The results achieved have recognised fairly good correlations with manual measurement. This is attributable mainly to the low accuracy of tree silhouette method in the detection of the protruding branches and crown irregularities, which were very common in olive trees studied. Nevertheless, additional studies will be done to improve the data management (reduction of amount and faster processing stage) in order to produce a realistically tool applicable in real operative contexts.

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