ASSEMBLY OF AN ULTRASOUND SENSORS SYSTEM FOR MAPPING OF SUGAR CANE HEIGHT

M. J. Silva[1], A. H. S. Garcia[1], F. Rodrigues Júnior[1], A. Bastos[1,2], and P. S. Graziano Magalhães[1,2]

[1] *College of Agriculture Engineering*
Campinas State University, UNICAMP
Campinas, SP, Brazil

[2] *Brazilian Bioethanol Science and Technology Laboratory, CTBE.*
Brazilian Center of research in Energy and Materials, CNPEM,
Campinas, SP, Brazil

ABSTRACT

In Precision Agriculture, the use of sensors provides faster data collection on plant, soil, and climate, allowing collecting larger sample sets with better information quality. The objective of this study was the development of a system for plant height measurement in order to mapping of sugar cane crop, so that regions with plant growth variation and grow failures could be identified and used for crop yield forecasting and management purposes. For georeferencing of the plant height measurement, it was developed a control and data acquisition system, that communicates through ASCII commands via radiofrequency, using ZigBee protocol, and a PIC (Peripheral Interface Controller) board, which controls the ultrasound sensors. Also, the system communicates with a DGPS using the RS-232 interface emulated on the computer's USB “port”, synchronizing the height and location data. The experiment was performed 105 days after planting, using two ultrasound transducers, placed on distinct rows. The measurement system was assembled on a vehicle, which moved at an average speed of 5.7 m s^{-1}, in a total area of 25 ha. The mapping of the plant height allowed the visualization of the local plant height variation. Thus, the use of the ultrasound sensors system for plant height measurement proved agile and practical, enabling the localization and identification of areas with reduced grows, for further management intervention.

Keywords: on-the-go sensors; spatial variability; in season.

INTRODUCTION

Mapping of plant height and the identification and localization of regions with variability, provide information that can assist in promoting actions in agricultural production management. The causes of spatial variability may be several factors related to soil, climate, plants and agricultural management.

The crop status was measured and estimated using the vision system, and the crop size estimated from the captured image by Kaneko et al. (2002). Zhang et al. (2002) reported that cotton plant height was measured using mechanical fingers and infrared light beams by Searcy and Beck, (2000). Queiros et al. (2005) used ultrasonic sensors for measuring the height of cotton to identify the need to spray with growth regulators. More recently Jeon et al. (2011) reported the use of ultrasonic sensors for canopy volume sensing to be use in variable rate application, mentioning that ultrasonic sensors that are affordable, relatively robust during outdoor conditions, and capable of estimating the canopy volume of trees satisfactorily as have been reported by several researchers.

Therefore, the objective of work presented here was to test an ultrasonic sensor for crop height measurement, particularly in sugar cane, with a possible contribution toward developing an affordable way for to determine and estimate the crop growing status and estimate crop yield.

MATERIALS AND METHODS

The measurement of the canopy height of the sugar cane was done by means of a data acquisition system using ultrasonic sensors. The developed circuit used a Peripheral Interface Controller (PIC), 18F452® model (Microchip Technology©) to read the signals from ultrasonic sensors (SRF10 - Acroname Inc ®) connected to an I2C bus. The PIC function, beyond a data acquisition systems of sensors, made the processing data generating means, transmitted by UART serial communication (Universal Asynchronous Receiver / Transmitter) to XBeePro transmitter, making with ZigBee protocol a transfer, which were connected by USB interface to standard IBM-PC using the Windows XP operating system (Microsoft ©, 2003). Figure 1 shows the block diagram of the system acquisition.

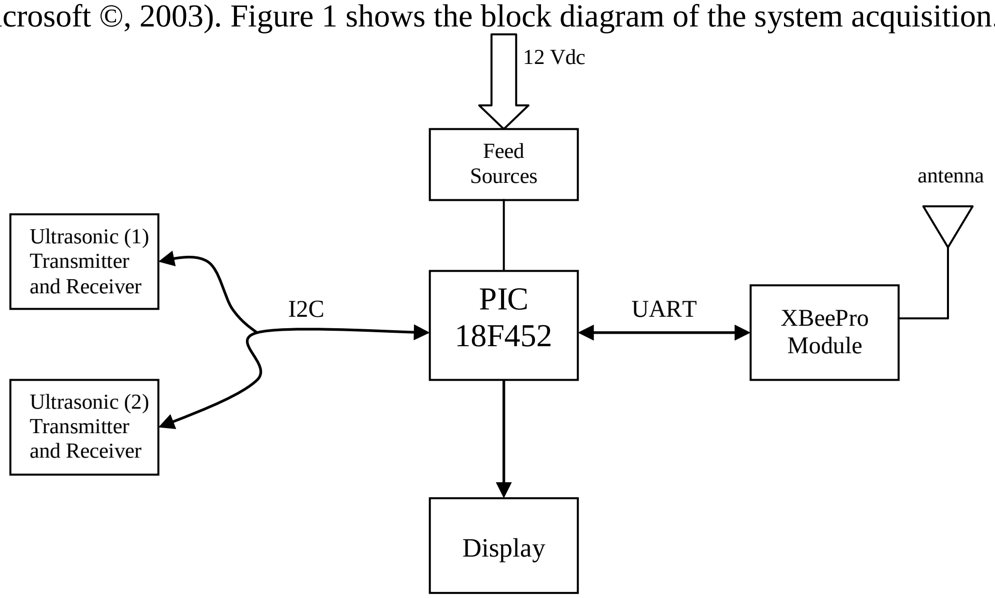

Fig. 1. Block diagram of data acquisition board of ultrasonic sensors.

The computer interface was performed by software developed in Visual Basic programming language, responsible for data acquisition. The data were obtained by synchronous serial interface from RS-232 emulated on the USB port of the computer. Figure 2 shows a functional diagram of the software with the communication interfaces. Concurrent with data acquisition systems of ultrasonic sensors, the software synchronized with DGPS (Differential Global Positioning System), model AgGPS® 114 (Trimble©, 2003), realized the NMEA code interpretation. The software, beyond acquisition, realized a creation of the data file, which stored the results for ultrasonic measures with their own global positions.

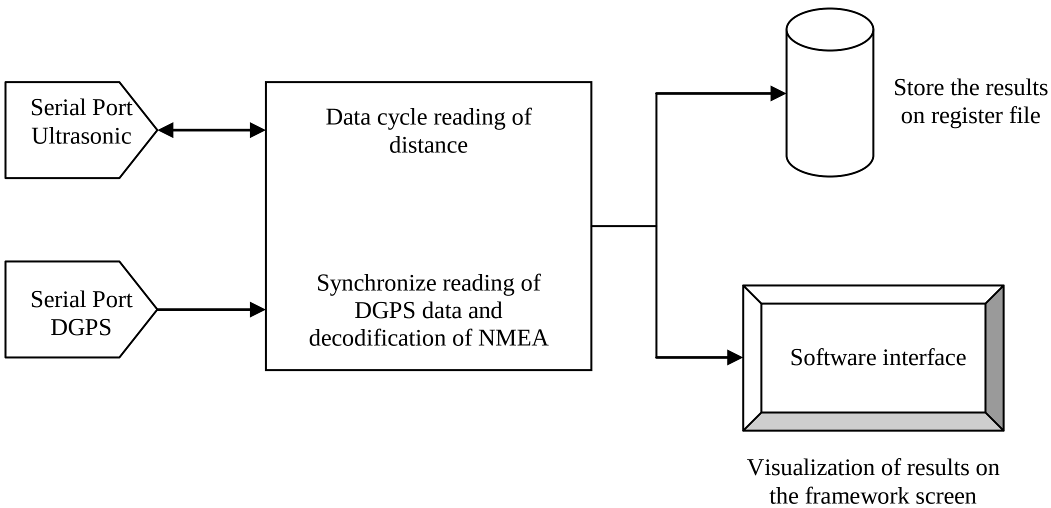

Fig. 2. Functional diagram of the software used to data acquisition

The data acquisition of the plants height was performed using 0.3 Hz rate at 5.7 m s^{-1} for vehicle speed.

Average plant height of cane sugar determination

The acquisition system were used in area belonging to Pedra Agroindustrial Mill, located in Serrana-SP (21 ° 12 '39"S, 47 ° 35 '45 "W). The tests were performed in sugar cane after 105 days of planting. The ultrasonic sensors survey was done in alternating rows, and the height values were corrected according to the calibration equation of ultrasonic sensors.

The sampled data for plant height were submitted to descriptive statistics, identifying the values of: minimum, first quartile, median, third quartile, maximum, mean, standard deviation, coefficient of variation, normality test of Kolmogorov-Smirnov, also plotted the box-plot graph for possible outliers identification. After the descriptive analysis, it was performed an average for plants height using the sensors values, and these was interpolated with 2 m of grid, using kriging point through local variogram using Vesper 1.6 (The University of Sydney, Sydney, Au), aiming to visualize and identify the spatial variability of plant height on the sugar cane area. As additional information, the standard deviation of predictions was generated for the Plants Mean Height map, indicating the quality of the interpolations throughout the experiment. The outputs from Vesper were carried out in Arcgis ®, 9.3 (ESRI, Environmental Systems Research Institute) using the Spatial Analyst extension (Fig. 3.).

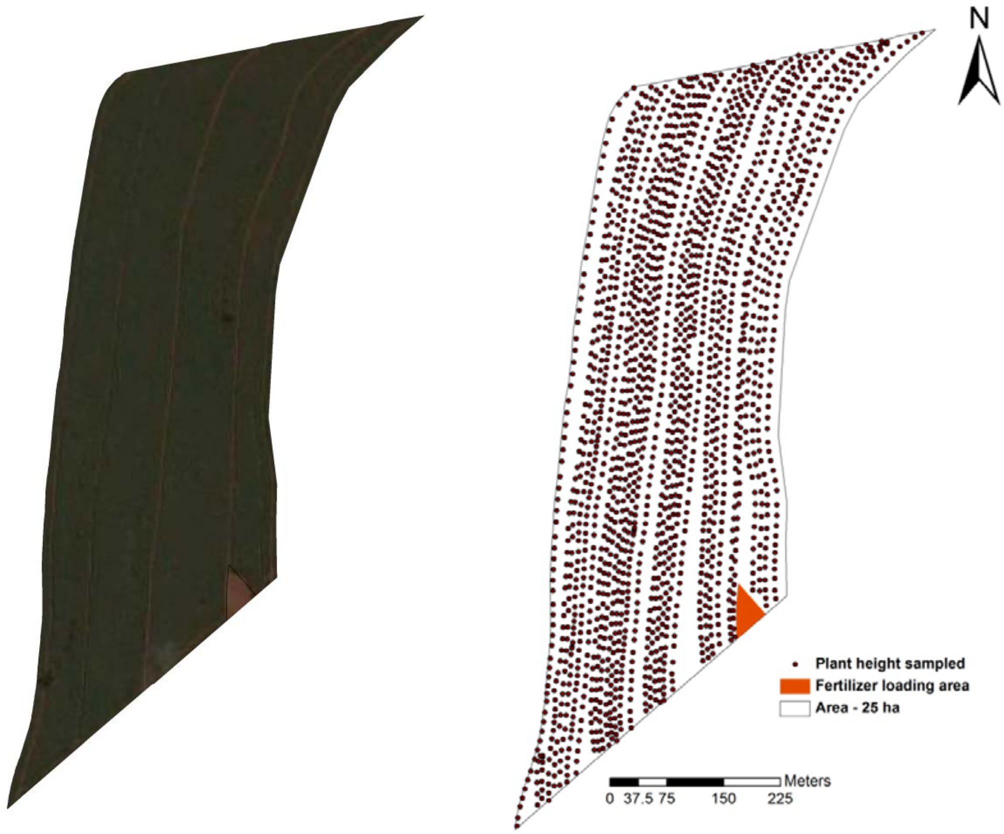

Fig. 3. Sugar cane area and sampling points collected.

RESULTS AND DISCUSSIONS

Table 1 presents the descriptive statistics of the results. The coefficients of variation (CV) were less than 8%, indicating low variation according to Pimentel Gomes (1985) criterions. Shiratsuchi et al. (2005) using ultrasonic sensors to measure cotton height in 50 ha crop area in alternate rows obtained CV between 21 - 41%.

In study about spatial variability of biometric parameters of sugar cane, Grego et al. (2010) used 97 points (10x10 m) as sampling arrangement grid to measure plants height manually. Hence, it was found 138 mm to standard deviation and 7% to CV. These results are similar with the values obtained by ultrasonic sensors. According to the authors, the sugar cane was also in the initial phenological stage of development.

In descriptive analysis it was not observed largest variation in sugar plants height. This result can be attributed to recent renewal done on the sugar cane field, decreasing soil compaction effects, being minimized by soil tillage for planting.

According to Kolmogorov-Smirnov for normality test, using 5% in the significance level, the data measured by sensors to plants height have a normal distribution, therefore achieving better reliability for interpolation. The skewness coefficients obtained were nearly to zero, and negative. Using boxplot diagram were observed possible outliers, which were identified on the sampling points, mainly for ends of rows, or on maneuver areas used by vehicle for data acquisition.

Table 1. Descriptive statistics for the average plant height of sugar cane

min	Q_1	med	Q_3	max	mean	S	CV	skew	kurt	normal
Ultrasonic sensor (1)										
95.47	120.8	125.67	129.97	143.44	124.95	7.47	5.98	-0.68	1.02	O.K.
Ultrasonic sensor (2)										
88.32	108.6	115.45	121.45	137.30	114.72	9.00	7.84	-0.34	-0.37	O.K.

min – minimum; Q – quartile; med – median; max – maximum; S –standard deviation; CV – coefficient de variation; skew – skewness; kurt – kurtoses; normal – normality according to Kolmogorov-Smirnov test using 5% in the significance level.

Figures 4A and 4B show maps for standard deviation of prediction and plants mean height of sugar cane variability measured by sensors. It can be observed through the interpolation quality map that spots with largest standard deviation of prediction are located on ends of the plants rows. In general, there was low variation of the standard deviation in the interpolation prediction (Figure 4A). Based on the Figure 4B, it was possible to identify the spatial variability of the plants heights. Through the thematic map, it was observed during the period of sampling, half of the area (12.5 ha or 50%) had plants with heights between 1169 to 1225 mm. Also, it can be observed lower heights on ends of the plants rows. The less advanced growth stage in these areas may be due to soil compaction effects, which are nearby the farming roads access, maneuvers regions and machine traffic in loading fertilizer area.

Through interpolation, the plants height ranged from 9920 to 1339 mm. In a study realized in Reunion Island (located in Pacific Ocean), Baghadadi et al. (2010) monitored the sugar cane heights during the first five months after the sugar cane planting. With the measurements performed manually in loco, it was observed after 150 days of planting results of 1100 mm for average height, and growth about 250 mm per month, being also observed 200 mm in maximum variation of plants height.

The phenological development of plants depends on several factors, as well as climate, soil, crop management, genetic diversity of plants, fitossanity, and weeds competition, among others factors. The use of ultrasonic sensors to measure plants height showed some skills on data acquisition, mainly about the agility on sampling, allowing the identification of the spatial variability. Therefore, the ultrasonic technology may be associated with Precision Agriculture tools on management of agricultural production. Thus, the information sampled from the sugar cane heights may be integrated to information such as yield, physical and chemical soil attributes, biometric plant data, topography, plant quality parameters, among others, to delineate management zones. Furthermore, it may be used in multivariate analysis to identify the possible causes of height spatial variability and beyond this, on investigation about how this variability reflects on the sugar cane yield.

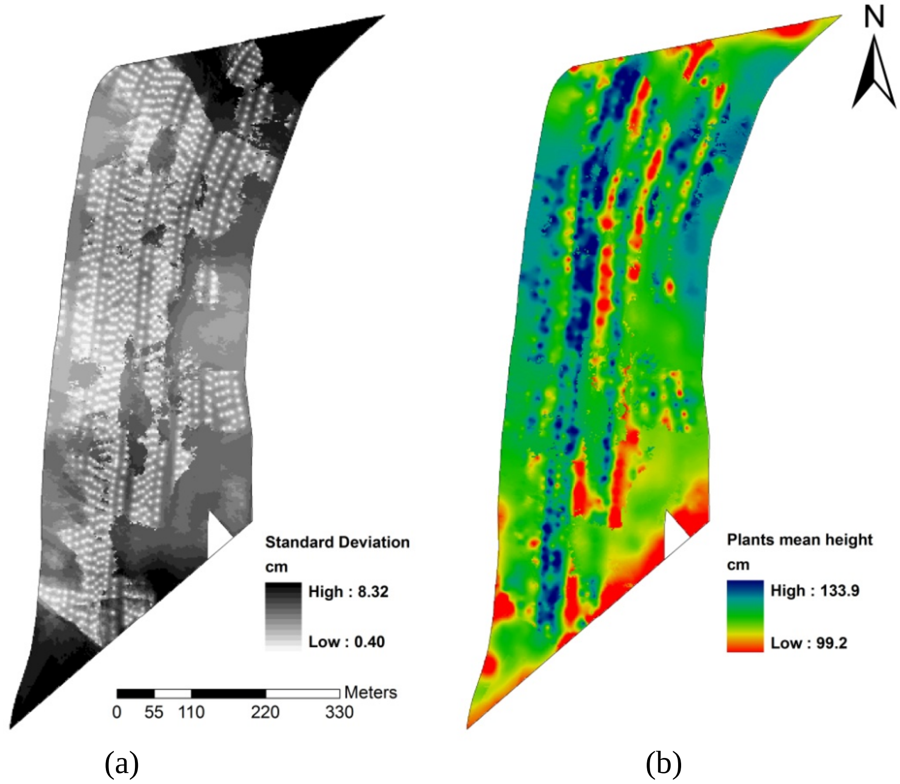

Fig. 4. Mapping of sugar cane heights. (a) Standard Deviation of Prediction (b) Plants Mean Height.

CONCLUSION

The development and assembly of the ultrasonic acquisition system for measurement of the plants height of cane sugar showed agility and practice, moving in 5.7 m s^{-1} speed to sampling and also by controlling and visualization of the data acquisition through the framework screen of the software on the field.

Using this method to measure plants height was observed low variation for the sugar cane. Through the variability detected by mapping, became possible to locate the areas with similar and different canopy heights.

Acknowledgements

The authors are very grateful to Pedra Agroindustrial Mill that made the area available, giving the necessary support and cooperation during the field tests. This project is funded by FAPESP (State of São Paulo Research Foundation), FINEP

(Brazilian Agency of Innovation) and CNPq (National Research Council) who provide the scholarship for the first author.

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