Design a capacitive sensor for rapid monitoring of seed rate of sugarcane planter

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Abstract: A capacitive sensor method for measuring billet spacing uniformity with sugarcane (*Saccharum officinarm L.*) billet planter is investigated in this paper. Therefore, an electronic device based on capacitive sensor was designed and developed to predict the planting spacing of sugarcane billets. It consisted of four components: a rectangular parallel plate capacitor, electronic circuitry, microcontroller, and display unit. Accordingly, a prototype of the precision metering device for sugarcane billets was developed. After calibrating the monitoring system, the results were verified with calibrated curve by means of linear regression and paired T-test. The performance of the device, including quality of feed index (QFI), multiple index and miss index was investigated under laboratory conditions using a capacitive sensor and a test stand with camera system. The results revealed that the forward speed had a significant effect on these variables. The coefficient of variation was less than 3%, which indicated that billet spacing calculated via capacitive sensing method has no significant difference with the computed billet spacing via image processing method.

Keywords: capacitive system, sugarcane, compare monitoring, performance indices, precision planting

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1 Introduction

Among the machines contributing to higher yield in current framings are planting machines (Maleki et al., 2006). Precision planting was pioneered by Datta (1974) as the placement of single seeds in the soil at the desired plants spacing (Datta, 1974). Usually, plant scientists use hand dibblers to achieve this degree of accuracy (Yasir et al., 2012). Sowing devices equipped with single seed metering devices are called precision planters. Among different sowing techniques, precision sowing is the preferred method since it provides more uniform seed spacing than other methods (Yazgi and Degirmencioglu, 2007). Seeds should be sown precisely without causing doubling and missing during planting operations (Önal et al., 2012). Seeds drilled by precision planting are sown with optimum row and within-row spacing depending on the seeding requirements for each specific crop (Bracy et al., 1998). Uniformity between seeds is important factors in crop production, which can affect uniform crop growth and yield (Navid et al., 2011). With uniform spacing, the roots can grow to a uniform size and fill the row space without being pushed out of the row by a neighboring root (Panning et al., 2000). Also there would be benefits such as increasing in the yield (Karayel et al., 2006). Plant spacing can affect both vegetative and reproductive growth and yield and is directly related to seed spacing uniformity.

1.2 Sugarcane

Sugarcane (*Saccharum officinarm L.*) is an important raw material for the sugar industries (Frank, 1984). Recently, sugarcane has received special attention due to

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its potential as a renewable energy source (Santos et al., 2006). Its stalk is an important source of sucrose (Murali and Hari, 2011; Sampietro et al., 2006) and provides about 65% of the sugar produced in the world (Zambrano et al., 2003). As a perennial crop, one planting of sugarcane will generally allow for three to six or more annual harvests before replanting is necessary (Taghinezhad et al., 2012). Today sugar is produced in 121 countries and global production exceeds 120 million tons per annum (Müller and Coetsee, 2008). In Iran, sugarcane is widely cultivated on an area of about 68352 ha with an annual production of about 5685090 ton (FAO, 2010). Stalks are cut in 30 to 40 cm long pieces, called setts. These setts are then placed or planted in an orderly manner in soil furrows (Srivastava, 2004) and each cutting must contain at least one bud (Mandal and Maji, 2008).

1.3 Capacitive Sensor

The capacitance sensor technique can be used for the determination of different properties of plant materials (Kumhála et al., 2007). The function of the capacitance sensors depends on the fact that the dielectric constant of the air/material mixture between two plates increases with the material density. For example Eubanks and Birrell (2001) determined the moisture content of hay and forages by using multiple frequency parallel plate capacitors. Jarimopas et al. (2005) designed and developed an electronic device with a cylindrical capacitive sensor to measure the volume of selected fruits and vegetables. Osman et al. (2002) built a parallel plate capacitor with a variable spacing for hay and forage moisture measurement. Campbell et al. (2005) designed and developed a system based on capacitive sensor for monitoring bees passing through a tunnel. Ragni et al. (2006) used a sine wave radio frequency oscillator with parallel plate capacitor sample probe to predict the quality of egg during storage period. Stafford et al. (1996) used a capacitance sensor for the determination of grain mass flow. According to their research, the effect of the moisture content can be compensated by measuring capacitance at two widely spaced frequencies. Afzal et al. (2010) estimated leaf moisture content by measuring the dielectric constant of leaves in five different types of crops. Jones et al. (2006) estimated mass of biomass using dielectric properties. Soltani et al. (2011) studied electrical properties of banana fruit in order to develop a rapid and non-destructive appraisal technique and to control its ripening treatment by using capacitive sensor. Kumhála et al. (2006) designed a parallel plate capacitance sensor for the forage weight determination. Soltani et al. (2011) designed and developed an electronic device with capacitive sensor basis to predict corn and lentil moisture content using dielectric properties.

The object of this paper is to study the electrical impedance technique by developing a device in order to rapid evaluation of the sugarcane planter.

2 Material and method

2.1 Sample preparation

Sugarcane stalks were harvested in October, 2011 from the field in DebelKhazaie, Ahvaz, Iran and transported to the Physical Properties of Materials Laboratory, Department of Agricultural Machinery Engineering, Faculty of Engineering and Technology, University of Tehran, Karaj, Iran. The collected sugarcane was stored (one week) indoors until experiments in a laboratory having air conditions of about 25°C and relative humidity of about 55%. A hundred samples of sugarcane stalks of approximate length of 30 cm were cut using a bandsaw with fine blade. No degradation of the canes was observed after the field rise and the indoor storage, as the canes had maintained their structural integrity as was evident during material preparation cuts of the canes.

2.2 Planter and belt system

A laboratory precision sugarcane planter was used in this study. The sugarcane planter has four components: main hopper, conveyor belt, secondary hopper, and metering device (Figure 1). First sugarcane billets reposed in the main hopper, after that the conveyor belt transmitted billets to the secondary hopper, the secondary hopper with its special shape directed billets tothe metering device, finally metering device delivered billets to belt that was used to test the "potential" seed spacing of laboratory sugarcane planter. This particular test stand (Figure 1) had a 50-cm wide belt with a 2 m long horizontal viewing surface. The unit was equipped with a multi-speed drive arrangement to provide a range of belt surface speeds from 0.9 to 3.6 km h^{-1}, relative to the stationary planter mechanism, and a range of seed spacings on the belt.

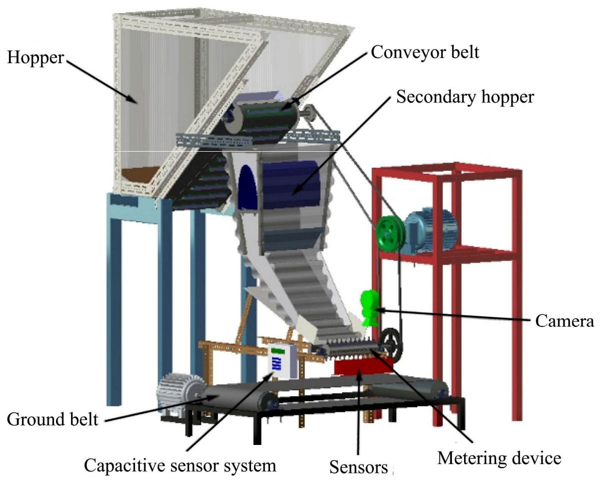

Figure 1 A graphical view of laboratory planter with capacitive sensor system

A Samsung digital camera recorder system with 26x optical zoom, 25 frame s^{-1}, 640 frame width and 480 frame height was installed in the above of metering device and belt for comparison results from image processing analysis with capacitive sensing method. The 720×576 pixel sensor produced sharp images with 256 levels of RGB. High light sensitivity of the system reduced the need for supplemental lighting. For image processing, ImageJ 1.44p software was used and Adobe Photoshop CS (6) Timeline software was used for analyzing frames.

2.3 Capacitive sensor system

In order to evaluate the sugarcane planter an electronic unit was designed and developed. The device for billets spacing measurement has four components: two rectangular parallel plate capacitors, electronic circuitry, microcontroller, and display, as shown in Figure 2.

Measuring of voltage is performed when the sugarcane billets were crossed between the capacitive sensor plates. Peak to peak voltage and time measurements were used for modeling performance of the planter and after each test performance indices were shown on the display. Also a parallel plate was used to eliminate the air effect between sensor plates and increment of system precision. The ATmega 32 microcontroller is the principal part of the system.

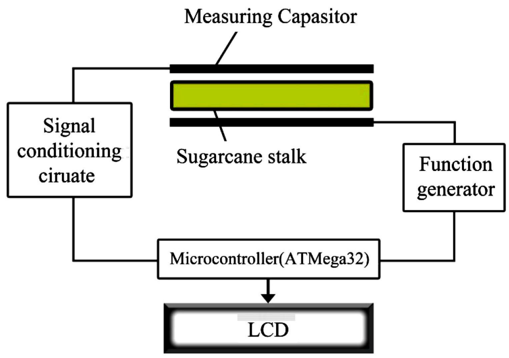

Figure 2 Block diagram of capacitive sensor for sensing sugarcane billet discharging

2.4 Data analysis

According to researches (Onal and Onal, 2009) for billets with 30 cm length, the seed spacing of 25 cm is desired space (S_d) between two consecutive billets. Three different seed spacing groups, according to S_d, can be classified in Figure 3, and three indexes can be defined:

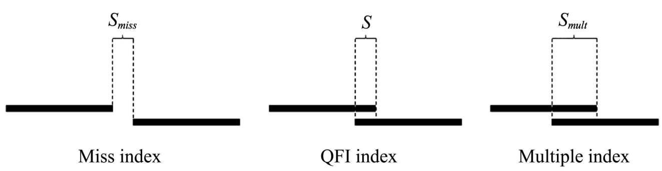

Figure 3 A sample for performance indices

1) The multiples index is the percentage of spacing that is less than or equal to half of the theoretical seed spacing, and indicates the percentage of multiple seed drops (0 to≤ 0.5 S_d).

2) The miss index is the percentage of spacing greater than 1.5 times the theoretical seed spacing and indicates the percentage of missed billet locations or 'skips' (> 1.5 S_d).

3) Quality of feed index (acceptable seed spacing, QFI, %) is the percent values with a seed spacing within the range from bigger than 0.5 times the theoretical seed spacing to equal or smaller than 1.5 times the theoretical seed spacing. Quality of feed index is calculated by subtracting miss and multiples indexes from 100, and indicates the percentage of single seed drops (> 0.5 S_d to≤

1.5 S_d).

2.5 Methods for the comparison of the seed spacing measurement techniques

In all, 27 tests with 0.25, 0.5, 0.75 and 1 m s^{-1} travel speeds were conducted in order to compare two different measurement techniques. Miss index, multiples index and quality of feed index values were calculated. One measurement technique involved using digital camera and image processing method. In this technique the performance of planter captured and seed spacing was measured by ImageJ software. With the second technique seed spacing was measured by the capacitive sensor. In order to compare the seed spacing values measured with the two techniques, regression analysis was used and coefficient of determination (R^2) values was calculated.

3 Results and discussion

3.1 Performance analysis of the Capacitive Sensor Method (CSM)

The performance indices of the capacitive sensor method for sugarcane planter among 0.25, 0.5, 0.75 and 1 m s^{-1} speeds are presented in Table 1. Also standard deviations are presented, and small values of standard deviations show that estimated values are quite acceptable.

Table 1 The performance indices for capacitive sensor method

Speed /m s^{-1}	Miss index	Standard deviation	Multiple index	Standard deviation	QFI	Standard deviation
0.25	2.81^a	0.37	7.23^a	1.51	89.72^a	2.51
0.5	3.12^b	0.52	3.55^b	0.82	93.43^b	0.83
0.75	4.83^c	0.63	2.81^c	0.45	92.41^b	0.98
1	7.26^d	1.25	2.52^c	0.65	90.35^c	1.62

According to Table 1 and Figure 4 miss index is high at higher speeds of metering device while multiple index is high at lower speeds of metering device. It is indictable that for quality of feed index middle speeds are shown better performance than that of others.

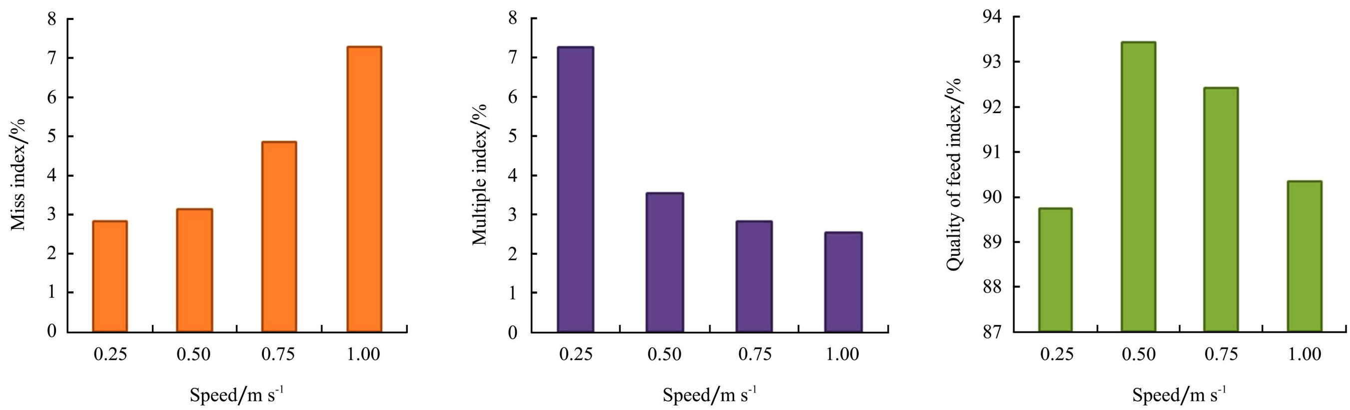

Figure 4 The performance indices for CSM measurement

3.2 Comparison of seed spacing measurement techniques

Miss index, multiple index and quality of feed index for sugarcane billet distribution patterns were analyzed according to capacitive sensing method (CSM) and image processing measurement (IPM) techniques, and are shown in Table 2. Performance indices in both capacitive sensing method and image processing measurement-based evaluation of sugarcane billets seed spacing distribution can be seen. Evaluation was initially based on the speed value. It is indicated that among different speed of the planter there is no significant difference between CSM and IPM measurement method. And middle speeds are better for better performance.

Table 2 Comparison of two measuring method

Travel speeds /m s^{-1}	Measuring techniques test	Miss index /%	Multiple index /%	QFI/%
0.25	CSM	2.81	7.23	89.72
	IPM	2.63	6.87	88.35
0.5	CSM	3.12	3.55	93.43
	IPM	3.05	3.25	94.65
0.75	CSM	4.83	2.81	92.41
	IPM	4.15	1.65	93.21
1	CSM	7.26	2.52	90.35
	IPM	6.57	1.03	89.32

The sugarcane planting performance indices obtained using the two measurement techniques were pooled into Microsoft Excel software. Regression analyses were used to compare the accuracy of performance indices values obtained with the CSM, and Image processing measure. Results indicate that performance indices measurements obtained using the CSM were strongly correlated with the same indices measurements obtained using image processing measurement (Figures 5, 6 and 7) also coefficient of determination R^2 for miss index, multiple index and quality of feed index was 0.9937, 0.9731 and 0.9975 for P<0.05 respectively. If the linear model fit the data well (coefficient of determination R^2 close to one), the CSM performance indices measurements were not significantly different than those of the image processing measurements.

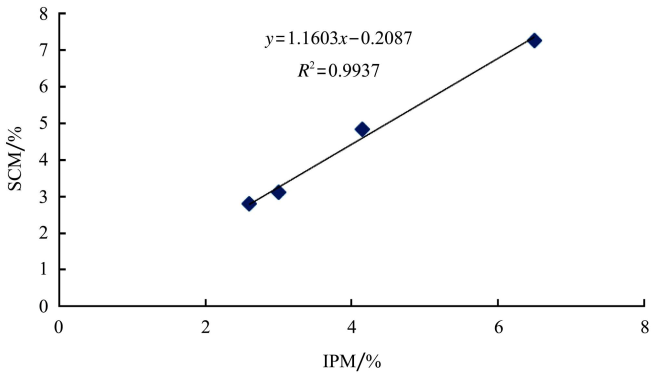

Figure 5 Comparison of miss index measured with the CMS with those measured from the image processing measure. Regression analysis shows a coefficient ofdetermination (R^2) of 0.9937 (P < 0.05)

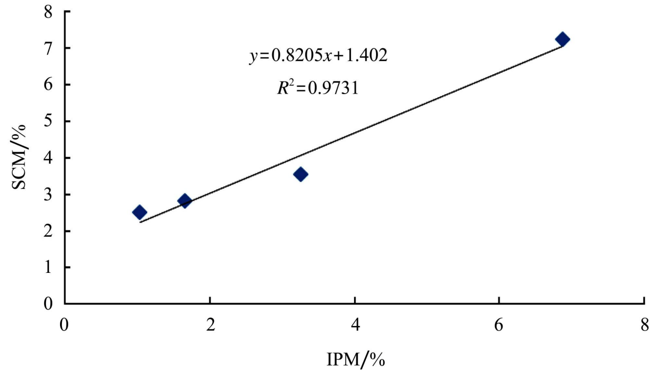

Figure 6 Comparison of multiple index measured with the CMS with those measured from the image processing measure. Regression analysis shows a coefficient of determination (R^2) of 0.9731 (P < 0.05)

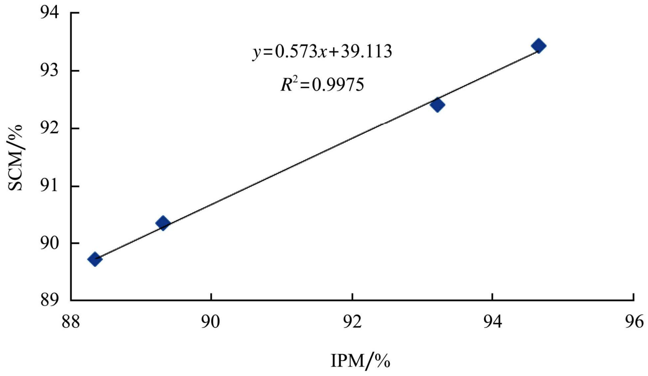

Figure 7 Comparison of quality of feed index measured with the CMS with those measured from the image processing measure. Regression analysis shows a coefficient of determination (R^2) of 0.9975 (P < 0.05)

4 Conclusion

In order to evaluate the performance of sugarcane billet planter, an electronic system was designed and developed and tested. The paired T-test results confirmed the significant effect of speed (at 5% level) on the performance indices of metering device. It can be indicated that in higher speeds we have lower miss index however in lower speeds we obtained higher multiple index but better quality of feed index is obtained in middle speeds. Image processing measurement used as an index for comparing performance results among different speed of metering device. The seed spacing data obtained from the capacitive sensing method and image processing measurement were not significantly different; therefor, the capacitive sensing method can be used instead of an image processing measurement technique to obtain rapid quantitative laboratory evaluations of sugarcane planter billet spacing uniformity. The capacitive sensor system, with two rectangular parallel plate capacitors and electronic circuitry, worked well to obtain sugarcane billet spacing. The capacitive sensing method provided the following advantages:

• A simple and cheaper system for determining billet uniformity spacing.

• Possibilities of measurement of velocity of fall of seeds.

• A low labour input requirement.

Then the capacitive sensor method for measuring the uniformity spacing in sugarcane planter is adequately a reliable method.

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