IJNES
International Journal of Natural and Engineering Sciences 6 (2) : 39-42, 2012
ISSN: 1307-1149, E-ISSN: 2146-0086, www.nobel.gen.tr

Automatic On-Line Depth Control of Seeding Units Using a Non-Contacting Ultrasonic Sensor

Sajad KİANİ
Department of Automotive Engineering, Islamic Azad University, Khomeini Shahr Branch, Isfahan, IRAN

***Corresponding Author**
e-mail: Sajad.Kiani@iaukhsh.ac.ir

Received : December 23, 2011
Accepted : January 31, 2012

Abstract

Previous investigations on seed placement depth emphasize the importance of proper seeding depth for optimal crop stand and yield. On moist soils, care should be taken to plant as shallow as possible, but when surface soils are dry and sufficient moisture is not available at lower depths the planter should seed in a normal depth. To this effect, a non-contacting range sensing and control device for automatic control of seeding depth (DS) was developed. This system can measure the distance between the soil surface and the frame of a planter where sensor is mounted. In this system time needed for an acoustic pulse to travel to and from a transducer (fixed to tool-bar) to a reference surface (RS) (attached to planter furrow opener) is measured and forms a base for this technique. The reference surface plate (RS) is mounted on one side of the runner type furrow opener in such a way that as the runner increases its working depth the RS is pushed up to the soil surface. The sensor measures the vertical distance between the transducer and the RS. The measured difference (with no regard to difference size) is transformed into proportionate signal which in turn results in appropriate operation controllable linear actuator. The actuator then adjusts the tractor hydraulic arms. Indoor and outdoor experiments were conducted to evaluate the performance of the system under varying conditions. The results showed satisfactory performance of the rig on uneven soil surfaces and acceptable depth control for the row crop planter.

Keywords: Non-Contact sensor, Depth of seeding, Automatic depth control

INTRODUCTION

The effective control of working depth of seeding equipment is important for improved seed germination and reduced energy consumption (Ouled Belgacem et al, 2006). Most earth moving operations, such as tillage, seeding and plowing are associated with manual depth control, based on an operator's judgment and experience. Often the operator's vision is obscured such that he cannot precisely observe the depth of the working member. Therefore, an automatic depth control system is needed to account for depth variation during online measurement depth when seeding. Several sensing approaches have been suggested which employ transducers mounted on the implement tool bar. These transducers sense distance to the ground from a point above the ground.

Tillage depth has a remarkable influence on implement draft. Increasing the working depth of an implement increases all force components, wheel slip and fuel consumption (M. Yasin et al 1991). Ultrasonic and infrared (both non-contact) sensors have been used extensively (Arrivo & Di Renzo, 1998; Lee et al., 1998). Working on an automatic header control for combine harvesters, Hesse (2000) reported that when ultrasound is directed onto soil covered with dense grass no echo is reflected towards the sensor, whereas, several echoes are reflected to the sensor from the soil with less dense vegetation. This indicates potential problems during the data collection with ultrasonic sensors, by recording undistinguishable distance measurements from the soil surface and from the top of plant residues.

Under laboratory experimental conditions, Lee et al. (1998) found that the infrared and ultrasonic sensors could be used as distance detectors for a tillage depth control system. In addition to the remarkable influence of surrounding temperature on the ultrasonic sensor measurement, it was determined that the detecting accuracy on the irregular ground surface was greatly affected by the measuring distance. This was due to the large reflection area of the ultrasound that made the sensor detect the distance between the top of the partition in the soil bin and the sensor. Therefore, the ultrasonic applicability was restricted on irregular soil surfaces to a short distance measurement only.

Lee et al. (1996) used a near- infrared sensor of light emitting diode with a wavelength of 880–950 nm to measure the distance from the ground surface. They found that the performance of the sensor was not affected by moisture content, the sensor accuracy decreased with the measured distance from the soil surface with the presence of a thin water layer on the soil surface. It was found in a preliminarily test that when ultrasound was projected to a soil surface covered with the stubble of forage maize, the echo was reflected from the top of the stubble rather than the ground itself. There was a wide fluctuation in the sensor output signal (Figure 1) due to the maize stubble, which cannot be filtered because of the inaccurate discrimination between the top of the stubble and the soil surface.

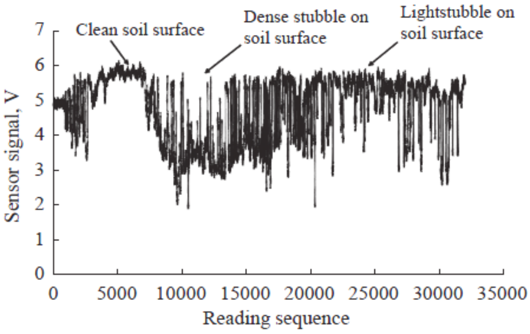

Fig.1. Ultrasonic sensor signal disturbance by maize stubble

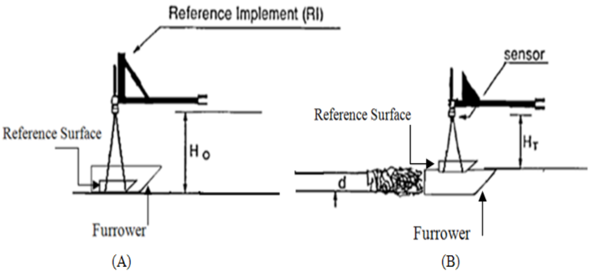

Fig.2. Schematic diagrams illustrating various depths; d: computed depth (Ho-HT) (cm), Ho: zero-working depth position (cm), and H_T: sensor height (cm)

A combination of a swinging arm type rubber wheel with an ultrasonic sensor and a swinging arm type roller with a displacement transducer has been used successfully to control the working depth of a finger weeder (Søgaard, 1998). However, the influence of plant stubble on the accuracy of the distance measurement with the linear variable displacement transducer (LVDT) sensor was not addressed.

A.M. Mouazen et al (2004) developed and evaluated a swinging arm type metal wheel equipped with a linear variable displacement transducer and an ultrasonic sensor to sense the frame vertical position relative to different ground surfaces. Perfect correspondence between frame height measurements was found for the two sensors when the measurements were carried out on a hard surface asphalt road. Moreover, the frame height measurement performed on the field soil surface showed good correspondences between the wheel-LVDT sensor and the ultrasonic sensor, and the soil deformation beneath the wheel-LVDT sensor led to over prediction ranging between 0.018 and 0.021m. In comparison with the ultrasonic sensor, the relatively large mass of 175N made the wheel-LVDT sensor apparently less sensitive to the height variation when crossing directly the plant stubble. The wheel-LVDT sensor can be used appropriately in fields covered with plant residue and stubble, whereas, the ultrasonic sensor provides incorrect and non-filtered measurements of the frame height from the soil surface. Based on the soil type, moisture content and dry bulk density, correction factors are required to be determined and subtracted from the wheel-LVDT sensor output to compensate the extra distance measured due to the wheel sinkage in clean surface soils. Therefore, the sensor output can used to control the position of the tractor three-point linkage aiming at online measurement of soil compaction at constant depths.

The objective of this study was to develop and evaluate the performance of a sensing system using non-contact ultrasonic sensor for detection of depth seeding. In the proposed system, RS is mounted on one side of the runner type furrow opener of a row crop planter.

MATERIALS AND METHOD

A row crop planter with for unit was used. An ultrasonic sensor was mounted on left hand side of one of the planting unit toolbar. The distance of the sensors from the reflecting surface can be varied at 20 cm intervals. Reference surface (RS) was mounted on one side of the runner furrow opener to follow the surface of the soil. As the runner increases its working depth the RS is pushed up to the soil surface freely in a vertical plane (Figure 2). Provisions were made so that soil could not flow on the RS. The frame was mounted on the three-point hitch of the tractor.

An ultrasonic sensor measures variations in the vertical distance between the RS and frame to which the plate are mounted. The signal from the ultrasonic sensor is transmitted to a control unit in the tractor cab. A control algorithm in the control unit was used to determine, if the detected working depth is within 2 mm of the preset reference working depth each second. Otherwise, the control unit will activate a linear electric actuator to adjust the seeding depth. A keypad was used to set the desired pre set value, such as the recommended seeding depth.

Ultrasonic proximity sensor The Ultrasonic Range Finder SRF08 proximity sensor was selected. This high performance ultrasonic range finder is compact and measures a wide range from 3 cm to 6 m. The unit has a wide beam, high gain sensing capability suitable for less reflective targets. The sensor is also composed of three main units: a transmitter, a receiver and a controller. The sensor uses 5-V DC input voltage and average current consumption measured on our sensor is around 15mA during ranging, and 3mA at standby. The sensor can easily be connected to microcontrollers such as the BasicX or BasicATOM. With this sensor, it is possible to know the exact distance of an obstacle in the sensor field of view.

An ultrasound with a frequency of 40 kHz was transmitted to a target by the controller. The ultrasound was reflected by the target and received by the receiver. The sensor begins counting the pulse signal when the ultrasound is transmitted and it stops

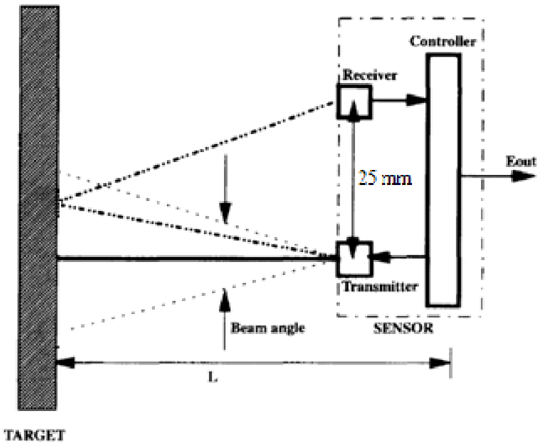

Fig.3. Principle of a typical ultrasonic sensor

counting when the first signal (reflected by the target) is received by the receiver. Once received, the signal is amplified and filtered. The elapsed time for the signal to travel to the object and return is related to the distance travelled. The analog output signals of the ultrasonic sensors were fed to the microcontroller for digitizing and processing. The beam angle of the sensor was 45 ° from the axis in this experiment (Figure 3).

The distance (L) from the target is calculated using the following equation.

$$L=K_2E_{out}-R$$

Where: k_2 and R were obtained from the linear relationship between measured output voltage and measuring distance [Jeyong Lee et al 1996].

EXPERIMENTS

Sensor Calibration And Indoor Experiments

The height of the sensor above the ground surface was adjustable. The seeding implement was parked on a fairly uniform and level surface (Cement surface). The implement was lowered down to the ground, with the entire unit seeding resting on the ground surface. The implement was considered to be at the zero position. Whereas, in this system time needed for an acoustic pulse to travel to and from a transducer to a reference surface is measured and forms a base for this study. The height of the sensor was manually measured and assumed to be the zero-working depth (Ho) of the implement. The elapsed time for the wave travel was also measured and recorded. The sensor was then moved down to a new position on the mounting unit without adjusting the implement. The new sensor height was manually measured at the lowered position (HT). Similarly the time elapsed time for the wave travel was also measured and recorded H_T. The height difference (d) and the zero working depth height were used by the calibration routine. After completing the calibration, the sensors were moved back to the zero working depth (Ho) position. For calibration purposes, indoor experiments were conducted; the output of sensor was measured and recorded at different distances.

Outdoor Experiments

Outdoor experiments were conducted to evaluate the performance of the system under varying conditions. Preliminary evaluation of the ultrasonic depth measuring system was conducted in Shiraz University both in Soil bin and field. The experiments were conducted in tilled (by disk harrow) and untilled field plots along three parallel row of seeding in three replication.

The row crop planter was used to plant seeds at three depths of 5, 9 and 11cm depth. The sensor measures the vertical distance between the transducer and the RS. The difference between the measured height and an arbitrarily maximum travel distance of 20 cm is then compared to the pre-set depth recorded in the controller circuit (target seeding depth). The existence of any difference (with no regard to difference size) is transformed into proportionate signal which in turn results in appropriate operation in the electronic actuator. The actuator then adjusts the tractor hydraulic arms. In addition to its control, the computed depths were recorded while the implement was moving. The measured values is detected and stored every second during seeding, namely, the working depth deviation from the reference working depth, measured in mm by the ultrasonic sensor. The manually measured depth was measured for a given depth. Thirty data points for sensor, each point was an average of three observations, were collected.

RESULTS AND DISCUSSION

The experiment was carried out on both concrete surface (indoor tests) and agricultural field (tilled and untilled fields). Indoor test were conducted, the output of sensor was measured and recorded at different distances such as 15, 25, 35 cm. Figure 4. Shows output of sensor. The average distance measured at height 15, 25 and 35 cm for the sensor calibration were 14.944, 25.055, 34.9888 cm for eight replication. Correlation variation for these measured height were 1.64 for 15cm depth, 0.493 for 25 cm depth, and 0.483 for 30 cm depth.

The statistical procedure used for this study a results showed that when the RS was used the depth of seeding and irregularity of the ground surface had no effects on the accuracy of height measurement system performance. The analysis of variance (ANOVA) for the implement depth values in the two field surface showed a not significantly influence (P=0.05) in average computed depths due to the treatments but, highly significant differences in average computed depths (four each surface) were found due to sensor control in each depth (P=0.01).

The test of the ultrasonic sensor used in this study shows that ultrasound waves were emitted towards two parallel

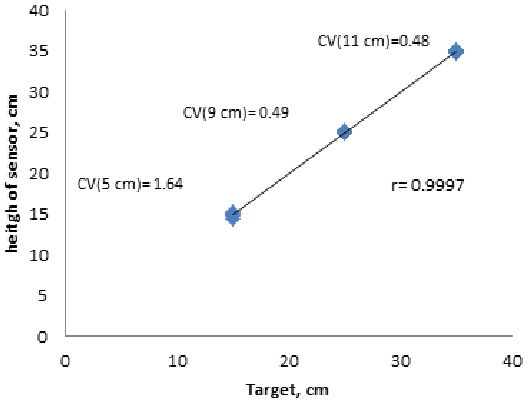

Fig.4. Measured values of indoor experiments for sensor calibration.

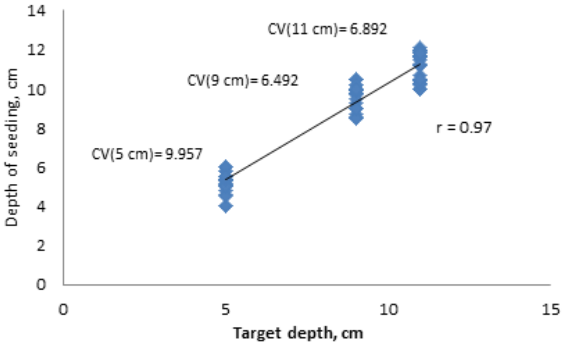

Fig.5. Measured values of outdoor experiments for manual depth control.

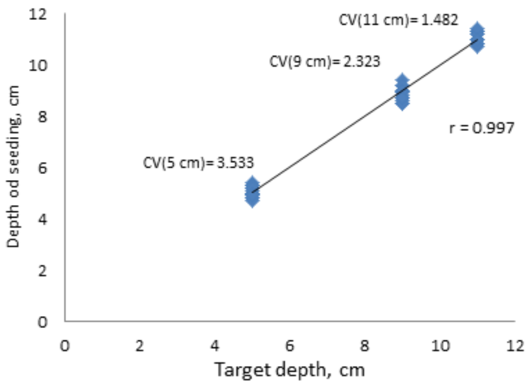

Fig.6. Measured values of outdoor experiments for automatic depth control.

columns, with a spacing of less than 15 cm reflected back from the top of the two adjacent columns. This interprets the smaller height measured with the ultrasonic sensor when passing the RS (Figure. 2). Since the ultrasound waves aren't emanated in a conical through irregularity shape, the ultrasonic distance measurement don have error. Since uneven ground surface and such as this irregularity like stubble don't have an influence effect on this system this is a significant advantage. The overall objective will be directed towards the online continuous measurement of seeding at relatively constant depths.

Three planting depths (5, 9 and 11 cm) were also considered for the outdoor tests. Thus, the total numbers of treatment combinations were 360 for each test (three depths, two ground surface, two controls and 30 values in three replications). The average depths at the depths 3, 9 and 11 cm for the automatic field tests were 5.0517, 8.910, 11.0172 cm and The average depths for the manual tests were 5.293, 9.6137, 11,141 cm. Correlation variation for measured depth for automatic depth control were 9.957, 6.429 and 6.892 and for manual control were 0.527, 0.671, 0.527 sequential for 5, 9 and 11 cm depth. Figure 5 and Figure 6 shows results of output test.

CONCLUSION

Indoor and outdoor experimental results show that it is possible to maintain a reasonably constant working depth with the developed system. To some extent, the experiments confirm that the ultrasonic sensor can detect truly the distance from ground surface in spite of irregularity of ground surface due to tilling operation, plant residue and stubble. Therefore, the ultrasonic sensor output can be coupled with the controller circuit to alter the hitch position aiming at online seeding depth control.

REFERENCES

[1] Arrivo, A., G C. Di Renzo. 1998. Trailed unit for testing implements under field conditions. Journal of Agricultural Engineering Research, 71, 19–24

[2] Hesse, H. 2000. Electro-hydraulic control for combine harvester. Proceedings of the 28th International Symposium on Agricultural Engineering, 'Actual Tasks on Agricultural Engineering', Opatija, Croatia, pp 33–41.

[3] Jiang, Y., N. Honami and S. Umeda. 1992. Microcomputer control system for tractor implements. JSAM, 1992, 54(3), 5-13.

[4] Lee J; Yamazaki M; Oida A; Nakashima H; Shimizu H (1996). Non-contact sensors for distance measurement from ground surface. Journal of Terramechanics, 33(3), 155–165, doi:10.1016/S0022-489(96)00016-X.

[5] Lee J., M. Yamazaki, A. Oida, H. Nakashima, H. Shimizu. 1998. Electro-hydraulic tillage depth control system for rotary implements mounted on agricultural tractor design and

[6] response experiments of control system. Journal of Terramechanics, 35(1998), 229–238, doi:10.1016/S0022-4898(98)00026-3.

[7] Mouazen, A.M., J. Anthonis, W. Saeys and H. Ramon. 2004. An Automatic Depth Control System for Online Measurement of Spatial Variation in Soil Compaction, Part 1: Sensor Design for Measurement of Frame Height Variation from Soil Surface. Biosystems Engineering (2004) 89 (2), 139–150.

[8] Ouled Belgacem, A., M. Neffati, V.P. Papanastasis and M. Chaieb. 2006. Effects of seed age and seeding depth on growth of Stipa lagascae R. & Sch. Seedlings. Journal of Arid Environments 65 (2006) 682–687.

[9] Søgaard, H T. 1998. Automatic control of a finger weeder with respect to the harrowing intensity at varying soil structure. Journal of Agricultural Engineering Research, 70, 157–163.

[10] Yasin, M., R D. Grisso, G M. Lackas. 1992. Non-contact system for measuring tillage depth. Computer and Electronics in Agriculture, 7, 133–147.