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A practical approach to comparative design of non-contact sensing techniques for seed flow rate detection

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ABSTRACT

This study, as a part of a broader research project on development of a seed drill performance monitoring system, seeks to make a practical approach to comparative design of non-contact sensing techniques for seed flow rate detection. To determine actual flow rate, various non-contact sensing techniques have been proposed by other researchers. The methods of light dependent resistors (LDR), infrared (IR), and laser diodes (LD) drew more attention. LD, IR, and LDR sensing units were successfully designed and developed. Each of these sensors has a type of LEDs, consist of infrared, visible light and laser-LED as well as an element as a radiation receiver. When the seeds pass through the seed sensor and through the band of light beams, their shades fall on the receiver elements, resulting in output voltage changes. Thus, the seed flow rate could be estimated by investigating signal information corresponding to the passing seeds. A particular test apparatus was designed to compare proposed sensing units ability in confronting with the same seed flow. For each seed flow rate in experiments, individual LDR, IR, and LD, pulse signals and discharged seeds mass were recorded. Results show that there is a strong linear relationship (r = 0.87) between the actual seed mass changes and the corresponding voltages of IR sensing unit. Due to obtained results in comparison with other investigated sensing methods, it is recommended that IR detection technique is a more proper non-contact sensing technique for estimating of the seed flow rate.

1. Introduction

Appropriate and uniform seeds planting result in better germination of plants and yield enhancement by minimizing competition between plants for available light, water, and nutrients (Karayel and Ozmerzi, 2002). Proper placement of seed in the soil in sowing operation is highly desired for optimum growth and high productivity of any crop (Gürsoy, 2014). Achieving the desired plant population largely depends on the performance of the seeds planter (Murray et al., 2006). Approaching to proper and precise sowing rate per unit area requires development of an accurate sensing device for evaluating the seeding performance of the planters. In the literature, there are various studies on developing of appropriate sensing device to determine real sowing rate.

Machine vision sensing technique, including an image acquisition system and a software to realize the desired measures using some image processing algorithms, have been frequently applied by some researches. Karayel et al. (2006) and Navid et al. (2011) used a camera system for evaluating individual seed spacing. The performance of the camera system was compared with a sticky belt test stand as a reference in terms of seed spacing evaluation. Yongfang et al. (2011) and Akdemir et al. (2014) developed a detecting method based on machine vision to count the number of fallen seeds from planting machine in a determined area on a conveyor band by using image analyses techniques. An acoustic seed sensing system was also developed based on a rising voltage value that a microphone senses in each impact of seeds to a steel plate (Karimi et al., 2012, 2015). In this system, seeds hit to the plate one by one and related seed spacing data is automatically calculated.

Recently, fiber sensor has been used to detect the seed flow. In this technique when the beam of light is blocked by falling seeds, their shade fall on the surface of the receiver causing a difference in intensity. Then amplifier translates the intensity difference into a signal of voltage. Al-Mallahi and Kataoka (2013, 2016) presented a new methodology to estimate the mass of grain seeds, which flow in the shape of clumps. The methodology used an off-the-shelf digital fiber sensor to detect the behavior of the clumps, including the length and the density of the clumps. Ding et al. (2016) installed a time interval measuring fiber-optical sensor to sense each passing seed in a seeding outlet of one precision drill.

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In the proposed system, each passing seed was converted to time-interval sequence grabbed by a time-capture interrupt of a microcontroller. Seeding time-interval sequences were processed to estimate the seeding performance indexes such as normal index, miss index, and multiple index.

Numerous studies have been conducted for developing an optoelectronic system with infrared sensing method. The major part of the optoelectronic systems was a photogate consist of several pairs of infrared light emitting diodes (LEDs) along with photo-detectors as receivers. The optoelectronic sensing technique is relying on reflection of the infrared radiation ray from the individual seed as they pass through the photogate (Kocher et al., 1998; Lan et al., 1999; Xia et al., 2010).

Deividson et al. (2014) suggested the use of the infrared sensor DF robot RB-DFR-49 connected to the microcontroller to determine the distance between individual fallen seeds in laboratory tests. Raheman and Kumar (2015) designed an infrared sensor based embedded system for sensing seed flow through the delivery tube of a seed drill. In this system, released seeds from the seed metering device passed through the band of radiation coming out from the two infrared LEDs. On the other side, the reflected radiation was realized by the infrared receiver. The developed embedded system could detect choking in a seed delivery tube giving a digital output of 0 and 1 for no flow of seeds and flow of seeds, respectively. Lu et al. (2017) employed a photoelectric sensor to monitor the status of the seed tube by converting quantities of seed tube status into voltage signals. The photoelectric sensor was comprised of 4 infrared LEDs and 4 infrared electric triodes that were uniformly arranged around the seed tube to monitor the whole zone of the cross section of the seed tube. This sensor was designed to directly determine three statuses of the seed tube, including normal seeds (normally passed) missing planting (no seeds passed), and blocked planting (seeds were blocked in the seed tube).

Cuhac et al. (2012) employed light dependent resistors as receiver components for seed flow measurement. They presented a real-time wireless seed flow monitoring system for seed drill implements. The seed flow estimation was determined through the use of the seed counting information acquired by light emitting diodes and light dependent resistors, which were installed on every pipe.

Appropriate seed sensing device must be able to sense the passage of the seeds at different flow rates. In a further step, the mass of delivered seeds in a specific time period should be estimated by processing acquired data from sensors. Utilizing a sensing device includes transmitter and receiver units, installed on the opposite side of each other in seeds delivering tube, seems to be a proper technique to sense passing seeds. The different seed flows during the planting operation make different response signals. According to the mentioned bases, it is conceivable that developed sensing system can estimate seed flow rate by processing signal information corresponding to seeds being planted. This study was carried out as a part of a research project with an ultimate objective of developing a seed drill performance monitoring systems. The study reported here seeks to make a practical approach to comparative design of non-contact sensing techniques for seed flow rate detection. Such that, findings would be the basis for the subsequent researches about developing a real-time seed flow monitoring system.

2. Materials and methods

2.1. Seeds

In this study, wheat seeds with an average thousand seed mass of 35.4 g were used as experiment material. The seeds had elongated shape with an approximate average length (L) of 7.1 mm, width (W) of 3.6 mm and thickness (T) of about 2.8 mm. Approximate sphericity (S_p) was determined about 0.58 using the axial dimensions of seeds in (Mohsenin, 1986) formula:

$$S_p = \frac{(LWT)^{\frac{1}{3}}}{L} \quad (1)$$

2.2. Sensing method selection considerations

There were different methods for seed sensing like ultrasonic, microwave and proximity sensors. As a result of the comparatively small sizes of wheat seeds, existing high-frequency ultrasonic sensors were found insufficient to be used as a sensing device for sowing rate determination. Employing microwave sensors would be another choice, but it might be more costly due to the complicated sensor structures. In addition to these kinds, proximity sensors were also considered, but commercially available proximity sensors require a flat surface to reflect their pulses. So they could not undertake such small surfaces like grains (Cuhac et al., 2012). In addition, in proposing a proper sensing technology, some factors such as cost, localization capability, and simplicity should be taken into consideration.

Due to aforementioned issues and reviews of past studies (Cuhac et al., 2012; Deividson et al., 2014; Ehsani et al., 2009; Kocher et al., 1998; Lan et al., 1999; Lu et al., 2017; Raheman and Kumar, 2015; Zheng and Liu, 2011) three kinds of noncontact sensors including light dependent resistors, infrared and laser diodes were considered to be used as seed flow sensing elements. Each of three sensors has a type of LEDs, consist of infrared, visible light and laser-LED as well as an element as the radiation receiver. When the seeds pass through the seed sensor and through the band of the light beam, their shade falls on the surface of the receiver elements so output voltage of sensor increase and transit to the data acquisition. In some early tests, the strength of chosen sensors was examined by exposing each sensing element to falling seeds and investigating output voltage changes in several trials. Initial experimental results showed that using three kinds of noncontact sensors, including groups of light dependent resistors (LDR, photoresistors, or photocell), Infrared (IR) and laser diodes (LD) as transmitter units and receiver units in confronting with a flow of seeds would response properly.

Transmitter and also receiver elements were placed side by side to provide radiations in a horizontal plane. Such that, any optical interference caused by passing seeds in the whole zone of the cross section of the seed tube is investigated. The number of elements in each sensing unit was associated with the quantity that could fit on each side of the tube with about 3 cm diameter. Aligning sensing elements in one row in a seed tube was causing non-sensing area between adjacent blocks. In the final design, receiver and transmitter elements were arranged in two rows to provide almost complete optical coverage in the seed tube. A typical arrangement is shown for LDRs elements in Fig. 1. Transmitter elements were also arranged in the same rule.

2.3. Light-dependent resistor (LDR)

Light Dependent Resistor (LDR) is also called photoresistor or photocell. LDR is a sensitive component to light. When light falls upon LDR then the resistance changes. Such a way that, the value of the resistance is falling as the level of light increases. LDR provides a low-cost photosensitive element with acceptable quality performance. Early evaluations have shown that using a group of light-emitting diodes (LEDs) in two rows as a transmitter unit (Fig. 1) and LDRs in two rows as a receiver unit is an appropriate choice for sensing of the seed flow. Proposed LDR sensing unit con-