A MACHINE VISION SYSTEM FOR EVALUATION OF PLANTER SEED SPATIAL DISTRIBUTION

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Abstract

High precision pneumatic planters have been developed for many varieties of crops, for a wide range of seed sizes, resulting to uniform seeds distribution along the travel path, in predefined spacing. The objective of the present work was to develop a high-resolution optical system for evaluation of performance parameters of pneumatic planters. This paper describes the design, construction and evaluation of the optical system. The hardware setup along with the image processing and statistical analysis algorithms are presented. The developed system includes a line scan camera, connected to a frame grabber, installed in personal computer. The lines acquired by the camera were processed on-line. Seeds' location, as well as seeds' spacing, on a virtual belt running underneath the planter were computed. Furthermore, seeds' distribution parameters were calculated and displayed on-line, while they exit from the planter. Comparison of the developed optical system with a conventional grease belt, showed that the seeds' location as calculated by the optical system coincided with the seeds location as measured on a grease belt. The developed system provided reliable statistical parameters of the seeds' distribution, as defined by ISO standards, for regular shape seeds like cotton, as well as for irregular shape seeds like sunflower.

[keywords] planter performance, seed spacing, grease belt, line scan, machine vision, on-line

1. Introduction

High precision pneumatic planters have been developed for many varieties of crops, for a wide range of seed sizes. Pneumatic planters provide uniform distribution of the seeds along the travel path, in predefined spacing. In order to determine the optimal operating parameters for a combination of any type of seed and planter, different seed distribution evaluation methods have been developed (Pasternak et al., 1987).

The most common method for testing planters in the lab is the grease belt system (Kelly and Palmer, 1993; Chhinnan *et al.*, 1975). The planter is placed above a moving belt covered with adhesive material (usually grease) so that the seeds that exit from the planter remain at the point where they hit the belt. Then, the belt is stopped, and the location of each seed on the belt is recorded, either manually or electronically. The data of the seeds location is then processed, to produce the spacing distribution of the seeds.

Opto-electronic sensors have been developed the last 7 years for measuring the spacing distribution of seeds, instead of the adhesive belt. Most of the systems reported in literature are based on Light Emitting Diodes (LED) and photo-detectors in order to create a photo-electric sensing system that senses the seeds as they pass through (Lan *et al.*, 1999; Kocher *et al.*, 1998; Muller *et al.*, 1994). Their main limitations are that they cannot be used for small sized seeds due to their poor spatial resolution (4 mm or more) and their inability to reliably sense multiple seeds when they are in the same line. In addition to that, the seeds measurement is based only on sensing their presence, and they lack the capability of

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determining the seed's geometrical features like area, center etc. In a recent work, kinetic image processing was applied to measure seed distribution (Hu *et al*. 2000).

In order to obtain high resolution and to be able to measure small seeds, an imaging approach was adopted in this work. Furthermore, shape analysis of the seeds contour enables more reliable determination of groups of multiple seeds, even if they appear as one contiguous object in the acquired image. Features, such as size and area, of individual seeds can also be computed, but their contribution to the evaluation of the seeding machine performance is today marginal.

The present paper describes the sampling methodology using a machine vision system and demonstrates how the obtained data can be used to evaluate the planter's performance. The design, construction and evaluation of the optical system are described. The hardware setup along with the image processing and statistical analysis algorithms are presented. Special attention was paid to the online implementation of the image processing algorithms and various aspects of the latter are discussed.

2. Objective

The overall objective of the present work was to develop a high-resolution optical system for online evaluation of seed spacing uniformity of pneumatic planters. Specifically, we wanted to determine whether a machine vision system based on a line scan camera can be reliably used in order to obtain rapid quantitative evaluation of seed spacing uniformity, as well as seed misses and other performance indices, as defined by ISO 7256/1-1984(E) standard. Furthermore, an additional objective of this work was to determine whether the machine-vision based system can be used for evaluating small seeds, in addition to the medium and large seeds.

3. Materials and methods

3.1 Adhesive belt system and planter

A grease belt test stand was used as a reference to test the seed spacing of each planter configuration. The test stand was constructed at the Institute of Agricultural Engineering in Volcani Center. It is comprised of a 0.4 m wide and six meters long belt, driven by an AC motor. The unit is equipped with a mechanical variator, to provide a range of belt surface speeds from three to ten km/h. A support stand was designed to position the planter unit over the belt, with the viewing surface of the belt spaced below the planter in a vertical position to duplicate the relative distance between the bottom of the seed tube and the bottom of the seed furrow. The planter mechanism was driven by a second AC motor equipped with an electronic variator, to provide variable rate of seeds. Sufficient grease was added on the top surface of the belt in order to capture the seeds as they were released from the planter and prevent bouncing.

3.2 Vision system

The machine vision system was based on a line scan camera (CL512M, DALSA Inc., Ontario, Canada) that monitored a horizontal line at the desired level of seeds deposition, as shown in *fig. 1*. A long-filament halogen light and a diffuser produced uniform background illumination. The camera recorded the seeds as dark objects on a bright background. A dimmer controlled the illumination intensity. A zoom lens was used in its macro feature to focus a 12 cm field of view on the camera's CCD sensor. The camera was placed at a distance of approximately 20 cm from the measuring plane. Background illumination plane was placed approximately 25 cm from the lens and was wide enough to provide a uniform illumination across the entire field of view. The field of view and the number of pixels on the CCD sensor determined the spatial resolution of the system. The sensor had 512 pixels and therefore the spatial resolution within a line in the acquired image was 0.24 mm per pixel.

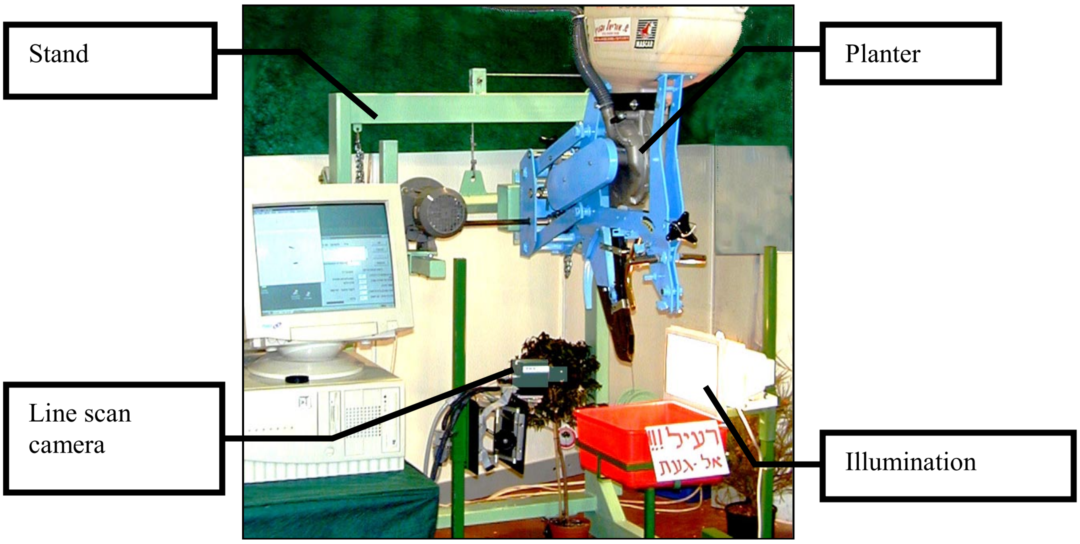

Figure 1: Machine vision system for measurement of planters seeds spacing distribution

According to the calculated system's resolution, one can measure all 4 types of seeds (a-d), for multipurpose seeding machines, as defined in the ISO 7256/1-1984 standard. The smallest seeds are about 0.5 mm wide, which is twice the system's resolution. The spatial resolution in the vertical direction, the direction of fall, depends on the vertical velocity of the seed and on the line scan rate of the camera.

The video signal of the line scan camera was digitized by a frame grabber (MV1000 with MV1100 add-on, Mutech Corp., MA, US). The frame grabber controlled the camera's line scan rate, integration time, as well as the acquisition process. Dedicated software was developed, for data acquisition and on-line image processing. The developed software is a Windows application package that includes user interface for controlling the camera, on-line image display of the seeds as they are entering the camera's field of view, on-line image processing algorithms for seeds detection and spacing computation, as well as computation of statistical parameters of the seeds distribution. The statistical parameters of the seeds distribution are displayed on the screen and are continuously updated as the test is in progress.

4. Processing

4.1 Image processing

Image processing algorithms were developed to (1) separate the seeds from the background, (2) determine the seeds location in the image coordinate system (3) compute the seeds area and (4) calculate seeds spacing distribution and statistical features.

(1) Background illumination provides images with high contrast, which makes the separation of the seeds from the background possible by a simple threshold

operation. The threshold was implemented by a Look Up Table (LUT) in the input path of the frame grabber, so that the acquired digital image was already in a binary form. Seeds appeared as black objects on a white background. *Figure 2* depicts an example of an acquired image, after the threshold operation.

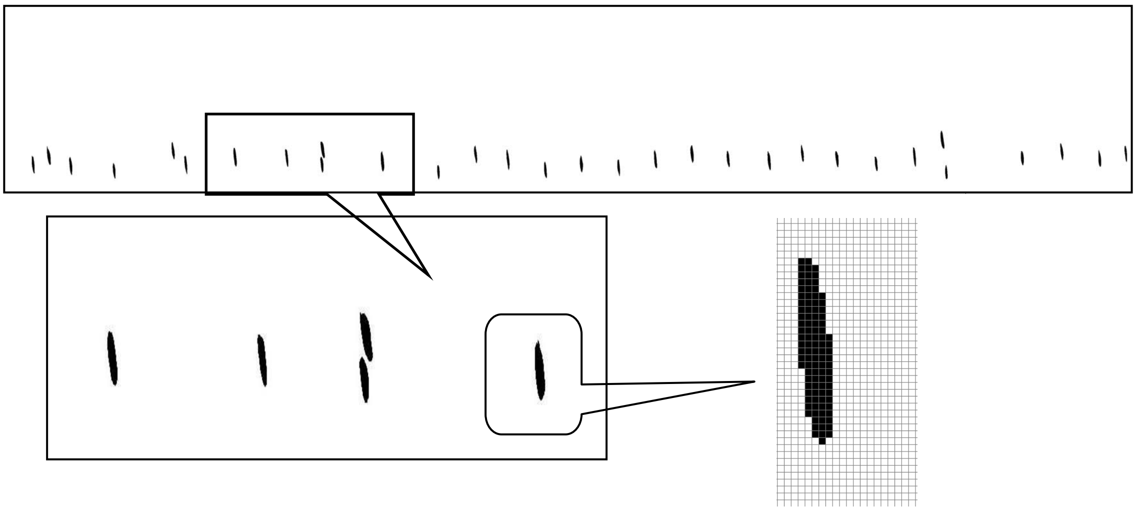

Figure 2 Sample binary image of cotton seeds processed on-line by the machine vision system

(2) Seed detection algorithms were developed to determine the seed's coordinates. Since the line scan camera provides one line at a time, the processing algorithm was line oriented. Each line was Run Length Encoded (RLE) in order to detect segments that belong to seeds. The RLE operation provided the coordinates of the segments edges, i.e., points where there was a transition from background to seed and from seed to background. The detected segments were then checked for overlap with segments of the previous line, by comparing the edge coordinates of the previous line segments with those of the segments processed. If overlap was found, the segment was attached to the object of the overlapping segment at the previous line. If no overlap was found, then a new object was created.

(3) The dimensions and area of each object were updated at each line. The number of pixels of each detected segment was accumulated to the number of pixels of the corresponding object.

(4) When the whole seed was detected, its image coordinates (as discussed in what follows) were passed to the algorithm that calculates the seeds interval distribution. The interval between the terminated seed and the preceding one was calculated, and the statistical properties of the seeds interval distribution were updated.

On-line processing is achieved by parallel processing and acquisition. For that purpose, two different memory segments were defined in the host computer as shown in *fig. 3*. While one memory segment was used for image acquisition, the other was used for processing the acquired lines. Each memory segment was able to hold 512 lines. The developed software, arbitrated the control over the two memory segments between the PCI bus (image acquisition through the frame grabber) and the host CPU (image processing).

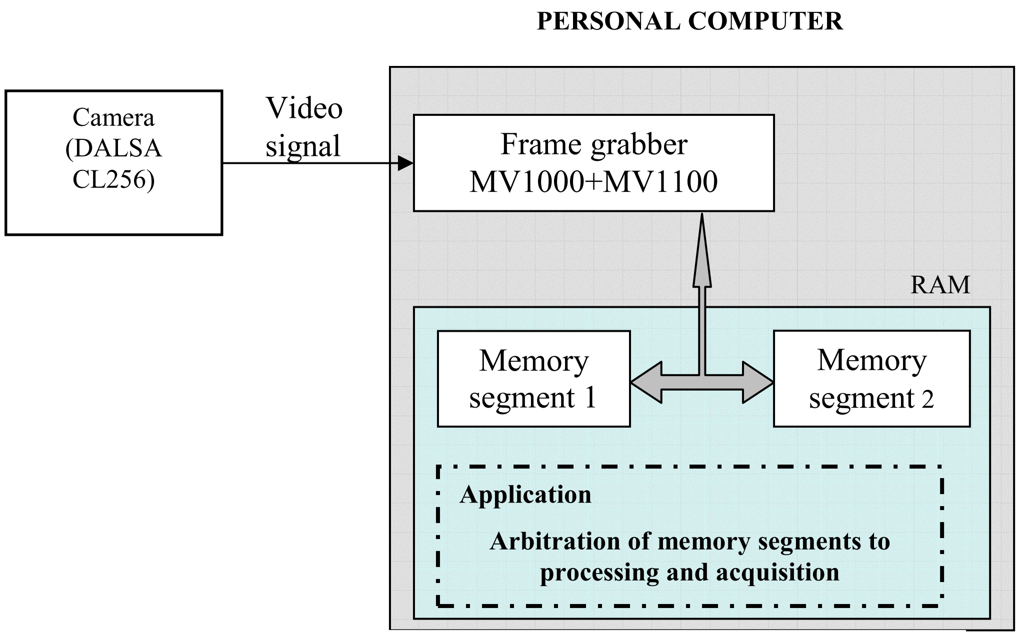

Figure 3 Schematic layout of memory management for asynchronous acquisition and processing

4.2 Seeds spacing

The location of the seed center on a virtual plane propagating underneath the planter was determined using the coordinates provided by the image processing system (*fig. 4*). The provided coordinates were: (1) the distance X1 and X2 in pixels, of the seed's right and left edges from the beginning of the camera's field of view and (2) the lines Y1 and Y2, that the top and bottom seed edges were detected. Using the above parameters, the location of the seed, X, on a virtual propagating plane was computed by:

$$X = -\frac{(X_1 + X_2)}{2} * Xres + \frac{(Y_1 + Y_2)}{2} * LineRate * Speed * C$$

where:

X1, X2, Y1, Y3 as defined above

Xres is the spatial resolution along the direction of the line in mm/pixel

LineRate is the rate of line acquisition in MHz

Speed is the assumed velocity of planter propagation, in Km/h

C is a constant factor for matching the units of (*LineRate***Speed)* to mm/line

Seeds interval was calculated after determining the location of the detected seeds. Statistical characteristics of the seeds spacing distribution were calculated according to ISO 7256/1-1984(E) standard and displayed on the screen during the test.

5. Results and discussion

In order to evaluate the accuracy and capabilities of the optical system, it was operated in parallel with a conventional grease belt system. The planter was placed above the grease belt and the camera was directed to view at a height a few mm above the belt. The optical system continuously acquired data, while the planter and the grease belt were operated. The optical system detected seeds continuously and therefore the optical test contained more seeds than the belt test. Nevertheless, the group of seeds that the grease belt system measured is included in the seeds that the optical system detected. In order to compare the results of the two tests,

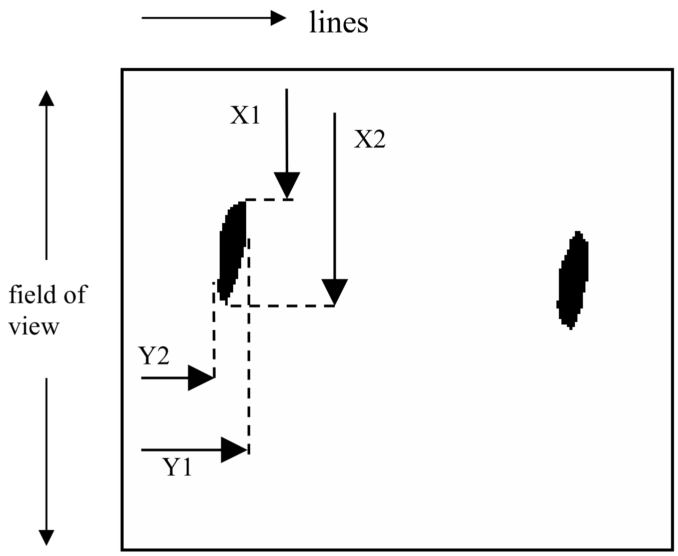

Figure 4 Coordinates for calculation of seed location

the common group of seeds had to be determined, and specifically, the first seed of the common group had to be located.

Statistical methods were employed to match the common group from the two tests. First, for each test, the intervals between the seeds were calculated. Then the two resulting vectors with the interval data were shifted one with respect to the other, the optical test vector was then truncated to the size of the grease belt test vector, and they were statistically pair wise correlated:

$$Cr(s)=CorrelationCoefficient\ \{X(s),Y(0)\}$$

where:

Cr(s) is the correlation coefficient between the two vectors when the relative shift between them is s

X(s) is the vector with the calculated interval data for the optical test, shifted s seeds and truncated

Y(0) is the vector with the calculated interval data for the belt test, not shifted

A high correlation coefficient indicates that the two groups comprise the same seeds. *Figure 5* shows the correlation coefficient between the two groups, as a function of the location of the first seed in the common group (shift). It can be readily seen that for the common group of seeds, the correlation coefficient is close to one, while in all other cases its value is considerably lower. Therefore, the first seed measured by both systems can be determined by the highest corresponding value of *Cr*. *Figure 6* shows the seeds spacing as measured by the two systems, after the common group was determined using the correlation coefficient method described above. The close match of the two curves indicates that the two systems measure the same values and the optical system can be an alternative to the conventional grease belt system.

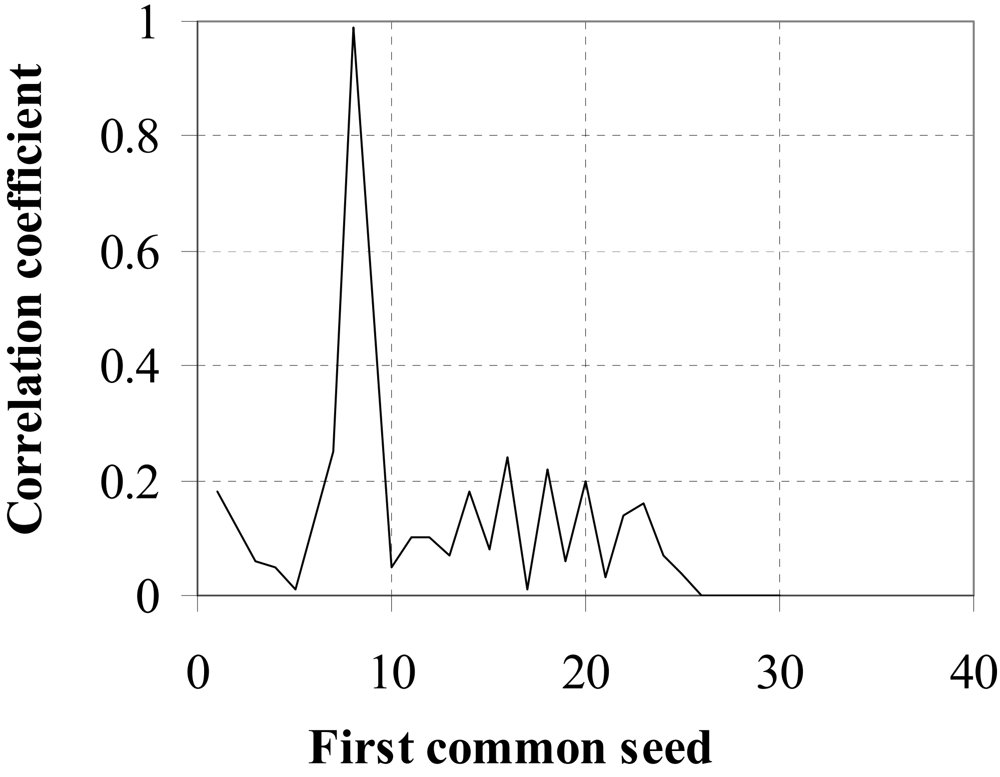

Figure 5 Correlation coefficient of seed spacing vectors as measured by the optical and the conventional methods

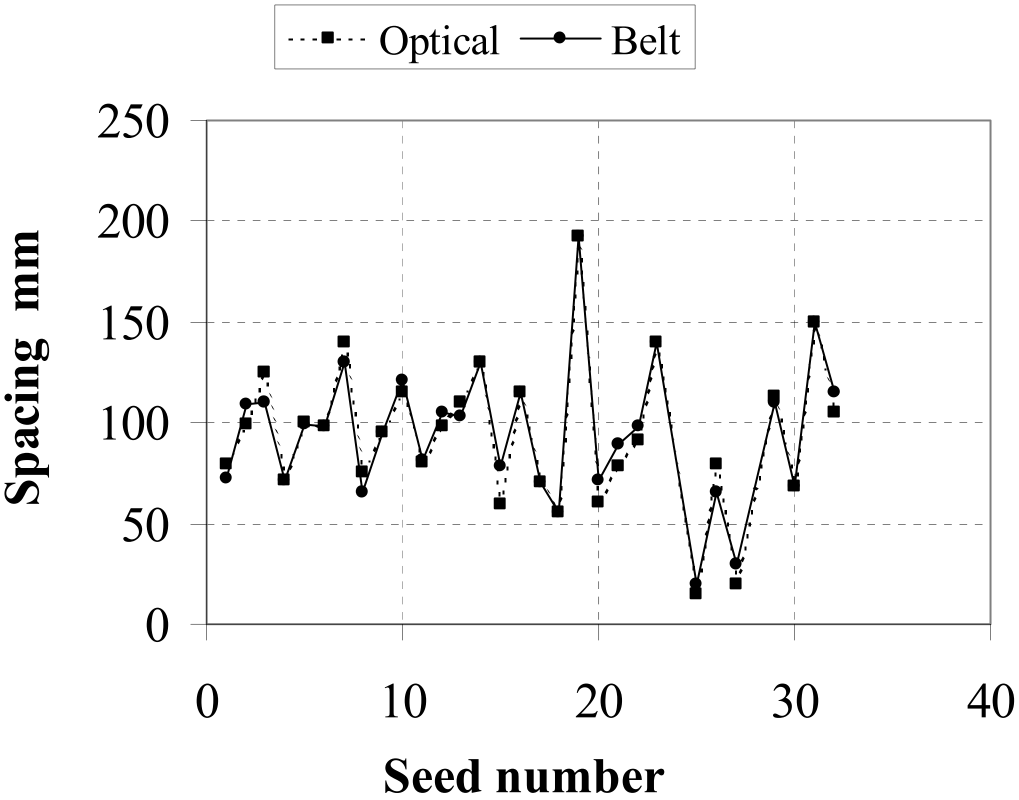

Figure 6 Seeds spacing as measured by the two systems, after the common group was determined using the correlation coefficient method

After having proven the accuracy of the optical system, it was used to measure seeds distribution of cotton seeds. *Table 1* shows the value of statistical parameters of cotton seeds interval distribution, obtained with the conventional grease belt system and with the optical system. The parameters were calculated according to ISO standard 7256/1-1984(E). The results show that the average measured interval is similar for the two methods since the measurement error of the grease belt system was ±3 mm. Coefficient of variation and feeding index, are important factors that depict planter's performance. With respect to those factors, Table 1 shows that both the conventional grease belt system and the developed optical system result to the same evaluation of the planter's performance. In addition to that, the optical system was capable to perform on-line shape analysis and successfully determine and identify groups of multiple seeds that were ejected together from the planter and traveled one in the shadow of the other. Table 1 shows that the number of doubles was also measured in a similar way by the two systems.

Table 1 Statistical parameters of cotton seeds spacing distribution as measured by the optical and the grease belt system

	Average spacing, mm		Coefficient of variation [%]		Feeding index [%]		Doubles	
	Belt	Optic	Belt	Optic	Belt	Optic	Belt	Optic
Test 1	98	100	31	28	91	90	2	2
Test 2	106	106	42	43	89	88	1	1

The optical system was then tested with parsley seeds. Parsley seeds are small seeds with average width of 1.2mm. The planter was operated to provide 200 seeds per meter, at a planter propagation velocity of 3 km/h. Evaluation of the optical system was performed by counting the number of seeds passed through the planter. Four tests were performed, where 4,000 to 10,000 seeds were counted at each test. The number of seeds was first measured by the optical system and then evaluated by weight. One thousand seeds were manually counted and weighed. The seeds of each test were then weighed and the number of seeds was calculated accordingly. Table 2 shows the results of the tests. In two tests, the number of seeds measured by the optical system was less than 1% different than the estimated number of seeds by weight. In the two remaining tests, the difference between the optical measurement and the weight estimation method was approximately 7%. Keeping in mind that the estimation of the number of seeds has a intrinsic error of about 6%, the results of table 2 show that small seeds are accurately detected by the optical system.

Table 2 Experimental results for small (Parsley) seeds

	Weight [gr]	Estimated count	Measured count	Difference [%]
Test 1	16.67	8623	8705	0.9
Test 2	8.72	4511	4810	6.2
Test 3	15.87	8210	8846	7.2
Test 4	18.95	9803	9723	0.8

Manual measurement of interval distribution of small seeds was not performed, since the grease belt method is not appropriate. The manual measurement error (+/-3mm) is greater than the physical dimensions of the seeds (1.2 mm) and similar to the required seeds spacing (5 mm).

The line scan camera and the frame grabber are capable of acquiring at a line scan rate of 36KHz. With a Pentium II 350MHz processor and the currently developed image processing algorithms, the fastest line scan rate for on-line processing was 15KHz. In the results presented above, the system was slowed down to a line scan rate of 4KHz because all acquired lines were also saved on disk for later evaluation of the performance of the image processing algorithms.

Off-line analysis and evaluation of the performance of the image processing algorithms revealed that the algorithms could also record the cross section area and shape of the seeds. Although these parameters were computed on-line as well, they were not used in this work for evaluating the planter’s performance.

The developed system has overcome the main two limitations of previously reported systems. The resolution was increased by one order of magnitude and the image processing algorithms can process and identify on-line multiple seeds. The optical system recorded the seeds location as they exit from the planter, and could be used as an alternative to the grease belt, to evaluate the performance of the planter.

6. Conclusion

An optical system, based on a line scan camera and image processing algorithms, was developed for on-line measurement of seeds interval distribution. The optical resolution of the system enables to measure the spacing distribution of small seeds, which is not feasible with the optical systems reported in the literature until now. Fast algorithms for seeds detection, based on asynchronous image acquisition and processing were developed. The developed algorithms could process 15K lines/sec and characterize the seeds distribution on-line. Seeds location, as well as seeds intervals, on a virtual belt running underneath the planter were computed. In addition, seeds distribution parameters like average seeds spacing, coefficient of variation of seeds intervals, feeding index etc., were computed and displayed on-line, while the seeds exit from the planter.

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