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Sensor Ranging Technique for Determining Corn Plant Population

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***Abstract**. Mapping of corn plant population can provide useful information for making field management decisions. This research focused on using low cost infra-red sensors to count plants. The voltage output data from the sensors were processed using an algorithm developed to extract plant populations. Preliminary investigations were conducted using sensors mounted on a stationary track for laboratory testing and on a row crop tractor for field testing. Repeated measurements were taken on a manually counted corn row. Visual inspection of the data from the field test indicated the potential to identify corn stalks based on approximate physical widths of the stalks. Corn plant populations tended to be overestimated for all eight field trials, with errors ranging from +0.7% to +4.4%. Overestimation was most likely due to leaves or other objects detected by the sensors during the field trials wrongly identified as corn stalks.*

Keywords. infra-red sensor, signal processing, remote sensing, machine vision.

Introduction

Corn population variation is crucial in making field management decisions. Reduction in crop yield is a result of many factors and knowing spatial corn population variation can aid in determining the potential for yield reductions. Crop yield may be reduced due to the increased variations in spacing between the corn plants which is a result of planter inaccuracies (Nielsen, 1995). Plant population - yield relationship, accurate interpretation of yield maps, identifying zones of crop loss and analyzing the planter performance is possible with the availability of corn plant population (Hummel et.al, 2001). Corn population sensing can aid in identifying variation in plant spacing, planter skips, and doubles.

Researchers in the past have developed different types of corn population sensing systems. Easton (1996) developed a system which rolls in between the plant rows and uses a small pivoted arm to count the number of corn plants. A moisture detector was used to count the number of corn stalks during harvest by Nichols (2000). Plattner and Hummel (1996) used a photoelectric emitter and receiver pair to determine the corn population, spacing, skips and doubles. The sensor was tested at early growth stage and during the harvest. Errors of 3.1% and 6.2% were found in plant spacing in the respective tests. Weeds and corn plant leaves were found to be the main sources of errors. Filter algorithms were developed to remove the narrow beam interruptions due to small weeds. Mechanical corn population sensor mounted on the row crop divider of a combine corn header was developed by Birrell and Sudduth (1995). Deflection of a spring loaded rod was used to count the number of corn stalks. Accuracy of the corn plant population was within 5% of actual count when operated at combine speeds of 1.6 m/s to 2.2 m/s and gaps were consistently identified by the sensor. The sensor was redesigned and improved by the year 1997 to increase its accuracy and reliability. A stalk counter with 95% accuracy in estimating corn population was developed by engineers at Deere and Company (Gore 1995). Stalks closer than 1.5 in. and the presence of weeds were found to be the major sources of errors. However, with the recent development of glyphosate resistant corn, it is anticipated that errors resulting from weed interference could be reduced.

Objectives

The objectives of this research were to: i) utilize low cost infrared ranging sensors to develop a method for non-invasive corn plant population sensing, ii) test the sensors under laboratory conditions and during early growth stages of the corn plants, and iii) utilize signal processing techniques for filtering the raw data obtained from testing to determine corn plant populations.

Materials and Methods

Sensor Calibration

A low cost infrared sensor (GP2Y0A02YK manufactured by SHARP) with sensing range of 20 cm to 150 cm was used to sense the presence of corn plants. A calibration of the sensor was performed with sensor placed at distances 5, 10, 20, 37.5 (25% of d_{max}), and 112.5 (75% of d_{max}) and 150 (d_{max}) cm away from the target. Five replications were made at each distance and the average voltage output from the sensor was plotted against the known distance to obtain a calibration curve. Figure 1 depicts the calibration curve of the sensor which conforms to the specifications provided by the manufacturer.

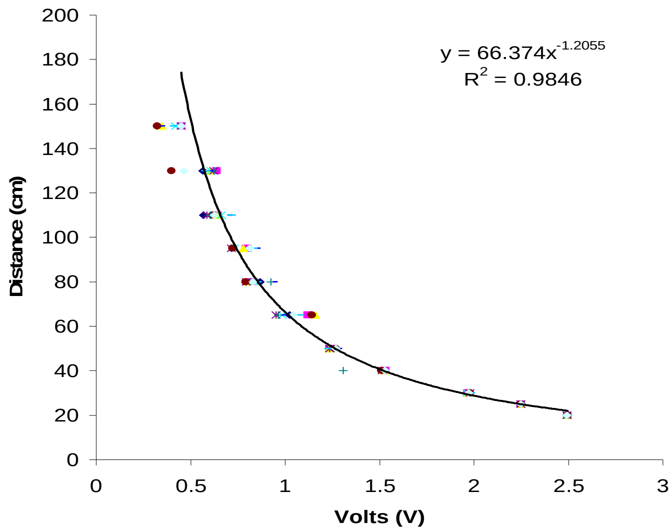

Figure 1. Infrared sensor calibration curve.

Laboratory Testing

During laboratory testing, the sensor was mounted on 3 m of track which allowed for the sensor to be positioned at different heights and distance from a simulated corn stand. Corn stalks collected from the previous harvest season were mounted on a stand at 14 cm intervals (Figure 2). During the first series of tests, the sensor was positioned at a distance of 20 cm from the corn stalks at a height of 23 cm from the ground. During the second series of tests, one end of the track was placed at 80 cm from the stalks while the other end was placed at 20, 40, and 60 cm, respectively. There was nothing placed behind the stalks so that there would be no other readings within the range of the sensor. The speed of the sensor was controlled by a motor with gear reduction that moved the sensor bracket along the track at a speed of 0.17 ms^{-1} (0.61 kmh^{-1}).

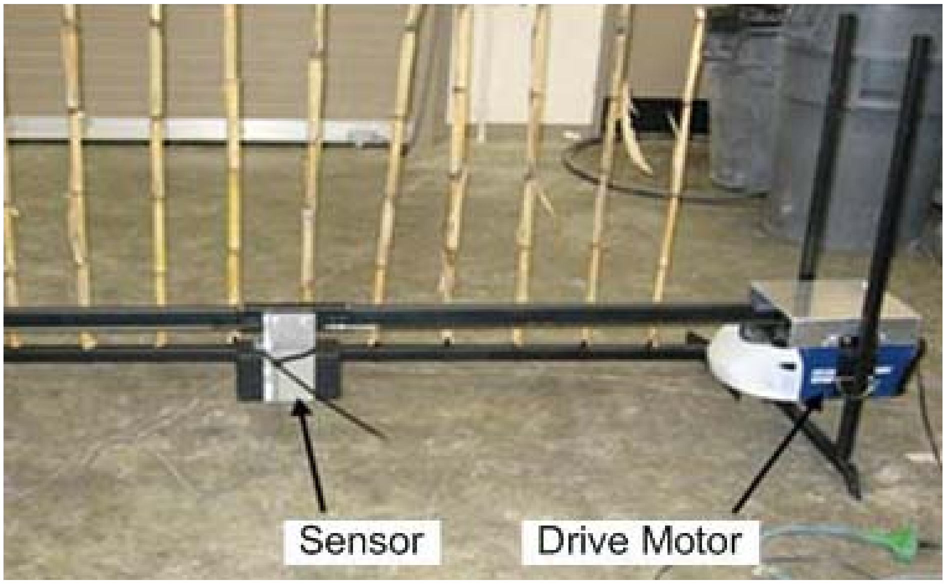

Figure 2. Laboratory test fixture for sensor evaluation.

Field Testing

Two sensors were mounted on a row crop tractor for field testing. A 30 m row of corn was isolated in the field and manually counted yielding 136 stalks. The corn was approximately 1 m in height at the time of testing (V7-V9 growth stage) and the diameters of 25 stalks were measured at a height of 23 cm which yielded an average diameter of 2.85 cm (standard deviation of 0.27 cm). This number would be used later to identify minimum widths in the output from the sensors as potential corn stalks. However, since the stalks were measured perpendicular to the sensor path, it was noted that in many cases, the leaves attached to the stalk at approximately 23 cm above the ground would also have been measured by the sensor. The average of these measurements including the stalks and leaves for the 25 corn stalks was 3.5 cm (standard deviation of 0.88 cm). The sensors were mounted such that the distance from the sensor and the row to be counted was 38 cm at a height of 23 cm (Figure 3). A solid plate was mounted at 90 cm from the sensors so that no readings would be taken from the adjacent row (Figure 3). The sensors can be seen to the right of the row in the center of Figure 3 with the plate located to the left of the center row. The speed of the tractor was maintained at 3.2 kmh^{-1} and the senor signal sampling rate was 1000 Hz.

Figure 3. Field testing sensor placement with plate.

The data were collected and stored using the methods in the flow chart of Figure 4. The voltage output was sampled using a 12 bit A/D converter. Discretized sensor output voltages were converted into distances using the calibration curve. The data were then plotted to determine what patterns might exist.

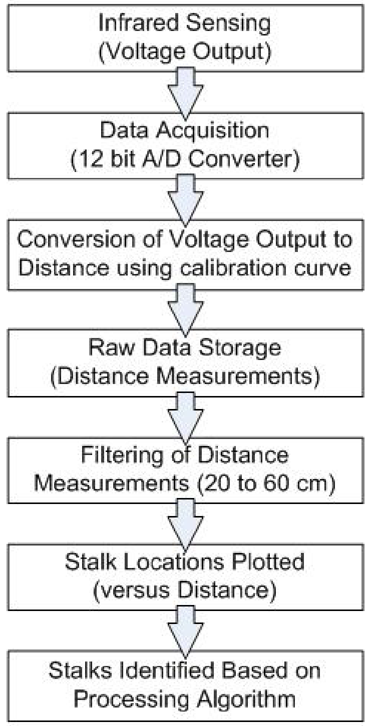

Figure 4. Flowchart of data acquisition/processing algorithm.

Results and Discussion

Laboratory Testing

The data output from the sensor placed at a constant 20 cm away from the corn stalks can be found in Figure 5. The data were plotted versus elapsed time for the sensors to travel the entire 3 m of track. The corn stalks are easily identifiable on the plot which can be seen at a distance of approximately 20 cm from the sensor. Visual inspection of the plots generated from the repeated tests showed the potential to identify all 21 corn stalks during each test.

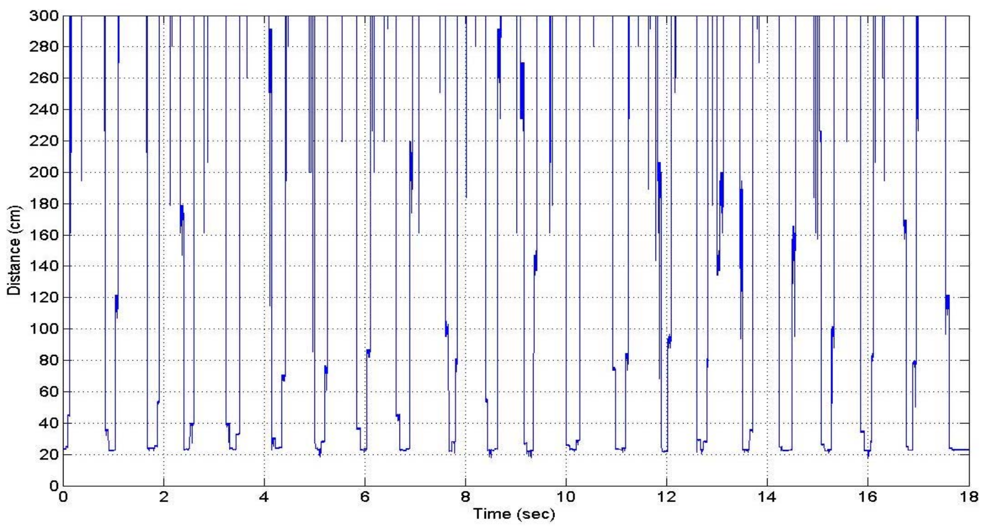

Figure 5. Plot of data collected from laboratory testing with constant distance from sensor.

The data output for different sensor displacements from the corn stalks can be found in Figure 6 where the consistent ending distance of 80 cm for each test can be seen at the right. The 21 corn stalks were easily identifiable by visual inspection of the plot. This test was repeated for each run which yielded similar data and the visual identification of all 21 corn stalks.

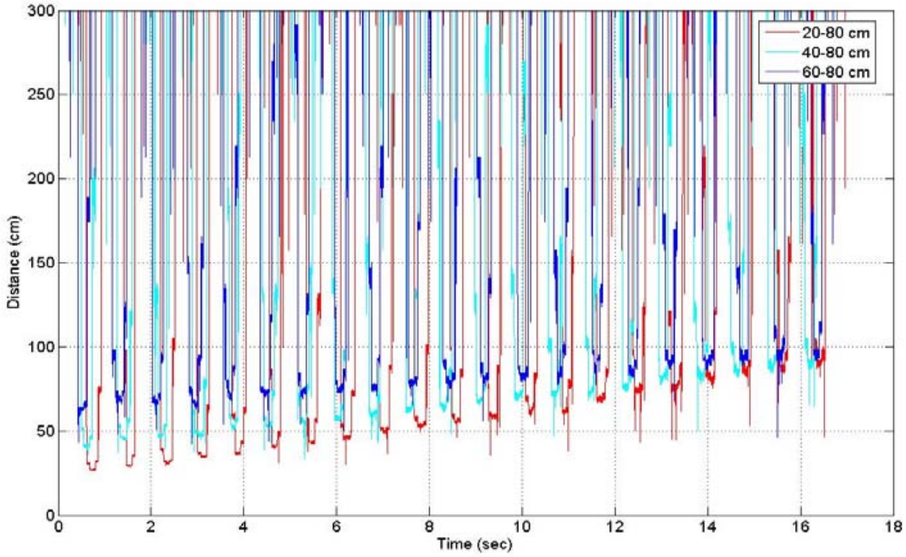

Figure 6. Plot of data collected from laboratory testing with multiple distances from sensor.

Field Testing

The data were filtered using Matlab® to remove points with values greater than 60 cm. This resulted in the elimination of points which made contact with the plate, while still allowing measurements into the area approximately halfway between the row measured and the adjacent row. This ensured that the corn stalks would be sensed and counted through this area, while removing much of the interference from the plate and adjacent row as practical.

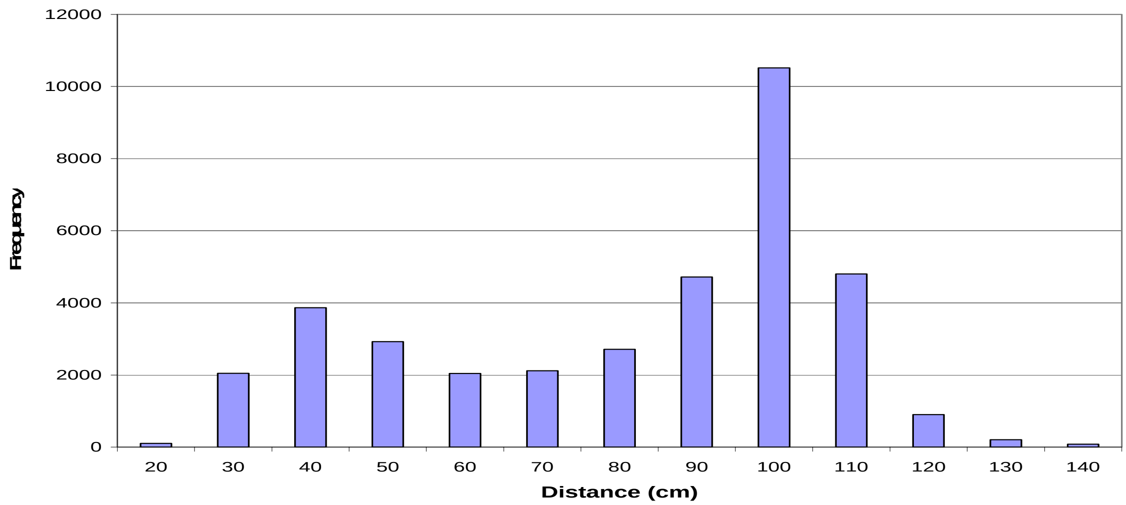

Figure 7. Distribution of distances measured by sensor with plate during one trial.

The threshold distance was selected based on a distribution of the data points which can be found in Figure 7. There is a peak in the frequency around 40 cm, which is the approximate location of the row being counted, and also a peak around 100 cm, which is the approximate location of the plate. Distances measuring less than 20 cm (the minimum sensing range of the sensor) and greater than 140 cm were found to be negligible during this process.

The filtered data (points less than 60 cm) were then plotted along with the unfiltered data in Matlab® for each trial run. Figure 8 shows a portion of one of the trial runs from the row being counted from 2500 to 3000 cm (of the total row length of 0 to 3500 cm). By plotting the data in Matlab®, it was possible to identify the areas between 0 cm and the data points stored for the filtered data. These areas indicate subsequent data points before the sensor was able to read zero or the plate. Based on the stalk width estimated from the field (widths greater than 2.85 cm), it was possible to identify where potential stalks occurred from these plots which were generated for every trial run (using the process summarized in Figure 4). In many cases the sensed stalk width was much wider, which is shown on the corn stalk identified to the far left of Figure 8. This was assumed to occur due to additional leaves that may have been encountered by the sensor in which case, the entire shaded area was counted as one corn stalk. The corn stalk identified at the far right of Figure 8 was measured to be almost exactly the same as the estimated stalk widths from the field. Therefore, shaded areas that did not have this minimum width were not counted as stalks. This identification process was repeated for each trial run. Although only three corn stalks are annotated on Figure 8, a total of 26 stalks can be counted based on the methods mentioned above. The shaded areas from all eight trial runs were counted and the total number of stalks from each trial run is summarized in Table 2. The sensors and processing technique consistently overestimated the actual number of stalks, ranging from 0.7 to 4.4 percent.

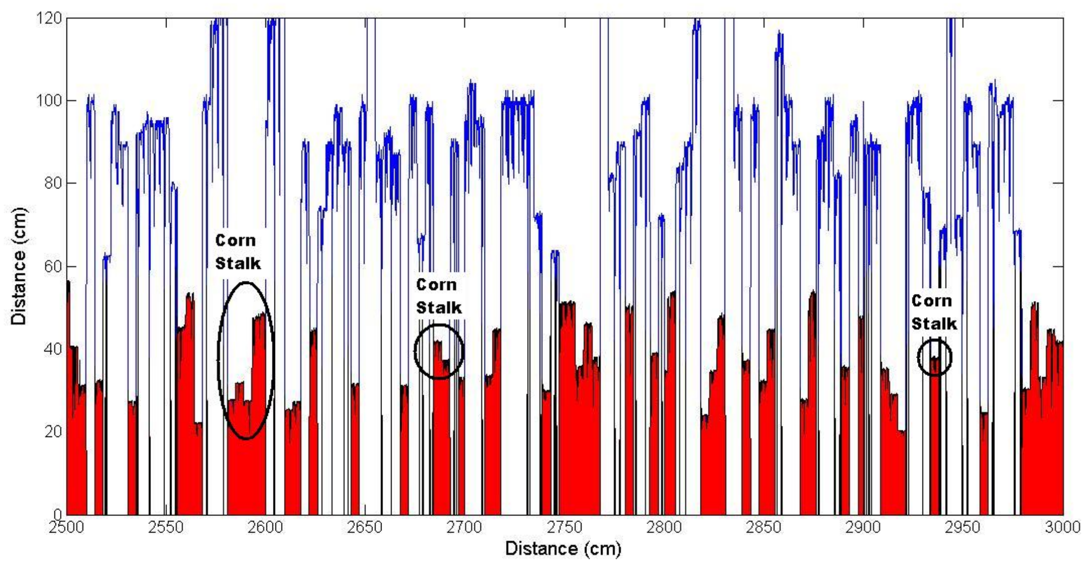

Figure 8. Sensor output from field testing with filtered data shown in red.

Identifying corn stalk locations based on the guidelines discussed above seemed to return positive results. For all eight trials, overestimation was less than 5%. Previous studies by Hummel (1996) utilized a photoelectric emitter which typically returned errors in the range of 3.1% to 6.2%. The stalk counter developed by Deere & Co. (Gore 1995) also was accurate to approximately 95% when estimating corn plant populations.

Table 2. Corn stalk counts from infrared sensor output in Matlab.

Sensor-Trial	Number of Stalks	Percent Difference from Manual Count (%)
(Manual Count)	136	-
1-1	140	+2.9%
2-1	142	+4.4%
1-2	137	+0.7%
2-2	140	+2.9%
1-3	139	+2.2%
2-3	137	+0.7%
1-4	141	+3.7%
2-4	140	+2.9%

Conclusions

The sensors and processing technique did an acceptable job of identifying corn stalks based on the data from the laboratory and field findings. The 2-D range sensing of data utilizing timing/distance processing techniques produced positive results in terms of plant population sensing. The data plots from laboratory testing made it easy to identify the locations of all 21 corn stalks measured during the tests.

The data plots from field testing were not quite as intuitive, however, by filtering the data to show only readings between 20 and 60 cm, it was possible to identify potential corn stalk locations. Visual inspection of the plots for all eight field trial runs showed the potential to estimate the total number of corn stalks to within +5%, which has been previously observed using mechanical measurement methods (Birrell and Sudduth, 1995).

There is much to be done if this approach is to be commercialized. The field testing data plots did show potential for identifying corn stalks, however additional algorithm development is needed to deploy this system under a range of field conditions. Future work must also include a more exhaustive field testing program which would include utilizing sensors to count multiple rows at different lengths. It would also be ideal to determine the accuracy of the sensors at various growth stages of the corn plants, while placing the sensors at different heights.

References

Birrell, S. J., and K. A. Sudduth. 1995. Corn population sensor for precision farming. ASAE Paper No. 951334. St. Joseph, Mich.: ASAE.

Easton, D. 1996. Corn population and plant spacing variability: the next mapping layer. pp. 723-727 in P. C. Robert, R. H. Rust, and W. E. Larson (ed.), Proc. 3rd Intl. Conf. on Precision Agriculture. ASA, CSSA, SSSA, Madison WI.

Gore, L. M. 1996. Report: Stalk counter for VRT study fall of 1995. Deere & Co., Moline, IL.

Hummel, J. W., B. M. Lobdell, K. A. Sudduth, and S. J. Birrell. 2001. Sensing corn population-another variable in the yield equation. in Proceedings of the 2001 InfoAg Conference, Indianapolis, IN.

Nichols, S. W. 2000. Method and apparatus for counting crops. U.S. Patent No. 6,073,427.

Nielsen, R. L. 1995. Planting speed effects on stand establishment and grain yield of corn. J. Prod. Agric. 8(3): 291-393.

Plattner, C. E. and J. W. Hummel. 1996. Corn plant population sensor for precision agriculture. pp. 785-794. in P. C. Robert, R. H. Rust, and W. E. Larson (ed.), Proc. 3rd Intl. Conf. on Precision Agriculture. ASA, CSSA, SSSA, Madison WI.