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Individual plant care in cropping systems

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Abstract

Individual plant care cropping systems, embodied in precision farming, may lead to new opportunities in agricultural crop management. The objective of the project was to provide high accuracy seed position mapping of a field of sugar beet. An RTK GPS was retrofitted on to a precision seeder to map the seeds as they were planted. The average error between the seed map and the actual plant map was about 32 mm to 59 mm. The results showed that the overall accuracy of the estimated plant positions is acceptable for the guidance of vehicles and implements. For subsequent individual plant care, the deviations were not, in all cases, small enough to ensure accurate individual plant targeting.

Keywords: crop management, individual plant care, weeding, seeding, RTK GPS

Introduction

Agriculture has benefited in the past from the success of technological developments that have brought greater productivity and economic efficiency. Historically, the emphasis of these developments has been on the mechanization of field operations to increase work rates achievable by individual operators. Today, however, the trend of increased efficiency through the use of larger and more powerful machines becomes more crucial due to environmental hazards such as soil compaction and high chemical and fuel inputs. Large scale machinery also seems to have drawbacks to match the general requirements for precision farming. The trend of increased machinery size and weight may be substituted by newer information based technologies that may ultimately enable reliable autonomous field operations. This scale-reduction process, embodied in precision farming, may lead to the possibility of individual plant care cropping systems.

These cropping systems require accurate information at least about the position of the crop plants and furthermore, if possible, additional information about the crop status. A highly accurate seed map would enable several automatic controlled field operations such as

- guidance of vehicles (e.g. parallel to row crops),
- guidance of implements or tools (e.g. inter- and intra-row weeding),
- application of fluids or granules to individual crop plants (e.g. insecticides, fungicides, fertilizers etc.) and
- measuring growth status of individual plants (e.g. multi-spectra, shape etc.).

The objective of the project was to provide high accuracy seed position mapping of a field of sugar beet. The mean position deviations between crop plants and seeds should be determined under varying field conditions such as soil type and seed bed quality. The hypothesis is that by knowing where the seeds have been placed, crop plants can be located. Furthermore, the overall aim of the project was to allow robotic physical or chemical treatment of individual plants.

The target areas for the application of chemicals or physical treatments within a field where the crop is established in rows are different. They require presumably different cultivation principles as there are (i) the area between the rows (inter-row area), (ii) the area between the crop seedlings within the rows (intra-row area), and (iii) the area close to and around the crop seedlings (close-to-crop area). Inter-row treatments as hoeing, harrowing or brushing are matured methods and has reached a high level of automation with automated guidance systems within the last years. The challenging tasks are still to spatially control either chemical or physical treatments within the intra-row and close-to-crop areas.

Papers about robotic weeding projects at research institutions have been published and show the high relevance of this topic (Lee et al., 1999; Madsen & Jakobsen, 1999; Van Zuydam, 1999; Astrand & Baerveldt, 2002; Blasco et al., 2002; Nielsen et al., 2002).

Materials and Methods

A six row precision seeder for sugar beet was retrofitted with real-time kinematic (RTK) GPS positioning and a data acquisition system. Six optical sensors (one per seeder unit) were mounted directly above the coulters and detected the seeds as they dropped into the furrows. In order to correct the tilt of the seeder and the attached GPS-antenna, an inclinometer was added to log the tilt information. The data logging system stored the GPS time and the UTM coordinates at a 20 Hz sample rate. The data logger also monitored the optical sensors and the seed drop times for each seeder were also stored in the memory. The data acquisition system is described in more detail in Nørremark et al. (2003). A similar project with a corn seeder was conducted some years ago in the US (Ehsani et al., 2000).

The magnitude of the deviations of the crop plant positions to the estimated seed positions are influenced by several parameters. These error sources include

- accuracy of the positioning system (RTK GPS),
- movement (play) of sowing devices relative to the positioning reference point,
- displacements of seeds in the furrows after passing the optical sensors and
- deviations of plant positions from seed positions affected by field conditions (soil type, seed bed quality, seeding depth etc.).

An RTK GPS was used to give high accuracy position determinations at the cm level. During the seeding operation, the antenna was attached to the seeder toolbar to avoid relative movements - e.g. due to play - between the reference point (GPS position) and the seed drop points. A kinematic inclination model allowed correction of two dimensional tilting of the seeder. The inclination was measured by a tiltmeter for pitch and roll rotation axles.

The positions where seeds drop into the furrow and where they remain after seed coverage are likely to be different. To ensure a small potential of seed displacement, a special seeder type was chosen. With this seeder type, the seeds drop into the furrow with a horizontal speed equal to the vehicle speed (Soucek & Pippig, 1990). Unfortunately this is not the case for all adjustable seed spacing.

Field tests were conducted to check the performance of the seeder and to verify the whole data logging and processing system. A first experiment was set up to investigate the effect of the seed bed quality and the soil type on the deviations between seed positions and positions where the plants emerge at the field surface. In a different experiment, the seed spacing and vehicle speed were altered in order to check the influence of these parameters onto the seeder's performance or the data logging system.

To investigate the overall deviations between estimated seed and true plant positions, geo-referenced pictures from selected plots marked by a 1.1 m x 1.1 m frame were taken. The images were processed on a computer and the plant positions were digitized. The position data of plants and seeds were analyzed and the two dimensional mean deviations per treatment were calculated.

Results and discussion

The field conditions are supposed to have an influence on where plants emerge related to their seed position. In Table 1, the results are shown for quantifying these deviations caused by varying soil type and seed bed condition. The range of deviations was 11.2 mm to 17.4 mm. This showed that field conditions have a significant effect on the estimation of plant positions from seed positions. These fully random errors will always occur because they appear due to normal and unavoidable soil structure conditions. The results show that the seed bed quality has an effect on the deviations at least on heavy soil types. These project results and conclusions have been published already in a student report (Buisman et al., 2001).

Figure 1 gives a graphical impression of the results of seed and crop plant mapping. The calculated seed positions of all six rows of the seeder, the 15 plant positions of one sample frame and the GPS data track are overlayed. The seeder did not place a seed at every location where it should have dropped a seed. This was due to an insufficient singulation process within each seeder unit which gave a cell filling of less than 100 %. Furthermore due to the field emergence there is sometimes no plant where a seed was placed by the machine. For several reasons, as described already, the plant positions were of course not identical with the seed positions.

Table 1. Mean deviation between seed and plant positions for different soil types and seed bed qualities

Soil type / seedbed quality	Mean deviation (mm)	Grouping*	n
Heavy / coarse	17.4	A	32
Heavy / fine	14.9	B A	42
Light / coarse	11.7	B	27
Light / fine	11.2	B	39

* Least significant difference (error 5 %) = 3.992 mm

By measuring the true plant positions from selected plots and comparing them with the calculated seed positions from the data logging system, it was possible to determine the overall deviation errors. Table 2 shows overall errors as mean seed spacing and machine velocity were varied. The range of the overall mean deviation was 31.8 mm to 59.2 mm. It seems that the higher speed around 7 km h^{-1} gave a higher deviation while the variation of the seed spacing was not clear. The results from these field experiments also showed no biased data. This could be expected due to seeder performance (seed displacements in the furrows) or to sensor attachments (GPS antenna, optical sensors etc.) or to delays within the data logging system. Results from a similar research project (Ehsani et al, 2000) with a corn planter in general confirmed these results. In that project, the average error lay between 43 mm and 53 mm.

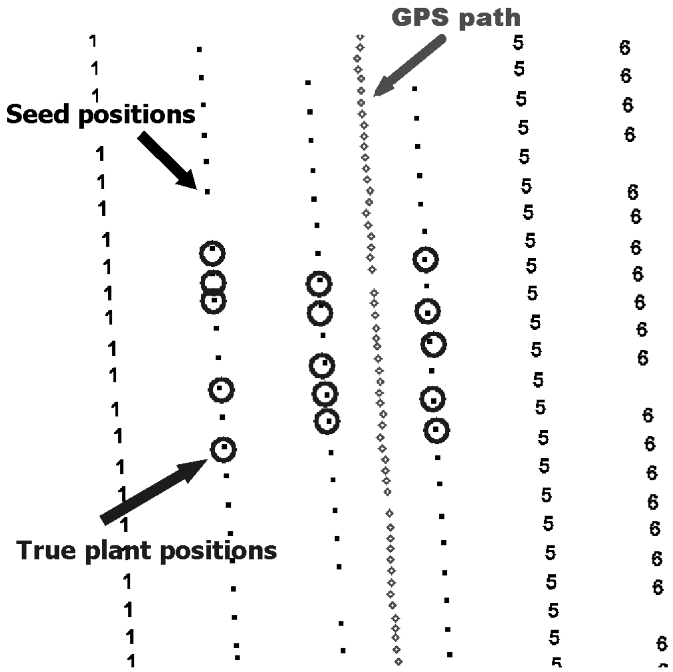

Figure 1. Seed and plant positions and 20 Hz RTK GPS track after sowing with a six-row sugar beet seeder (seed spacing 20.2 cm and row width 50 cm; circle centre represent true plant position)

Table 2. Mean deviations between estimated seed positions and true plant positions for treatments with different seed spacing and velocities

No.	Seed spacing (cm)	Velocity (km h^{-1})	Mean deviation (mm)	Grouping*	n
1	20.2	7.0	59.2	A	172
2	12.5	7.0	52.6	B	111
3	20.2	3.5	50.3	B	191
4	12.5	3.5	31.8	C	124

* Least significant difference (error 5 %) = 5.383 mm

The seed mapping technology developed will be improved and utilized within a new funded Danish research project called 'Robotic Weeding'. The mapped seed positions will give *a priori* information about a field for subsequent scouting tasks. The scouting shall provide accurate positional information not only about crop plants but furthermore also about the weed plants. A planned cultivation consisting of mechanical operations (intra-row weeding) or chemical treatments (micro spraying) are part of the planned project activities.

Conclusions

An RTK GPS was successfully retrofitted on to a precision seeder to map seeds as they were planted. The average error between the seed map produced by the seeder and the actual plant map was about 32 mm to 59 mm. The results showed that the overall accuracy of the estimated plant positions is acceptable for the guidance of vehicles and implements. For subsequent individual plant care, the deviations were not in all cases small enough to ensure an accurate individual plant targeting. We are currently working on reducing this error.

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