Robotic weeding of a maize field based on navigation data of the tractor that performed the seeding

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Abstract: This research presents robotic weeding of a maize field based on navigation data of the tractor that performed the seeding. The availability of tractors equipped with RTK-DGPS based automatic guidance potentially enables robots to perform subsequent tasks in the same field. In an experiment a tractor guidance system generated a route for sowing based on an initial path consisting of two logged positions (A-B line) and then planned the subsequent paths parallel to the initial path one working width apart. After sowing the maize, the A-B line was transferred to the Intelligent Autonomous Weeder (IAW) of Wageningen University. The IAW generated a route plan based on this A-B line and eight coordinates defining the borders of the field and the two headlands. It then successfully performed autonomous weeding of the entire field except of the headlands. The row width was 75 cm and the width of the hoes mounted on the robot was 50 cm. The results show that it is possible to perform robot weeding at field level with high accuracy based on navigation data of the tractor that performed the sowing.

Keywords: robot, robot weeding, RTK-DGPS, autonomous navigation, guidance.

1. INTRODUCTION

Major factors driving the presently increasing interest in non-chemical weed control are concern about herbicides polluting ground and surface water, human health risks from herbicide exposure or residues, effects on the flora and fauna and development of herbicide resistance. Although the alternative of mechanical weed control could potentially replace herbicides in certain crops like maize, the labor costs of mechanical weed control are much higher than the labor costs for chemical weed control. Robots performing mechanical weed control reduce labor costs and can so potentially contribute to a more sustainable agriculture (Van der Weide et al. 2008; Slaughter et al. 2008). Furthermore, the availability of tractors equipped with RTK-DGPS based automatic guidance potentially enables robots to perform subsequent tasks in the same field automatically. So it is possible to use data recorded by a machine equipped with RTK-DGPS at a first point in time for control of a robot equipped with another RTK-DGPS receiver at later point in time. The objective of this research is to show that it is possible to perform robotic weeding at field level with high accuracy based on navigation data of the tractor that performed the seeding two and a half week earlier.

2. MATERIALS AND METHOD

2.1 Seeding

A maize field was seeded at the beginning of week 31, 2009, with a standard New Holland tractor equipped with a RTK-DGPS based automatic guidance system from SBG-Innovatie (2008). The crop rows were seeded 75 cm apart. The tractor guidance system generated subsequent paths one working width apart relative to an initial path consisting of two logged positions (A-B line). During sowing of the parallel paths the tractor was steered automatically by the guidance system. Turning at the headland was performed by the driver. The coordinates of the A-B line were saved in a file.

2.2 Robot platform

The robot platform used for weeding was the Intelligent Autonomous Weeder (IAW) of Wageningen University that was specially designed for autonomous weed control (Bakker et al. 2010a).

Fig. 1. Robot platform in the field.

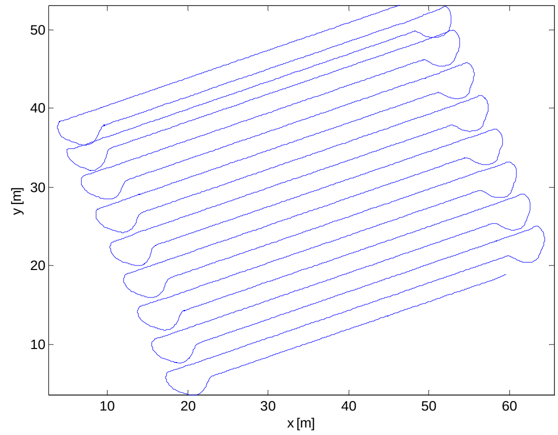

Fig. 2. Route over the field.

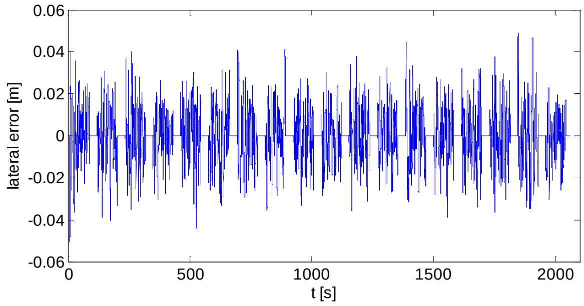

Fig. 3. Lateral error of path following during weeding.

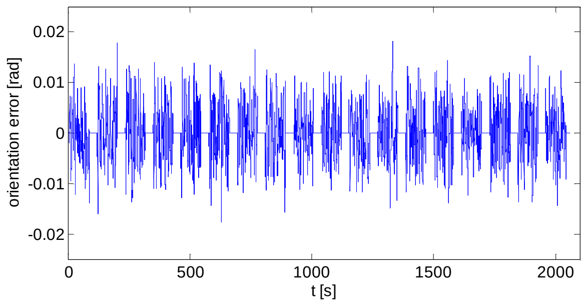

Fig. 4. Orientation error of path following during weeding.

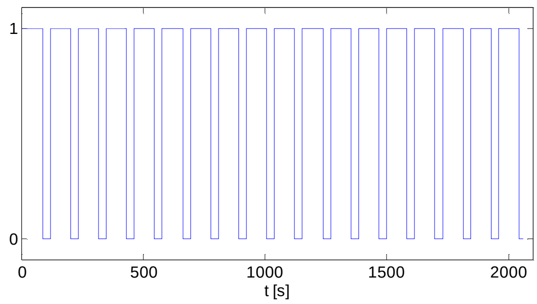

Fig. 5. Indicator value of actuator located in the main field area (value = 1).

The electronics used in the IAW are described in Bakker et al. (2010b). For this experiment the determination of the position was extended with a compensation for roll caused by the uneven ground surface: the height difference of the two RTK-DGPS antenna's was used to calculate an accurate position at ground level.

For this experiment the robot platform was further equipped with three sets of hoes, where each set performs the weeding in between two crop rows. So the robot's working width equalled three rows, i.e. 2.25 m. Each set of hoes consisted of three hoes allowing the adaptation of the working width per set. Individual hoes could be displaced relative to each other in the direction lateral to the driving direction. For this experiment the width per set was adjusted to 50 cm.

2.3 Method

After sowing the maize, the A-B line was transferred to the Intelligent Autonomous Weeder (IAW) of Wageningen University. A route plan was generated consisting of 18 paths parallel to this A-B line. Furthermore eight coordinates were logged defining the borders of the field and the two headlands. To cover the whole field exactly, 16 paths were defined 2.25 m. apart and 2 paths 1.5 m apart. Given the subsequent distances in between the parallel paths, the IAW generated automated headland turns connecting the subsequent paths.

The vehicle path following control consisted of two levels. At high level two PI controllers minimize the lateral error and the orientation error to the path. The four wheel angle setpoints were determined from inversion of the kinematic model. At low level each wheel angle was controlled by a proportional controller combined with a Smith predictor. The path following control is described more extensively in Bakker et al. (2010b).

The IAW used a point in polygon algorithm to determine if a position was located in one of the headlands, the main field area or outside the field boundary. This was used to lift the implement if it was located in the headland area and to stop the robot if any corner of the robot's frame would be located outside the field boundary. See for a more extensive description of the autonomous field navigation system including the automatic headland path planning Bakker et al. (2010c). The experiment was carried out August 21st, 2009.

3. RESULTS

The robot successfully performed autonomous weeding of the entire field except the headlands at a speed of 0.5 m/s. In 35 minutes, 18 parallel tramlines of about 40 m length each (see figure 2) were weeded. The logged lateral errors and orientation errors during weeding were measured with a RTK-DGPS and visualized in figures 3 and 4. The relevant periods are those in which the robot is performing the actual weeding, i.e. when the weeding actuator was located in the main field area. Figure 5 indicates whether or not the actuator was located in the main field area. The mean, standard deviation and maximum of the lateral error are respectively 0.0, 1.2 and 5.1 cm. The mean, standard deviation and maximum of the orientation error are respectively 0.000, 0.005 and 0.018 rad. At 75 cm maize row width and 50 cm hoe width no damage to the crop was found at any location.

4. CONCLUSIONS

The robot successfully performed autonomous weeding of the entire field except the headlands based RTK-DGPS at a driving speed of 0.5 m/s using the navigation data of the tractor that performed the seeding two and a half weeks earlier. At 75 cm maize row width and 50 cm hoe width no damage to the crop was found at any location. The mean, standard deviation and maximum of the lateral error relative to the path during weeding measured by RTK-DGPS are respectively 0.0, 1.2 and 5.1 cm. The mean, standard deviation and maximum of the orientation error are respectively 0.000, 0.005 and 0.018 rad.

REFERENCES

Bakker, T.; Asselt, C.J. van, Bontsema J., Müller, J. and Straten, G. van (2010a). Systematic design of an autonomous platform for robotic weeding. *Journal of Terramechanics* 47 (2), 63-73.

Bakker, T., Asselt, C.J. van, Bontsema J., Müller, J. and Straten, G. van (2010b). A path following algorithm for mobile robots. *Autonomous Robots* 29 (1), 85-97.

Bakker, T., Asselt, C.J. van, Bontsema J., Müller, J. and Straten, G. van (2010c). Autonomous navigation using a robot platform in a sugar beet field. *Biosystems Engineering*. Accepted for publication.

SBG-Innovatie (2008). SBGuidance - automatische besturing voor trekkers, zelfrijdende machines en werktuigen (automatic control for tractors, self-propelled machines and implements). Available from: www.sbg.nl/folders/sbguidance-2006-11.pdf. [5 November 2008].

Slaughter, D. C., Giles, D. K. and Downey, D. (2008). Autonomous robotic weed control systems: A review. *Computers and Electronics in Agriculture* 61 (1), 63–78.

Van der Weide, R. Y., Bleeker, P. O., Achten, V. T. J. M., Lotz, L. A. P., Fogelberg, F. and Melander, B. (2008). Innovation in mechanical weed control in crop rows. *Weed Research* 48 (3), 215–224.