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GPS-BASED AUTOMATIC AND MANUAL VEHICLE STEERING

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Abstract: The objective of the work was to determine the goodness of steering in GPS-based automatic steering and manual steering. The accuracy of automatic steering was better than it was with manual steering with or without GPS navigation aid. The error of automatic steering was lower than 0.08 m with four different tractor and implement combinations.

Key words: *GPS, precision agriculture, vehicle steering, guidance precision index.*

INTRODUCTION

There are different GPS-based navigation systems to reduce steering error especially with high speed and large working width operations. The navigation system is either a part of an automatic steering system, or it is a navigation aid having a special display indicating the direction of the proposed steering correction.

GPS-based navigation system should be used for minimizing overlapping and skips/gaps between consecutive runs with seeding, spraying, fertilizing, soil tillage, harvesting and especially when operating machines of large working width.

GPS-based navigation system is needed for different agricultural vehicles used for precision agriculture, especially for such purposes as soil sampling and data recording, field mapping, performing site specific operations, designating definite leading lines, following a definite leading line (by GPS navigation and manual steering) and following a definite leading line by GPS based automatic steering.

OBJECTIVE

The objective of the work reported herein was to measure and analyze the steering error with different steering modes, such as steering with GPS-based automatic vehicle steering, GPS based navigation aid and conventional manual steering.

METHOD

Experiments were performed along flat fields where a straight line was determined along the edge of the test field to be the leading line. The coordinates of this line were stored in the memory of the on-board computer to which the dGPS was connected and the tractor was driven along this line and the wheel ruts of the tractor provided with the actual leading line.

Test runs were done with a four-wheel drive tractor and with four different implement combinations.

The main characteristics of the implements used for the experiments were, as follows:

- disk harrow: working width: 6.9 m, average speed: 7.5 km/h
- field cultivator: working width: 8.9 m, average speed: 11.5 km/h
- seed drill: working width: 9.0 m, average speed: 10.0 km/h.
- fertilizer spreader: working width: 27 m, average speed: 14.0 km/h.

The purpose of the driver was to follow the straight leading line by

- automatic steering system
- manual steering according to the indications displayed by the navigation aid and
- manual steering without any navigation aid.

The automatic steering system used for the experiments was the John Deere „Auto Tracking" that controls the servo steering of the tractor via solenoid valves.

The GPS used for the experiments was a StarFire iTC with dual frequency receiver and the receiver had a built in gyroscope to compensate the roll (rotation on horizontal axis) to ensure approximately 100 mm accuracy.

The navigation aid (parallel tracking) was supported by John Deere „Parallel Tracking" device having StarFire iTC antenna with dual frequency receiver and built in gyroscope and the steering was performed by manual steering according to the display of the „Parallel Tracking" device.

Four test runs were performed with each tractor and implement combination with the three different steering modes. The result of the experiments was determined by the distance between the leading line and the central lines of the wheel ruts for four test runs. The maximal and minimal value of the working width, the average value of the width, the average error of the width and the standard deviation of the width were determined. 40 to 50 measurements were performed along the 400 to 500 m long test runs.

The best characteristics to describe the goodness of steering are the error and the range. The error characterizes the variations in the working width that is the difference between the set point of the working width and the average value of the actual working width. Another beneficial characteristic is when taking into account the maximum and minimum amplitude of the variation. This characteristic can be calculated from the difference of the maximum and the minimum value of the working width on a definite length.

Therefore the results of working width measurements were evaluated with different steering modes and the characteristics of the working width were determined, as follows: average value, maximum value, minimum value, the range that is the difference of maximum and minimum value and the error of the steering.

RESULTS

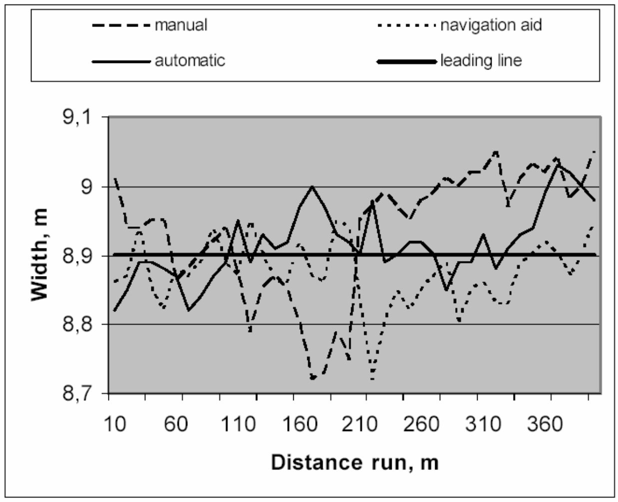

Figure 1: Working width in the function of the length run by the tractor and fieldcultivator combination with different steering modes (average speed: 11.5 km/h)

The working width in the function of the length run by the tractor and implement combination is shown for automatic steering, for steering according to navigation aid and for conventional manual steering in Figure 1.

The results obtained with the closed loop automatic steering system were independent on the skills of the driver. The driver with the navigation aid was aware of the relative position of the vehicle and he played the role of a part of the control system (sensor, controller and actuator), therefore the driver's skills had a definite influence on the goodness of the results. With conventional manual steering without any navigation aid the driver had to find out the relative position of the vehicle without any objective information and had to do the steering according to his skills.

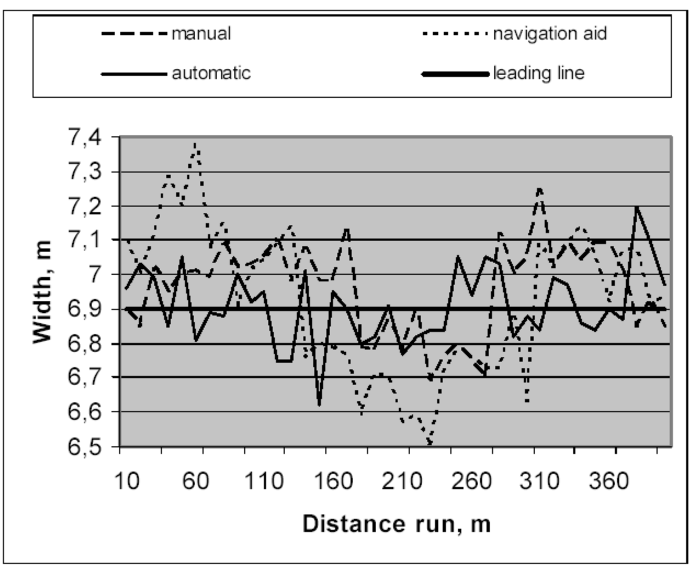

Figure 2: Working width in the function of the length run by the tractor and disk harrow combination with different steering modes (average speed: 7.5 km/h)

The results of working width measurements are shown in Tables 1 to 4 with different implements and steering modes. The characteristics of the working width (average value, error, maximum value, minimum value, difference of maximum and minimum value) were determined.

Table 1. Results of working width with disk harrowing

Steering mode	Average m	Error m	Maximum m	Minimum m	Range (max-min) m
Automatic	6.91	0.01	7.2	6.62	0.58
Navigation aid	6.96	0.06	7.25	6.69	0.56
Manual	6.92	0.02	7.38	6.50	0.88

Table 2. Results of working width with field cultivator

Steering mode	Average m	Error m	Maximum m	Minimum m	Range (max-min) m
Automatic	8.72	0.02	8.88	8.57	0.31
Navigation aid	8.69	-0.01	9.03	8.39	0.64
Manual	8.83	0.13	9.32	8.24	1.08

Table 3. Results of working width with seeding

Steering mode	Average m	Error m	Maximum m	Minimum m	Range, (max-min) m
Automatic	8.92	-0.08	9.03	8.82	0.21
Navigation aid	8.87	-0.13	8.95	8.72	0.23
Manual	8.93	-0.07	9.05	8.72	0.33

Table 4. Results of working width with fertilizer spreader

Steering mode	Average m	Error m	Maximum m	Minimum m	Range (max-min) m
Automatic	27.01	0.01	27.16	26.88	0.28
Navigation aid	26.92	-0.08	27.15	26.61	0.54
Manual	29.24	2.24	31.30	27.80	3.50

The error and the range were found to be the best with automatic steering mode. In this case the error was small, 0.01 to 0.08 m. The range was quite narrow between 0.21 and 0.58 m with different implements and different speeds. In automatic steering mode the error was dependent on the accuracy of the positioning by GPS and on the tuning of the closed loop steering control. Other disturbances had no considerable influence.

The error and the range were acceptable with manual steering according to the navigation aid. The error was in a relatively wide range between 0.01 and 0.13 m. The range was between 0.23 and 0.64 m with different implements and different speeds. In this steering mode the driver's skills played a principal role in the goodness of following the leading line.

The accuracy of the GPS was important, but other disturbances had no importance. Naturally, the reliability of the steering is not good in this mode since the error increases with the fatigue of the driver.

The error and the range were not acceptable with only manual steering without any navigation aid because there were large variations. In this case, the driver's skills and the visibility played considerable role in the goodness of the steering. The error and the range increased with higher forward speed and with wider working width. The error was between 0.02 and 2.24 m and the range was between 0.33 and 3.50 m. Naturally, the steering error was found to be dependent on the steering mode. The forward speed of the tractor and implement combination had a considerable influence on the error, as well. However, the error was dependent on the working width and the visibility of the edge of the previously cultivated/covered area. The results of the tests with four different implements showed that the average error in the working width was 0.04 to 0.07 m with automatic steering, 0.03 to 0.36 m with the navigation aid and 0.13 to 22.4 m with manual steering.

CONCLUSION

The error of the working width was found to be the best with automatic steering where it was independent on the driver's skills. The error was acceptable in several cases with the navigation aid. However, the error was dependent on the driver's skills and on paying attention to the display. With manual steering the error measured was too high in several cases and it was dependent on the driver's skills and attention.

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GPS AUTOMATSKO I RUČNO UPRAVLJANJE VOZILIMA

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***Sadržaj*:** Cilj ovog rada bio je da se odrede prednosti GPS automatskog i ručnog upravljanja vozilom. Preciznost automatskog vođenja je bila bolja u odnosu na ručno vođenje sa ili bez GPS navigacije. Greška pri automatskom upravljanju je bila niža od 0,08 m u slučaju četiri različite kombinacije traktora i priključnih mašina.

Ključne reči: *GPS, precizna poljoprivreda, upravljanje, indeks preciznosti.*