Int. Agrophysics, 1994, 8, 581-584

POSITIONING SYSTEMS FOR AGRICULTURAL FIELD OPERATIONS

H.J. Hellebrand, H. Beuche

Institute of Agrotechnology, Max-Eyth-Allee 1, D-14469 Potsdam - Bornim, Germany

A b s t r a c t. Agricultural positioning systems must be reliable, cost-effective and should have a precision according to the field operation to be carried out. The Global Positioning System (GPS) gives the opportunity to use commercially available receivers. Since dynamic real-time positions are needed for farming, reflection or absorption of satellite signals due to buildings, hills, trees, etc., should not disturb the position determination. The coupling of independent location information can be used to provide positions and updates through the down time. The field geometry (borders, direction and distance of rows), stored in an electronic map, is utilized with an internal system (speed and direction) to provide the positions when the GPS signal is disrupted. The combination of these various information sources (geometry, internal system, GPS) gives a way of increasing the reliability and accuracy of the whole system. Three different possibilities for the determination of the direction have been tested: (i) difference of two parallel radar sensors, (ii) fluxgate compass, and (iii) piezoelectric vibratory gyroscope. The experimental results and the principal algorithm for the on-line coupling of GPS, sensor data, and the field map are presented.

K e y w o r d s: agricultural field operations, global positioning-systems

INTRODUCTION

The development in agricultural technology is connected with utilisation of information. In crop production one possibility might be the adoption of methods of fieldwork, in which the variations within the field are considered. When the sensing of the variability like soil nutrient, soil density, or weed distribution takes place during a different operation than a precise location information is required for the responding activity, such as fertilising, tillage, or application of chemicals. The data of variability and the data for necessary activity can be linked and stored in a geographic information database, the electronic field map.

In order to use such type of technology the positioning system must be reliable and should have precision appropriate to the field operation. The Global Positioning System (GPS) as space-based trilateration has become the most universal way for positioning of vehicles in the air, on the sea and on land. The mass production of GPS-receivers has just started. For agricultural applications the accuracy of these simple GPS-receivers is not sufficient. Reference-stations have to be used to reach the required precision in position detection (Differential-GPS or DGPS). Wrong positions will be registered when the signals from the satellites or from the reference station are interrupted for short periods. At least three satellites must be clearly receivable for two-dimensional positioning. If the height is to be registered too, like at valleys and hills, then four or more satellites are needed simultaneously. Other possibilities, which may cause a short breakdown of the GPS receiver, are short time absorption or reflections with superposition of the electromagnetic signal waves. Once the precise Differential-GPS position is lost, then it takes some time (seconds to minutes) until the system reaches the accurate and stable state for location information (Fig. 1). The opinions in the literature concerning necessary and achievable accuracy and reliability differ slightly [1-5]. It depends on the agricultural field operation to be carried out and on the type and accuracy of the GPS receiver system chosen. Our experience is that short break downs will occur more or less regularly (Fig. 2). One way to overcome this difficulty is the coupling of independent location information.

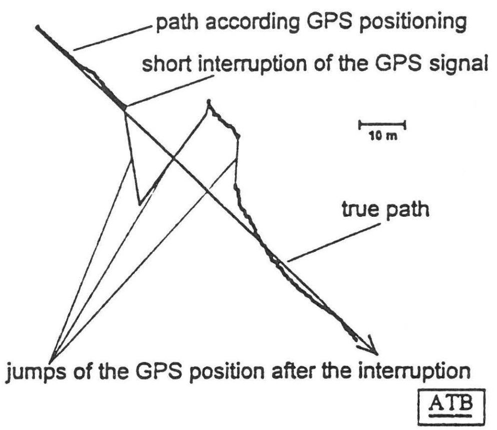

Fig. 1. Typical jumps of dynamic GPS location when the signal is interrupted for a short period.

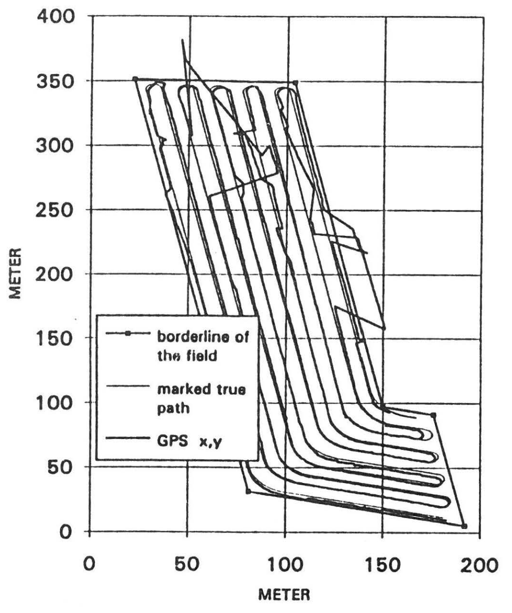

Fig. 2. True and measured path according to Differential-GPS data.

MATERIALS AND METHODS

The principle of a positioning system with information coupling is given in Fig. 3. Three sources are evaluated by the navigation computer. The field map describes the borders, where the machine must be in, and the main direction of linearised or parallel curvilinear rows or tramlines of known areas with fixed locations. The second source is an autonomous sensor system on the moving vehicle. The position and the path of the vehicle are gained by integration of speed and direction using a known or accurately determined, by means of GPS-accumulation, starting point. The third source of information is the actual GPS-position.

The objective of the experiments was the comparison of different sensors for the autonomous system. Two differently shaped

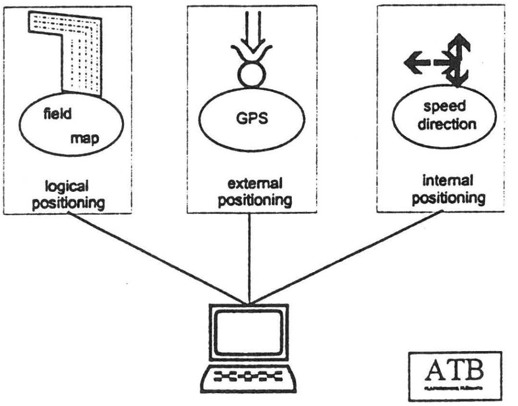

Fig. 3. Scheme for the connection of position information.

fields (one rectangular and one L-shaped) were surveyed and marked with an accuracy in the range of half a metre (true path). The tractor was equipped with a differential GPS-receiver in operation with a reference station. The DGPS-position resolution was of about one metre. For speed measurements two radar sensors were used. The direction was measured in three different ways: 1) by utilization of the difference signal of the two radar sensors, 2) by an electrodynamic fluxgate compass, and 3) by evaluation of the signal of a piezoelectric vibratory gyroscope (angular velocity sensor). All measured data (unprocessed raw data) were stored at a laptop during the experiments for further analysis, specially with the aim to test algorithm and software solutions for data coupling.

RESULTS AND DISCUSSION

Examples of the path calculated by measured raw data are given in the illustrations. The highest deviations were observed, when the direction was calculated using the radar sensor signal difference (Fig. 4). This has been expected, since small differences between the two parallel sensors are always produced, even when the tractor is going straight on, due to the erection of plants after had been rolled over and because of vibrating and staggering of the tractor. Additionally, measurements based on the difference of small signals give a greater relative error. The piezoelectric vibratory gyroscope was found less

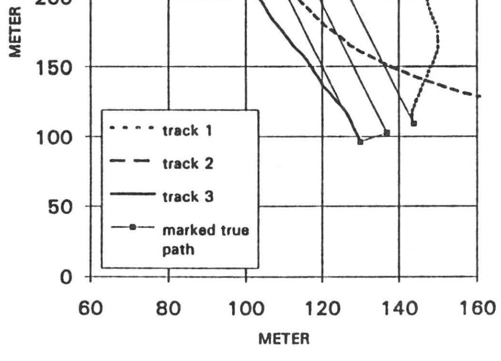

Fig. 4. Example for true and calculated path (speed by radar sensors and direction by difference of radar sensors).

fluctuating but generates a more continuous long time drift leading to deviations of the true path too (Fig. 5). A reasoning for the measured drift cannot be given clearly, but we assume a correlation to the change in temperature due to occasional sunshine. More detailed experimental studies concerning the sources of drift, specially temperature

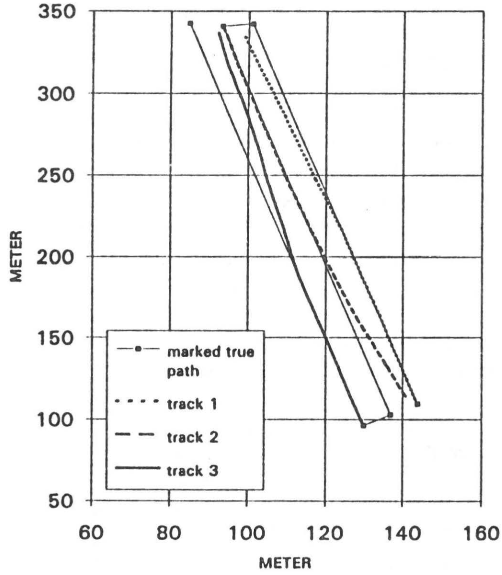

Fig. 5. Example for true and calculated path (speed by radar sensors and direction by piezoelectric vibratory gyroscope).

influence, are necessary further. The best results we got by means of the fluxgate compass (Fig. 6), because it gives a stable signal when the tractor goes straight on. It seems that a combination of compass and the radar sensor is already sufficient for averaging and updating the position and the path during GPS drop outs. The combination with the piezoelectric vibratory gyroscope gives the possibility for compensation of the local deviations and temporal changes of the external magnetic field caused by geophysical conditions or produced by vehicles, iron constructions, electric cables, etc. Therefore, a parallel evaluation of compass and gyroscope increases accuracy and could be the preferable solution.

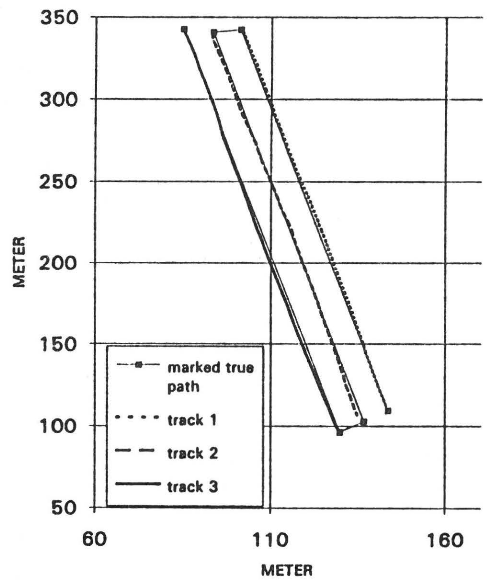

Fig. 6. Example for true and calculated path (speed by radar sensors and direction by fluxgate compass).

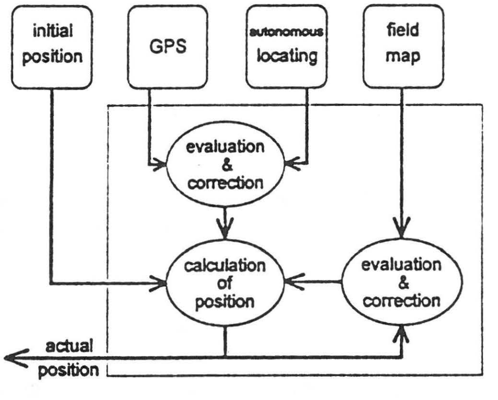

Fig. 7. Scheme for the principle algorithm of navigation computing.

THE PRINCIPLES FOR NAVIGATION COMPUTING

In Fig. 7 the principle for the evaluation of the collected data is shown. The farmer starts the system at the beginning of the field-work at a marked position or by accumulation of GPS data. This gives the initial position in the field map. Then in parallel GPS and sensor calculated positions and position differences are compared with the actual position and direction of motion. The new corrected position is stored after checking of reliability of the measured and calculated position in connection with the comparison regarding map borders and orientation of tracking lines. Then the change in direction is used or corrected during the next cycle of position calculation. Although the general algorithm is simple there are several problems to be solved. The criterion for the comparison and correction of the raw data must be defined and tested. Rules and objects for the classification and comparison with the data of the field map are necessary. One main problem still seems to be the coupling with geographical software for real time positioning at field conditions and low price computers.

REFERENCES

1. **Auernhammer H., Muhr T.**: GPS in a basic rule for environment protection in agriculture. Automated agriculture for the 21st century. ASAE Symp., Chicago, 394-402, 1991.
2. **Beuche H., Hellebrand H.J.**: Ortung in der Landwirtschaft-Ansätze für eine praxisorientierte Ortungslösung zur teilschlagspezifischen Bewirtschaftung. Landtechnik, 48, 4, 195-198, 1993.
3. **Muhr T., Auernhammer H.**: Technische Möglichkeiten zur Ortung landwirtschaftlicher Fahrzeuge im Feld. Ortung und Navigation landwirtschaftlicher Fahrzeuge, VDI/MEG Kolloq. Agrartechnik, Weihenstephan, 14, 49-56, 1992.
4. **Reitz P.**: Ertragskartierung-Technische Einrichtungen für den Mähdrescher. Landtechnik, 47, 6, 273-276, 1992.
5. **Schueller J.K., Borgelt S., Wild K.**: Ortung und Navigation in der Landwirtschaft der USA - Stand und Ausblick. Ortung und Navigation landwirtschaftlicher Fahrzeuge. VDI/MEG Kolloq. Agrartechnik, Weihenstephan, 14, 183-190, 1992.