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DEAD RECKONING AS BACKUP FOR DGPS-SYSTEMS IN AGRICULTURE

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Summary:

In Fall 1994 intensive tests were conducted on the accuracy of DGPS. Several dead reckoning systems were examined their suitabbility to provide DGPS-Systems with the necessary backup in situations of poor signal reception conditions. An automatic Laser based tracking system was used for reference.

Keywords:

Positioning, GPS global positioning system, data collection, precision farming, dead reckoning

Dead Reckoning as Backup for DGPS in Agriculture

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Abstract

Precision Farming is requiring reliable and precise position data. Although GPS during the last years proved already ist reliability in unobstructed areas, the availability and accuracy of the system is often subject to degradation in typical agricultural applications, e.g. while passing by forests and travelling on steep hills.

As automated application systems are being introduced to the precision farming market, tha availability of accurate position data becomes a matter of safety. Therefore backup systems for DGPS are needed, which are both affordable and reliable enough for the agricultural use.

In Fall 1994 intensive tests were conducted to check for possible solutions: mechanical and fibre optical gyros, magnetic compasses and combined subsystems in combination with several DGPS systems (both real-time and post-processing).

Post-processing and real-time is usually delivering accuracies within 1-5 m. This is at the same time the accuracy, many of the GPS receiver manufacturer are specifying for their code based pseudorange correction DGPS equipment. The tested dead reckoning systems are subject to an increasing error over the travelled distance. Despite this typical characteristic these systems could maintain the DGPS accuracy while the typical turn manouvers near the borderline of the forest. Thus these systems help to overcome the problems in reliabylity and safety of DGPS under these circumstances.

Further research work is necessary in order to optimize hardware and software for agricultural applications. As son as fibre optical gyros are becoming available on the market they should be considered as an further enhancement for their higher environmental resistance, for their smaller size and the lower power requirements.

Introduction

The use of DGPS for post-processing and real-time applications in automated field data acquisition became over the past two years a widely used standard procedure throughout the GIS industry. Also in the field of precision farming these systems allow for the automated and georeferenced collection of important input data such as yield- and soil-mapping.

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As soon as one is starting with application work based on this georeferenced data the availability of positional information becomes crucial for the safety of the operator, the environment and the machine itself. While in the evaluation process of data like local yield or soil nutrient content in general geostatistical methods are applied, which allow in a certain extent position data to be missing without loosing essential information, the application process needs continued position information in order to provide the correct realization of the control map.

So far there was no research work published which focused on the availability and accuracy of DGPS in a typical field work situation. Furthermore there could not be found any publication about tests of DGPS versus a precise tracking device fur such applications. The following paper presents also first time results on integrated low cost dead-reckoning techniques with DGPS for agricultural application.

Objectives

It was the aim to test DGPS for the availability and accuracy in a typical situation for a mixed forest and arable land situation.

A independent reference system should be able to test for the absolute accuracy of DGPS rather than to perform a repeatability test only. Precision farming will pay off only if a certain spot can also be relocated several years after the first survey. Usually tests are showing only the maximum cross deviation after several repeated runs over the same testcourse.

The areas of the influence near a forest line on signal availability and the degree of the deterioration of the position accuracy should be determined. Additionally we were looking for receiver specific signal reacquisition characteristics.

Finally the test of low-cost backup systems for the DGPS-System was a topic of the research work. The accuracy of an integrated DGPS / Dead-reckoning prototype system was of specific interest. Such a system should be tested against a reference Dead-reckoning system, too

Materials and Methods

In order to test for the availability, accuracy and the reacquisition of GPS-Signals the test field had to provide restrictive properties with respect to the open view for satellites in a good geometric constellation.

Fig.1 shows the aerial view of the test site with the test course as an overlay. Three sides of the field were thus surrounded by forest (coniferes and deciduous trees). The height of the trees was approx. 20-30 m and the headlands were mostly already below the canopy of the trees. The shape of the test course was simulating a typical tramline oriented application job like spreading fertilizer.

A laser based tracking device was used in order to obtain the vehicle's relative position to the position of the device itself. The device consists of a pulsed laser / receiver installed on a theodolite mount with a motorized drive. Once the unit is manually oriented towards a prism on a vehicle and it started to receive the reflected signal it is able to automatically track the prism when the vehicle is moving. The laser tracker is able to output range and angular information with a frequency of up to 10 Hz. Devices like that one used in the test usually achieve accuracies in the decimeter level for three dimensional coordinates of targets which are up to 10 km away for the station. The typical application for laser trackers is the survey of instrument landing systems (ILS) by tracking an aircraft while on an automatic approach.

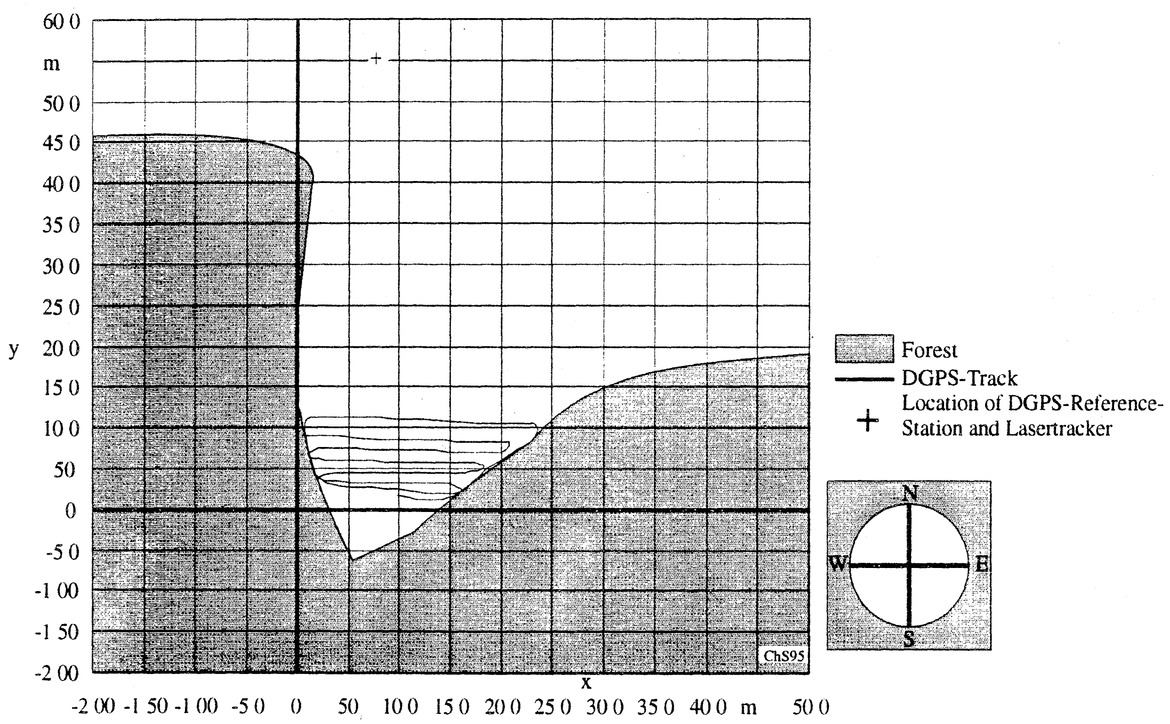

Figure 1: Local situation at the test site.

Several DGPS-Systems (6 types of 5 brands) were used in real-time and postprocessing. Two different reference stations were transmitting RTCM correction-signals over UHF Telemetry, one of which collected also data to be used in the postprocessing process.

An 3-axle mechanical gyro system integrated with real-time DGPS (Attitude Heading Reference System AHRS) was run in parallel. This system is designed for high precision aerial-photography.

An electronic compass module and a two axle mechanical gyro system, the heading axle of which was stabilized by another electronic compass module were installed to test lower cost alternatives to the AHRS.

The vehicle used was a four wheel driven tractor with suspension for both axles. The loading area in the back carried the batteries, the AHRS and the mast carrying the prism for the laser tracker.

The GPS and Datalogging equipment was installed in the cab. Incremental Angle Encoder (Resolution 720 Pulses / Revolution) were installed on both wheels of the rear axle, to provide the installation with a high resolution odometer signal.

All the data streams on board of the vehicle were recorded on several PC-based serial Data-loggers, except for the wheel sensors the digital signals of which had to be captured by a digital I/O card. Timestamping generally was done by using UTC-time which was generated by GPS receivers. To reduce the number of PC's involved in the data logging process multi-channel serial interface cards with local processors and memory were used.

Separate PCs logged the data streams of the laser tracker (timestamped to UTC by a separate GPS-Receiver) and of the GPS data for postprocessing.

Position data have been analysed by plotting and controlling the tractor's traces.

Results

DGPS without any Backup shows typical outliers, if receiver internal filter algorithms are disabled (Fig. 2). The position determination close to the forestline is not reliable, because of the intermitting reception of GPS-Signals in geometrically bad (i.e. high DOPs) satellite configurations.

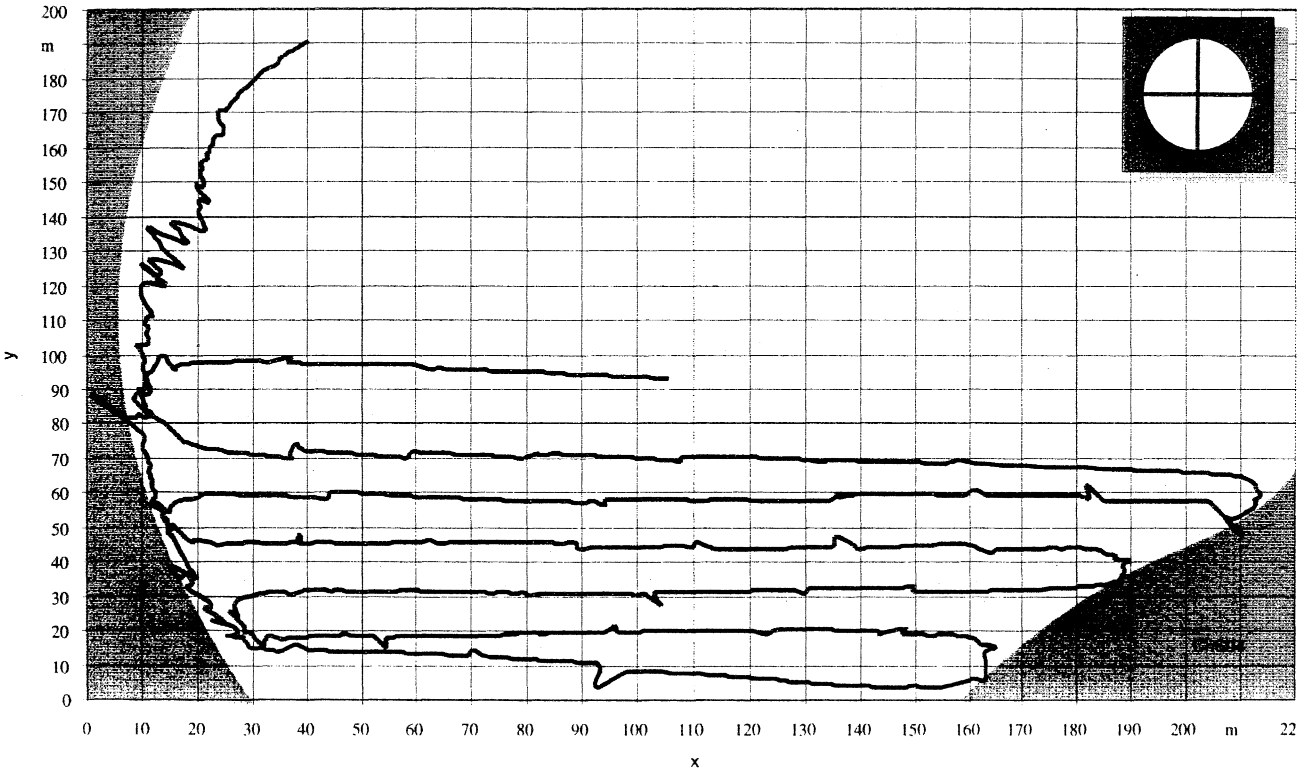

Figure 2: DGPS track of the test course

The simpliest approach to check the DGPS system for accuracy is by using the wheel sensors to determine the actual speed of the vehicle. In order to achieve an optimal calibration value for the effective wheel circumference during the test, an averaging procedure over several sections of the test course resulted in a Resolution of 472 pulses per m travelled distance. Fig. 3 clarifies the problem of using the wheels for generating the odometer data: The surface of the field was wet and slippery. Although the tractor had no pulling work to do and the driver maintained an almost constant (except for turns) number of revolutions per minute of the engine, the oscillating graph for the speed signal is proving a significant amount of slip. The GPS speed signal is much smoother. This is however mainly due to the effect that the GPVTG Sequence (according to the NMEA0183) was used, which usually is being averaged already in the receiver.

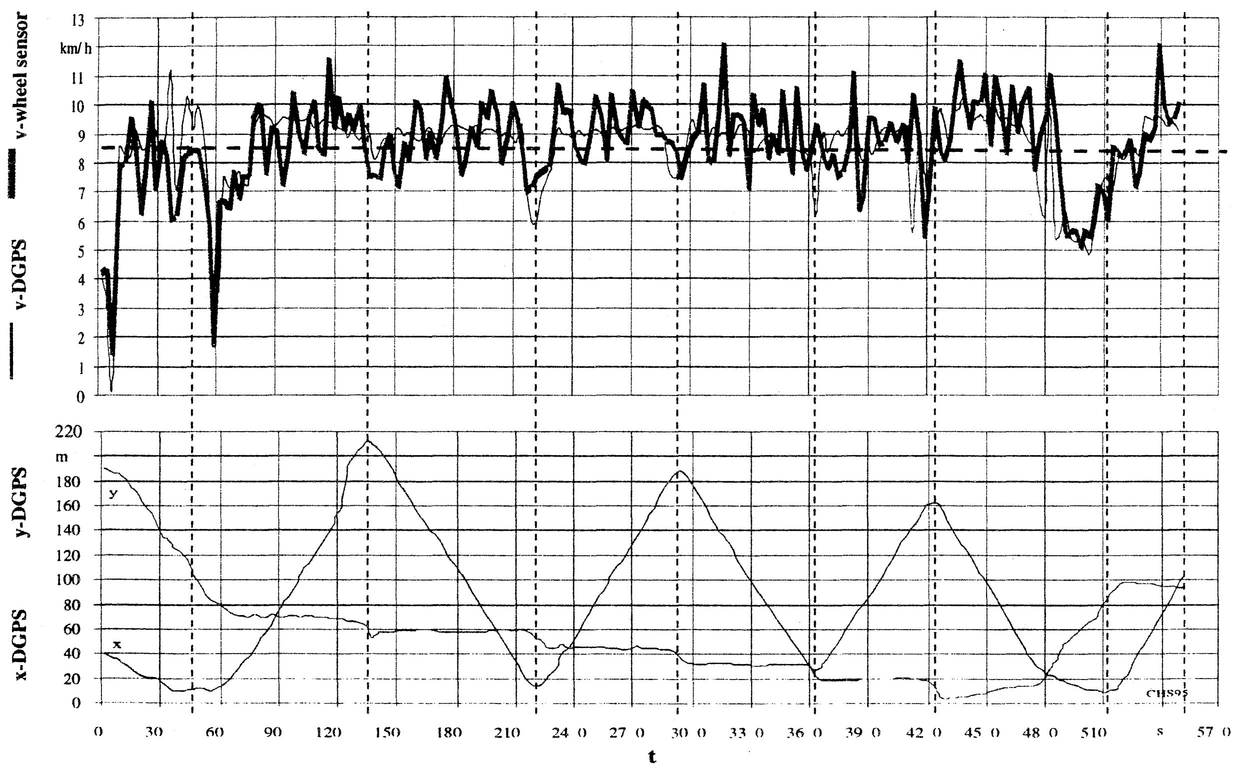

Figure 3: Comparison between speed signals coming from DGPS and wheel sensors.

To set up a working dead-reckoning system it is important to have also sensor systems installed which can deliver heading information. In principle the actual heading of the vehicle could also be derived from the wheel sensor by applying planimetric algorithms to the odometer information which then would have to be observed separately for the left and the right side of the vehicle. Earlier research work showed, that even under more optimal roadway conditions the achievable accuracy is not better than 30-40 m per minute. As a consequence of these results the actual tests were based on magnetic compass information. Because of the magnetic hostile environment of tractors and the generally heavy steel structures of agricultural equipment an absolute calibration of the magnetic compasses was not considered to be appropriate. The calibration was therefore done by the use of the GPVTG (according NMEA0183) String of the DGPS-Reciever. The application gyros helps to get rid off the magnetic problems, too: Under good DGPS reception conditions the heading information of the DGPS-System can be used to recalibrate the gyro's actual position. One of the tested systems used a magnetic compass for the stabilization of the gyro: Although being a very inexpensive this seems not to be a reliable backup in this kind of magnetic environment. Fig. 4 compares the different sources for deriving heading information in our tests.

The integration of the magnetic compass and the wheel sensors with DGPS (Fig. 5) shows how even a relatively simple and inexpensive approach helps to maintain the accuracy of a typical DGPS-System in absence of reliable GPS-Signals.

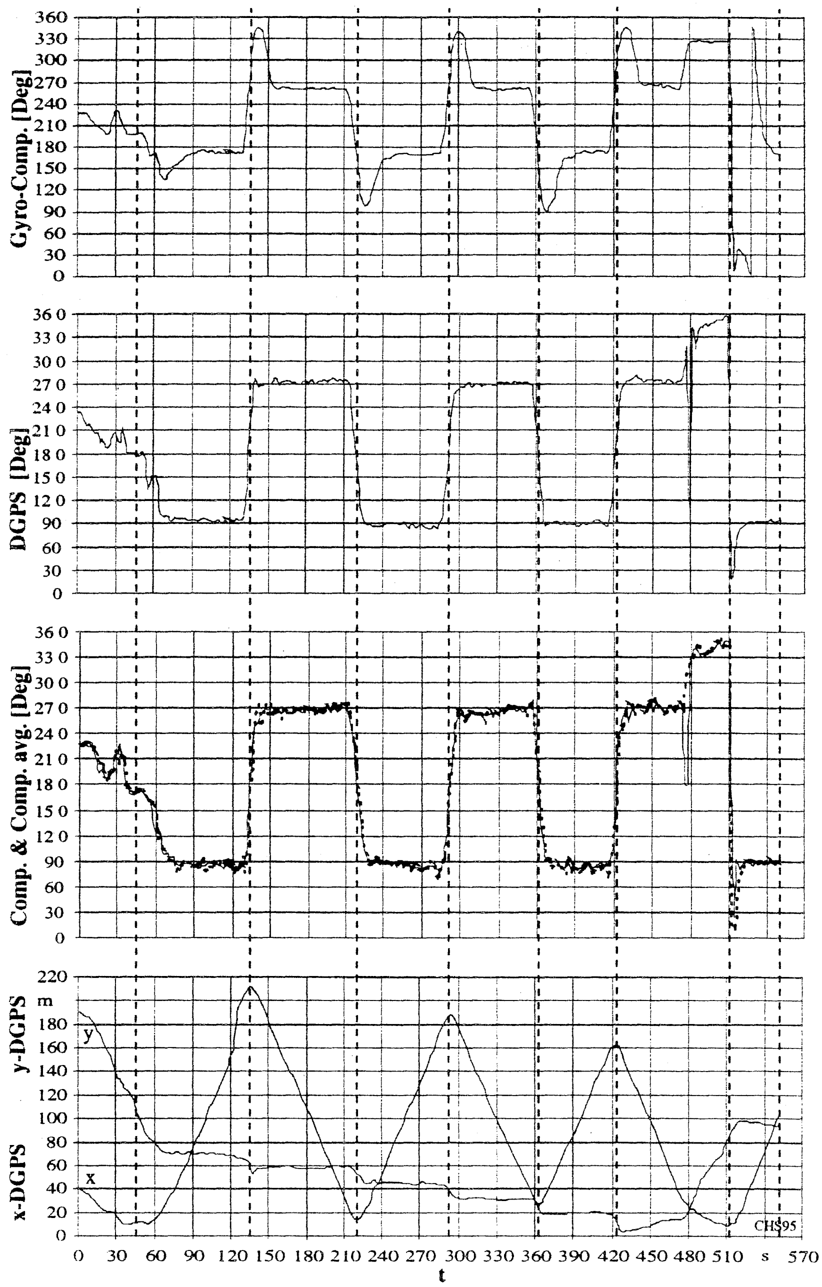

Figure 4: Comparison of different methods for heading determination

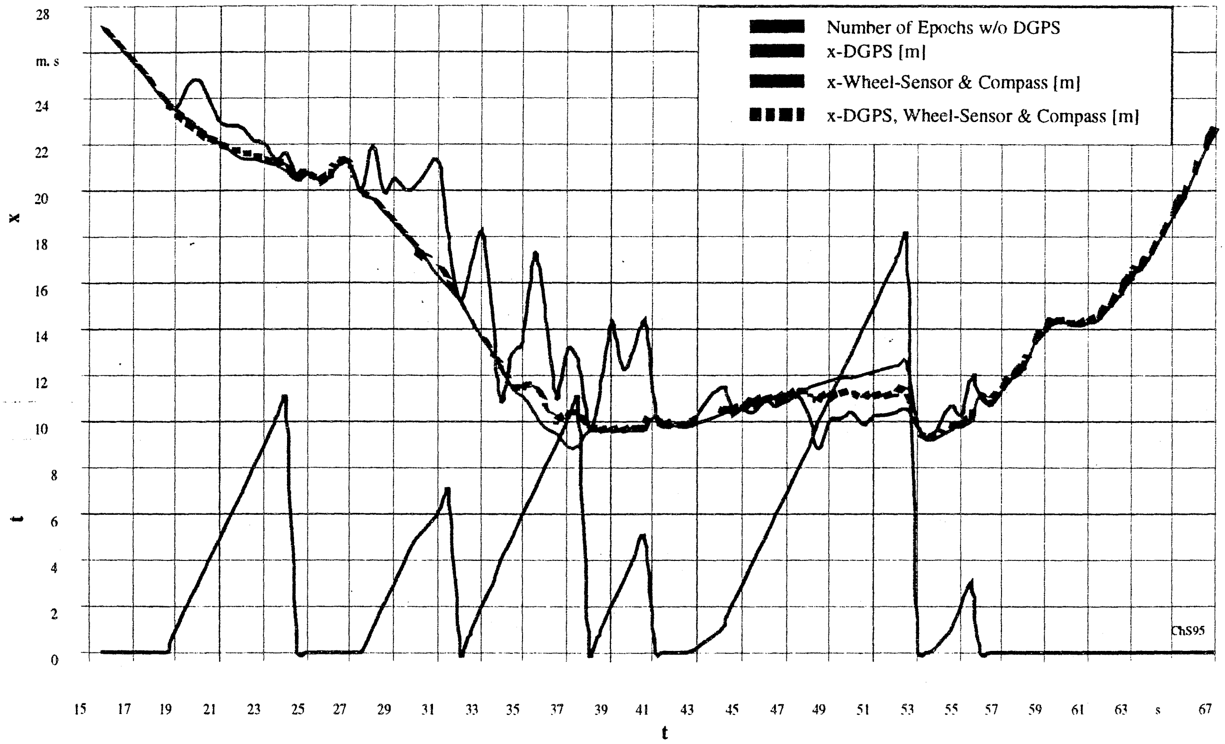

Figure 5: Dead-reckoning in the absence of reliable DGPS-information.

The use of a laser tracking device made for the first time possible to get precise information about the absolute accuracy of different positioning systems. Although the laser tracker was in operation for all of the test runs at this time only the accuracy of one real-time DGPS-system could be evaluated this way (Fig. 6).

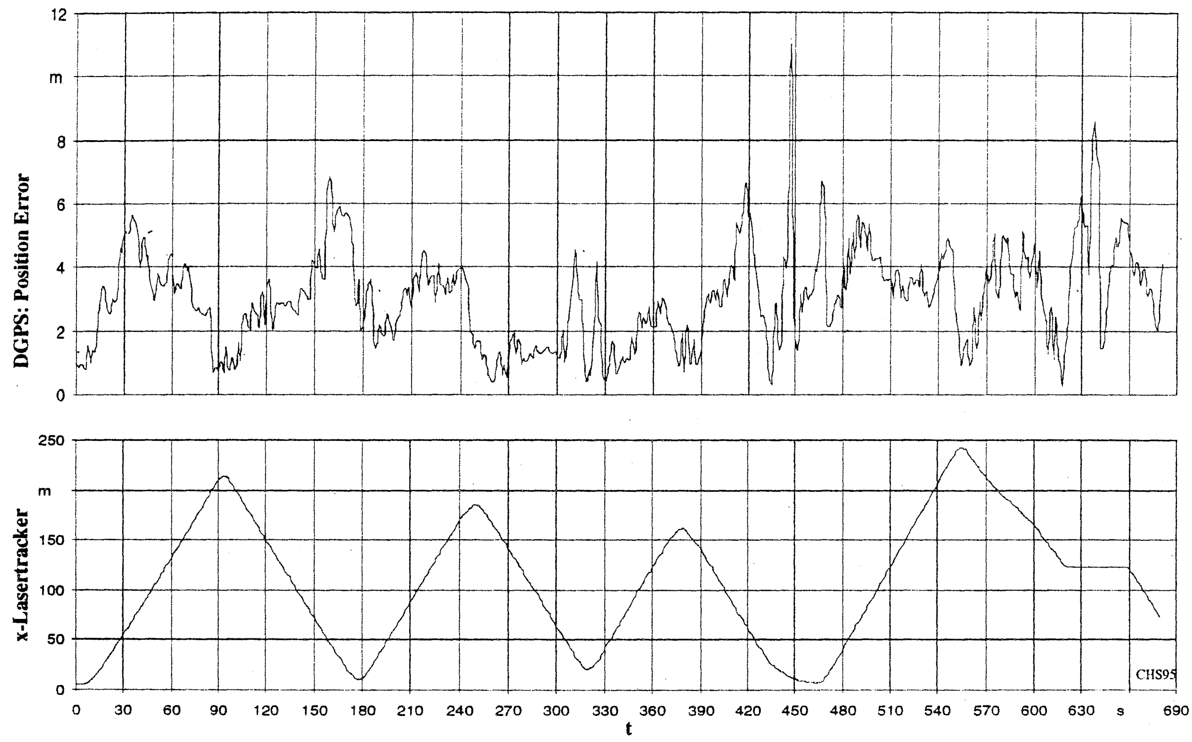

Figure 6: Error in Position of a real-time DGPS System vs. Lasertracker

Conclusions

- DGPS derived positions are subject to a significant deterioration while travelling close to a forest.

- The maximal deviations are then even in the presence of differential corrections up to 30 m.

- Forests are impacting the accuracy within a distance of one time the tree height during approach and two to three times the tree height during the departure form the forest line.

- Although electronic compasses can not be calibrated absolutely because of the magnetic distortions close to typical agricultural equipment, the integration with wheel sensors and DGPS allows for an inexpensive backup system. The accuracy of DGPS can be maintained for approx. 30 s.

- The Laser tracker proved the accuracy of real-time DGPS to be within the 1-5 m range.

- Fibre optical gyros should be considered as a further possibility to get precise heading information in the absence of GPS. Today these systems are not available in big numbers and at reasonable prices.

- Further research work needs to be done on Hard- and Software integration for dead reckoning applications with DGPS.

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