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Optimization Potential for Field Experiments through Automatic Vehicle Guidance

Designing parcel experiment structures for field experiments is labour and time consuming. By planning parcel experiments on the PC, labour requirements are reduced considerably. Furthermore, information available from other PC applications can be incorporated. Digital planning data are the basis for automating the experimental facility. On the one hand they can be used to guide the tractor with the plot drill using automatic steering systems. On the other hand, starting seeding at the beginning of a parcel can be triggered by the electronic control system.

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Not only plant or animal production are under continuing pressure to reduce costs. Also agricultural research faces these necessities. Against the background of the difficult financial situation of the state this situation especially affects public researchers. Staff reduction is the result. To save efficient and independent field experimentation, the Bavarian State Research Center for Plant Production started in 1998 together with the company GEOTEC to optimize field research by the use of automatic vehicle guidance with GPS. The aim was to avoid the time consuming manual measuring and marking of parcel experiments by an electronic planning tool, to realize the electronic plan with an automatically guided vehicle and to substitute the driver of the vehicle [1]. Despite a huge commitment for development and testing of a first prototype the system with the name AGRONAV could not be completed and established because the manufacturer backed out of the market.

System requirements for automatic vehicle guidance in field experiments

Against the background of the experiences with the automated vehicle guidance in the years 1998 until 2001 and the expected future personnel developments and encouraged by the technical progress of automated steering systems for agricultural vehicles [2], the Bavarian State Research Center for Agriculture decided in 2004 to continue the integration of this technology into field research. A first step was the definition of a requirement specification for such a system. It built up on the requirement list from 1988. Aim of the use of an automatic vehicle guidance system in field research is to avoid the time consuming manual measuring and marking of parcel experiments, the increase of accuracy of the seeding of parcels and the trouble free and secure holding of identical positions in fixed parcel experiments.

After generating a plan for the structure of the field experiment with a computer program, the system on the vehicle must be able to load the control file and to realize the plan exactly. The required accuracy must be better ± 5 cm. It should be possible to install the system on tractors with engine rates of 40 to 60 kW (wheel base = parcel width = 150 cm). For some reasons it seems that in future standard tractors will be used for field experiments instead of special tool carriers. The requirement to run the system without a driver was withdrawn. Absolute requirements are the possibility to control a parcel drill (automatic opening of the seed hopper at the beginning of the parcel) and to control parcel fertilizer applicators according to the amount of fertilizer calculated for the parcels. All tracks and actions of the system must be documented. It must be possible to use the plans and the control files of the parcel experiments identical or with modifications, at the same location or at another place again and again.

System selection and configuration

Based on the requirement specification, all automatic guidance systems available on the market in 2004 have been evaluated. Especially the criteria “availability for a tractor with 40 to 60 kW,” “open interface to import data from an external planning program” and “possibility to control an implement (drill, fertilizer distributor, sprayer) with the same system” proved to be critical. At that moment only the automatic guidance system Trimble Autopilot together with the board computer Trimble AgGPS 170 could fulfil these requirements.

The demanded accuracy (± 2 to 3 cm) makes a real time kinematic differential GPS (RTK DGPS) positioning system with sensors to compensate the motions of the tractor like yawing, pitching and rolling necessary.

The guidance system was installed on a tractor with 50 kW engine rate and mechanical front wheel drive (manufacturer Deutz-Fahr). Because of the small volume of the steering cylinder, a modification of the solenoid steering valve was necessary. The GPS antenna and the radio antenna were mounted on the roof of the tractor. The navigation controller with the inertia and inclination

Fig. 1: Tractor with plot drill during automated seeding

sensors was installed in the cab behind the driver's seat. The board computer was mounted on the right hand of the driver.

The parcel drill (manufacturer Wintersteiger-Hege) was equipped with an electric solenoid actuator to empty the hopper reservoir for seed at the beginning of each parcel (*Fig. 2*). This solenoid actuator is activated by a relay which is controlled by an output from the Trimble AgGPS 170. Engage time and engage duration is stored with its geo-reference in the control file.

Software for geo-referenced planning of plot trials

As mentioned before, the planning program is an essential element of the system "automatic vehicle guidance in field research". It integrates all information of a field experiment, transfers it to a geo-referenced structure and makes it available for the guidance system on the tractor. Despite it's complexity it must be easy to use for agricultural technicians.

Since such a product wasn't available on the market, a development request was given to geo-konzept gmbh after functional specifications have been defined. Geo-konzept used the platform of a self developed GIS named "MiniGIS" for the development of the application.

The planning program, which meanwhile is available in an improved version, is able to integrate data of parcel trials from the data base program PIAF which is used all over Germany to administrate information of agricultural field experiments. PIAF data have to be amended by the dimensions of the plots (length, width, way width) and the location of the experiment in the field. With this information the program automatically generates the control file for the automatic guidance system. If there are no data available from PIAF, the experimenter has the possibility to enter the number of columns and rows together with the dimensions (length, width, way width) and to place generated structure on the screen. Then the program generates the control file. Like in most GIS programs aerial photos or digital maps can be imported and displayed.

If it turned out that the position of the plot trial in the field is incorrect, the whole parcel structure can be displaced and/or rotated. The modified position is recorded in a documentation file.

First experiences with the developed system

First tests have been conducted in summer 2005. The automatic steering system was adapted to the uncommon dimensions of the tractor (short wheel base, small volume of steering cylinder). Since the planning software was not available at this time the control file for a simple parcel trial was created using an available GIS program. Utilizing this control file the parcel trial was established several times. Measurements showed an accuracy of the tractor traces of $< \pm 2$ cm. After some optimisation of the forerun and delay time, the trigger time of the plot drill and the resulting start of seeding at the beginning of each plot reached an accuracy of $\pm$ 10 cm.

The planning software was available in spring 2006 and fulfilled most functional requirements. But it turned out that the handling was complicated. In a revision this problem should be solved.

In summer 2006 the whole system will be intensively tested for seeding several parcel trials at three locations near Freising.

Future prospects – further developments

During the last year the Institute for Agricultural Engineering, Farm Buildings and Environmental Technology of the Bavarian State Research Center for Agriculture developed and successfully tested an exact fertilizer distributor for field experiments. The box applicator with electrically driven and electronically controlled fluted roller feed mechanism is mounted on a light, also electrically driven carriage. In future the fertilizer distributor will also be produced in a version to be mounted at a tractor three point linkage. In this version the electronic controller will be able to communicate with the computer of the automatic guidance system. During fertilizer application with automatic steering this communication will make it possible to automatically control the differing amounts of fertilizer for each parcel according to the information stored in the control file. Similar to seeding, where the board computer AgGPS 170 controls the trigger solenoid, for fertilizer application the computer transmits the application rate of each parcel the tractor runs in to he controller of the distributor. Again this will make field experiments easier, saver and more accurate.

Fig. 2: Seed hopper with lifting magnet

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