Stefan Kübler, Winfried Fechner, Karlheinz Wendt and Peter Pickel, Halle (Saale)

Development of Agricultural Simulation Software

The main focus of process engineering in agriculture has always been solving operational problems in agronomy and in animal production, but mostly targeted on finding a single solution for a single problem. By measuring partial times and computing them, solution variants were established, although mostly only after purchasing the machines and implements. Or the solutions only applied to certain constellations. Through simulating agricultural operational processes, multifarious procedures can be tested for their suitability under real conditions: with no costly field measurements and within a short period of time, or non-existent machines and implements can be virtually created and can serve as future design goals for the farm machinery industry.

Dipl.-Ing. agr. Stefan Kübler, Dipl.-Ing. Winfried Fechner and Dr. rer. nat. Karlheinz Wendt are scientists and Prof. Dr.-Ing. Peter Pickel is chairman of the Institute of Agricultural Engineering and Land Use Management, Ludwig-Wucherer-Str. 81, 06108 Halle (Saale), Germany ;
e-mail: *kuebler@landw.uni-halle.de*

Keywords

Simulation, field farming processes

Today, computer simulation is a standard procedure to assess processes in the manufacturing industry. In agriculture, however, time consuming on-site experiments are still the prevalent, though increasingly outdated approach. Also, no simulation software for agricultural processes exists. Thus, a need to quickly find feasible solutions for problems in agricultural processes led us to develop such a simulation software.

To expedite our work we first reviewed existing process engineering software to check if it can be used for our purposes. We found the modular software package "Simpro", which is used in car assembly, to be a good basis. However, after applying Simpro to some simple cases, it became obvious that it cannot be applied directly to most problems in agriculture, because it (and all other existing process engineering software) lacks the spatial aspect present in farming.

Hence, our prime task was the development of an area module, later followed by modules for other objectives, which can be incorporated into the existing Simpro software package. In this paper the current state of development, the verification of and first results obtained with the new simulation tools are presented.

Advantages of simulation

The effective use of existing or new machinery and implements resulting in highly efficient farming processes is a prerequisite to stay competitive in today's farming environment. There is room for improvement in the efficiency of most machines and processes. Once weaknesses are identified and corrected, significant increases in output can result. For maximum gain, the whole process must be analysed, e. g. in crop production all steps from seeding to harvest, including soil tillage.

At present, with time-consuming field trials being the prevalent mode to evaluate a process, usually only a particular problem, e. g. the most effective travelling speed for a harvester, rather than a complete farming process is looked at. Consequently, a solution is obtained only for this problem, while other aspects, e. g. seeding or soil tillage, are

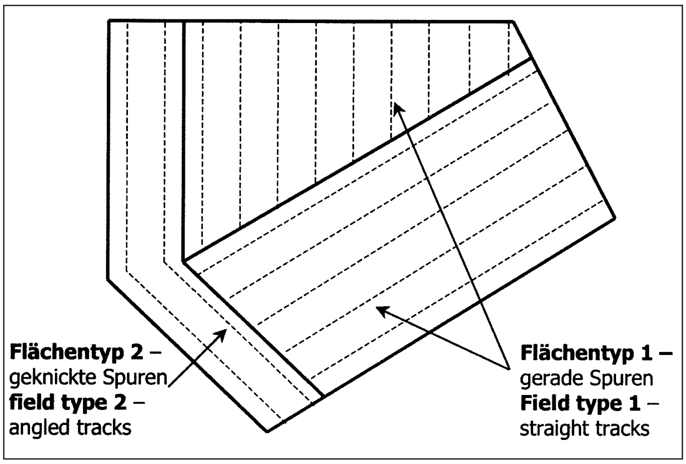

Fig. 1: Part-field with driving tracks and lands

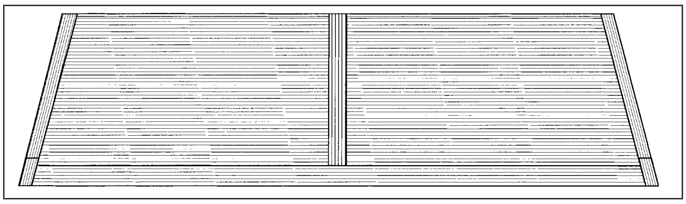

Fig. 2: Scheme of the sugar beet field investigated

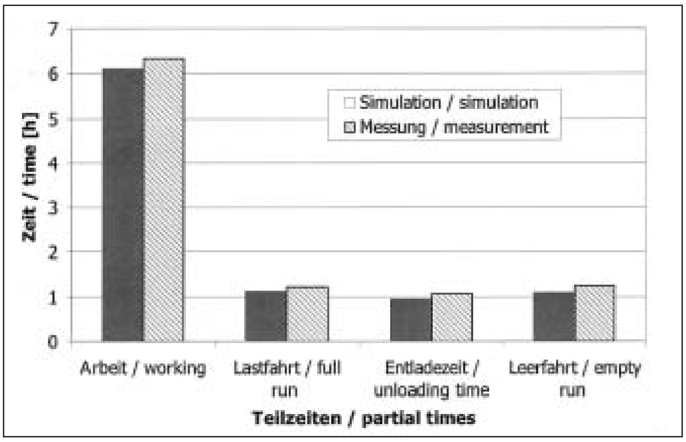

Fig. 3: Comparing measured and simulated results for various partial times

not considered. Field trials have the additional problem that the conditions during an experiment are often unique and cannot be reproduced, e. g. temperature, straw moisture content or yield in the case of wheat harvest. Thus, a field comparison of combine harvesters can only tell, which one works best under the site conditions during the trials. A repetition on the next day may already lead to different results due to changed site conditions. In addition, fields are not homogeneous, so that it is virtually impossible to expose different machines to the same conditions even on the same day. Apart from saving time, this is where computer simulation comes to the fore: one can harvest or otherwise work a field an unlimited number of times. It also makes it possible to look at different machinery and processes under the same site conditions.

Furthermore, in contrast to a simple calculation (e. g. in MS Excel®), a simulation run can react to an occurring event, i.e. an event can change the course of the simulation. Hence, the principle of a simulation is that working machines and transport vehicles experience certain conditions and then react accordingly (e. g. if full, then unload). A change in conditions can be brought about by own actions (e. g. harvesting) or the actions of other machinery (e. g. loading) during the simulation run.

Area module

Our simulation software is based on a databank (MS Access®) and an associated programme, which steers and visualises the simulation. Its fundamental new feature is the possibility to generate areas in the databank. The areas can be subdivided into sections, including special ones such as turning areas or obstacles. Furthermore, tracks for the working machines are delineated in each area or section. There are two methods to do this, which leads to two field types. In field type 1, the tracks are delineated by the programme as straight lines parallel to the one connecting the two corner points entered first for the field in question. In field type 2, a series of points is specified and parallel tracks are then drawn by the computer according to the course of the points, resulting in angled tracks. The latter allow the machinery to go around obstacles or to follow irregular field boundaries. In both methods the distance between individual tracks (i. e. the working width) is specified by the user. *Figure 1* shows a subdivided field with the two field types.

Simulation - weightings, priorities and track concept

In principle a simulation run can be started and then left to proceed without further intervention by the user. In this case the tracks taken by the machinery are selected by the programme and depend on the parameters specified for the machinery, e. g. turning radius. However, our software also provides possibilities for the user to influence the course of the machinery. He can set priorities concerning the order

- in which to work the sections of a field and
- in which to work the tracks in a section.

Note that more than one section or track can have the same priority. To decide which one to process first then, weighting factors are introduced for

- the direction a track should be entered from,
- the time required to get to the next track and
- the harvest status of the track on the left side of the machinery (already harvested or not).

With the help of these priorities and weightings, some guidance of the machinery can be achieved, but one cannot determine the precise course.

Working machines are parameterised by their working width, tanker volume, loading and unloading capacity as well as working and travelling speed. Transport vehicles are separated into two types: type I (active) includes all those able to move freely inside and outside the field, e. g. a tractor with a trailer. Type II (passive) is not a transport vehicle at all, but rather a temporary storage clamp, e. g. for sugar beets.

It is worth mentioning that in our software the machinery moves, while the object to be processed (i. e. the field) is stationary. In the Simpro software, by contrast, the object to be processed moves, while the machinery is stationary.

Software development - design steps hitherto, verification

For the development of our software we first recorded the individual steps in various whole field processes (e. g. wheat or sugar beet production) from seedbed preparation to harvest and grouped them according to the number of machines involved and the processing pattern. At the same time we devised sensible ways to subdivide a field into part-fields for a particular process.

Then flow diagrams were developed for three types of processes: parallel, dependent and independent. This approach is sufficient to depict most of the common working procedures (as well as some not yet employed but feasible ones) and to serve as a basis for programming simulation runs. To test our algorithms for consistency, simple field shapes, usually triangles or rectangles with the two principle track contours described above, were generated and various field operations simulated under assumed conditions.

Once consistency was established, we used measured data obtained with real machinery and implements on a 30 ha sugar beet field during harvest to verify our software under actual field conditions. *Figure 2* gives a schematic of the field, whose mean length was 1000 m and mean width 300 m. Temporary storage areas were placed in the two lower corners.

To create as realistic an image as possible of the different field operations, the type of work and the necessary machine parameters (speed, tanker size, etc.) were listed and entered into the simulation.

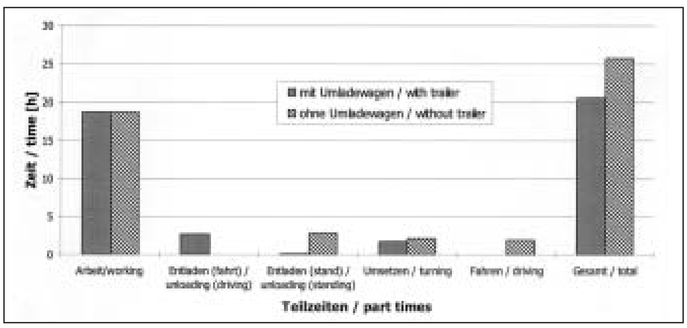

Fig. 4: Comparing key data for the original and for the modified processes

Sugar beet harvest - results of time analyses in the field

Today, sugar beet harvesting in Germany is usually carried out with self-propelled, six row tanker sugar beet harvesters. During harvest time they are usually operated in 2 to 3 shifts to reach an economical annual utilisation of 450 to 750 ha. The harvester may drive to the headlands for unloading, during which it is not in motion. Sometimes a tractor with a dump trailer or, more recently, with a special sugar beet reloading trailer is used to unload the harvester in the field. We made time measurements only for the first option.

A DGPS-receiver was installed on the harvester. Its travel path, i.e. its location (x, y, z) and the associated time, was recorded with a frequency of 1 Hz and stored on an PC. These data can be displayed graphically using an special programme routine, which makes it possible to "virtually" follow the driven path and to assign to individual points or a series of points the task carried out by the machinery at this point, e. g. working or turning. Based on these assignments the partial times can easily be summed up and grouped. The results for the investigated area are shown in *Figure 3*.

Sugar beet harvest - simulation results

For the simulation the field dimensions were measured and entered into the programme. Then the tracks were delineated according to the actual situation in the field. For verification of the software, measured values of working and driving speeds and times for unloading were entered into the model. With these entries the simulated partial times for working, turning, unloading etc. were similar to the observed values (Fig. 3). Hence, they can be applied to analyse the process of sugar beet harvesting in further simulations.

Doing this we found that adding a tractor with a dump trailer to the harvesting process is not effective for the field considered. Due to the length of the plant rows, the travel distances are too long for the trailer to serve the harvester effectively. The time required for a trip to the temporary storage area, unloading and returning to the harvester is greater than the time needed for filling the bunker of the harvester. As a result the harvester has to stop frequently, which is unacceptable.

A second possible modification, namely changing the plant row direction, was no good either, because turning time increases then by 300 %.

A third modification was found to significantly increase the efficiency of the harvesting process. Here the field is divided into two equal halves perpendicular to its longitudinal axis. In addition, one temporary storage area at the field centre replaces the two at the lower corners, so that the driving distances for the tractor and dump trailer combination to the harvester are small. *Figure 4* compares key data for the original and the modified process.