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Algorithmic analysis of transport systems of biomass

Especially the increasing use of biomass as energy resource causes an increasing amount of agricultural transports. The efficiency of the used logistic systems is often low. The presented system analysis is based on the recording of position data during the harvest. The evaluation of the data with specific algorithms shows planning errors in the logistic chains and generates the basic data for a systematic optimization.

Keywords
Agricultural logistics, transport of biomass, modelling, system analysis

Abstract
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Structural changes in German agriculture like a continuously growing average farm size and an increasing use of biomass as a resource for the production of energy cause an increasing amount of agricultural transports. Both upcoming mass flows and transport distances are growing. Apart from that, the energy density of the transported goods is low. Therefore a well-organized transport system is an important component for the economic success in agriculture.

Modern fleet management systems [1] support automatic assignments of work orders to machines and operators and contain navigation applications for agricultural purpose. Furthermore economic systems that enable automatic calculations of provided labor are state of the art [2]. However, reliable planning tools to create optimized harvesting process chains do net yet exist. Therefore the organization of the logistic systems is usually based on empirical knowledge of farmers and contractors.

The analysis of the currently used forms of mechanization is essential for the optimization of agricultural logistic systems. The presented algorithmic efficiency analysis identifies machine parameters of the used vehicles evaluating the position data of all vehicles of a harvesting chain by different algorithms. Additional geographic information about used routes and harvested fields is included in this evaluation. Using this data-base the developed applications first assign a specific operating state to each machine at each point of time. Afterwards process parameters (process time, velocities, proportion of interruption, etc.) can be derived. So, especially performance parameters of competing transporting systems are visible. For example the operational range of trucks for agricultural transports can become clear with this method.

Methods and Algorithms

The algorithmic efficiency analysis of harvesting process chains is divided into the two main parts data recording and data analysis. These two parts are executed separately.

Data recording

The analysis of the logistic systems is based on the collection of position data which are recorded during the harvest. Therefore GPS data loggers are attached to all machines of a regarded process chain. The following data are recorded with a frequency of 1 Hz:

- GPS-time
- Current position (latitude and longitude)
- Altitude
- Velocity
- Additional parameters (GPS quality, course, etc.)

The methodology of the collection of the data is designed in a way that the setup time before the beginning of the measuring is reduced to a minimum. This includes that the used data loggers have internal data storage and batteries which makes it unnecessary to lay cables during the installation. So it is possible to react on short-term shifts of the beginning of the harvest or on changes in the combination of the process chains. Due to the dependence on the weather conditions, similar happenings occur in practice comparatively often.

The installation of additional sensors like ultrasonic sensors on transport trailers to document the loading state of the trailer would certainly give wider information for the analysis of the data. The developed methods to record data should indeed be usable universally and particularly usable at short notice. For that reason no additional parameters are recorded.

Data analysis

At the beginning of the analysis the data have to be tested for their plausibility. Positions errors can be filtered by defining a maximal acceptable change of the position of a vehicle according to its accelerating power. Furthermore time sequences have to be checked on continuity.

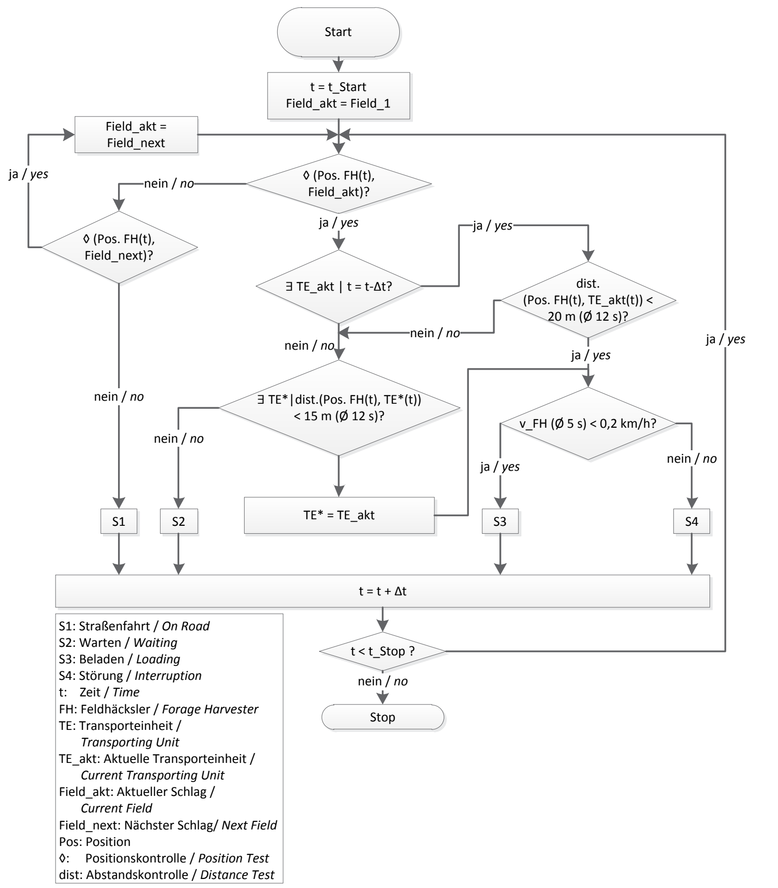
After that the recorded data of the single machines are connected to each other and supplemented with additional parameters about harvested fields. To get characteristic parameters about a process chain like average loading and unloading times, transporting velocities or waiting times on a field, it is first necessary to assign specific jobs to the machines at each point of time. For forage harvesting process chains the application distinguishes between the jobs being on road, loading, waiting at a field, unloading at a silo and interruption. The underlying algorithm for the assignment of the jobs for a forage harvester is illustrated in **Figure 1**. First the algorithm checks if the forage harvester is on a field to be harvested. After that, it decides whether the forage harvester is harvesting, waiting or interrupted using velocities and relative positions of harvester and transporting units. Basically there is a maximum of one unit that can be regarded at the same time as transporting unit to be currently loaded (TE_akt). The conditions that a transporting unit has to fulfill to be identified as unit to be currently loaded are stricter than the conditions that a unit has to fulfill to be regarded as unit to be currently loaded further on in the progress of time. A positive effect of this is that the algorithm does not tend to wrongly identify waiting transporting units, which often drive closely behind the forage harvester, as units to be currently loaded.

A similar algorithm assigns corresponding jobs to the transporting units. The process unloading depends on the distance of the transporter to the silo. The transporter is regarded as being waiting, if it is on the currently harvested field, but is presently not loaded. It is also considered as waiting time if the transporting unit is close to the field and is standing still there. This often occurs at the beginning of a new field. If the transporter is neither on the field nor at the silo it is regarded as being on road. So, if traffic forces the transporting unit to stand still this is seen as part of being on road and not as waiting.

Results

Based on the identification of operating states of all machines during the algorithmic data analysis, various significant parameters of the regarded harvesting process chain can be obtained. It is possible to get information about single vehicles as well as about parameters concerning the complete system. Using a Gantt chart the chronological sequences of the harvesting processes can be identified. The visualization of the percentage of waiting times and interruptions in the whole process reflects the total efficiency of the analyzed logistic system. Regarding

Fig. 1



Flow chart of the assignment of operating conditions for a forage harvester

Fig. 2

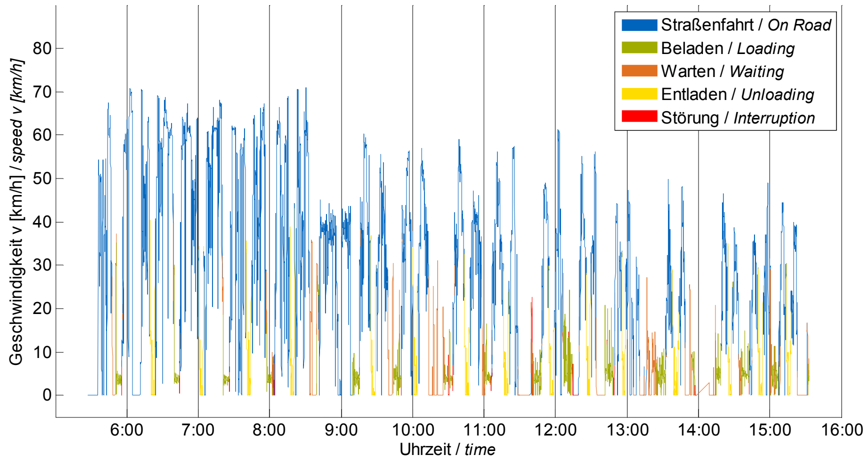
Left: agricultural truck (photo: Agrolohn Agrardienstleistungs GmbH), right: tractor with forage transport trailer

single vehicles, it is for example possible to identify the times spent at the silo of each transporting unit.

Due to the increase of the process outputs of harvesting machines and because of structural changes in German agriculture in the last years, upcoming mass flows and transport distances increase a lot. So the substitution of tractors with trailers by agricultural trucks (**Figure 2**) is not far to seek. Hereafter a closer look on the influences of the use of agricultural trucks on transporting velocities follows.

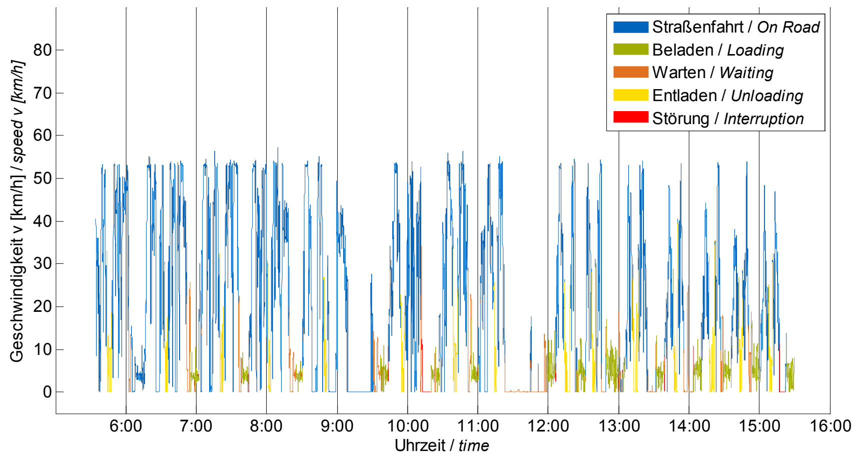
The basic advantages of a truck compared to a tractor are higher maximum velocity, lower fuel consumption and lower empty weight. The measured transporting velocities indicate how far these general advantages have an effect in practical use (**Figure 3** and **4**). In the analyzed harvesting process chain,

Fig. 3



Velocity agricultural truck, silage maize harvest 2011

Fig. 4



Velocity tractor with trailer, silage maize harvest 2011 tractor with trailers and agricultural trucks are used concurrently. Therefore the comparability of both systems is guaranteed. Using the algorithmic assignment of jobs to particular points of time it is possible to regard only the time slices used for transporting processes. On the regarded harvesting day average transporting velocities of 35.3 km/h for the truck and 27.8 km/h for a concurrently used tractor are measured. A closer look shows that the tractor reaches its maximum velocity of about 50 km/h all over the day. In contrast the measured maximum velocities of the truck are in the range of 60 to 70 km/h before the change of the field at about 8:30 a. m. After that it goes down to about 50 km/h. A reflection of the used roads reveals that before 8:30 a. m. wide federal and country roads can be used, where the truck can reach its maximum velocity. The roads that have to be used after the change of the field are in a poorer condition. The comparison of both transporting systems shows that the condition of the roads during the studies has much bigger influence on the maximum velocities of the truck than it has on the velocities of tractors.

Conclusion

To be able to transport biomass as efficiently as possible in the future it is necessary to plan harvesting process chains systematically. Therefore simulation models like the model of Sonnen [3] need appropriate input data. As the simulation of complex real processes goes along by definition with a simplification [4], even if using exact arithmetic operations certain inaccuracies are unavoidable. To minimize these inaccuracies, it is absolutely necessary to be able to draw on exact input data. The analysis of the transporting velocities of trucks and tractors shows that different systems can react very differently on the conditions during the harvest. To optimize these systems methodically, a reliable data basis is a basic requirement. As no single machines but whole transporting systems are analyzed, manufactures' data give sufficient data basis under no circumstances. The presented analysis faces harvesting process chains algorithmically regarding their complete structures. Hence it is possible to detect significant parameters that describe the analyzed systems exactly. Therefore this analysis method can be regarded as part of the systematic optimization of agricultural transporting systems.

Literature

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