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Bulk heap and loading state models for automated parallel loading

In large harvesting machines, the focus is on the minimization of losses during overloading processes as well as the maximum exploitation of machine capacity. Assistance systems for overloading can facilitate work considerably in particular for unexperienced operators. With regard to automated overloading assistance, the computer-based visual monitoring of the loading status proves difficult due to the often adverse agricultural marginal conditions. Therefore, a model-based loading and overloading strategy can play a key role. This paper derives an overview of the software approaches developed during the research project 'model based loading of agricultural trailers', which is promoted by the German Research Foundation.

Keywords
GPS-based position control, spout control, precision overloading, bulk heap software model, loading process model, cooperating machinery

Abstract
Landtechnik 64 (2009), no. 4, pp. 264 - 267, 3 figures, 8 references

Following a common trend in agricultural engineering size and weight of harvesting machines are increasing as well as working width and throughput are rising. The higher demands causes higher financial investments and relative high operating costs of the machinery. To preserve sustainability in harvesting process, large harvesting machines have to be run at:

- the most efficient configuration as possible and
- high amount of operating time per harvesting period.

If the harvesting machine and the transport unit (generally tractors with trailers like in the case of a self-propelled forage harvester) are parallel operated, the quality of the overloading process is another significant value for the assessment of the efficiency of the entire process. Therefore, the attention of the operators must focus on the working process as well as the overloading process. Moreover, machine collisions must absolutely be avoided. This division of attention is even more problematic because long operating times (which often include night-time work) are necessary for optimal capacity exploitation, which wears the operator out even more. Additionally, increasing working velocities as well as larger transportation capacities are intended. ([1] [2])

Assistance system for the overloading of agricultural materials (ASUL)

In order to solve the problems addressed in the introduction, an assistance system for the overloading of agricultural materials based on a self-propelled forage harvester and a tractor was developed at the Institute of Agricultural Machinery and Fluid Power in cooperation with the Institute of Control Engineering of the Technische Universität Braunschweig, Germany. Thanks to the GPS-based determination of the relative position of the self-propelled forage harvester and the tractor, the prototype allows the position of the loading point to be controlled with the aid of the spout actuator. This system reaches a position accuracy of the loading point of 50 cm. The development of the ASUL has been promoted by the German Research Foundation (DFG).

Model based loading control of agricultural crops

Modern harvesting machinery is generally equipped with an increasing number of sensors [3, 4, and 5]. Regarding to [6], the usage of reasonable camera-based sensor systems in agricultural environment is highly limited. But still the consecutive step towards a full automation of the loading process is the enhancement of the ASUL system, so that the loading is processed without interaction of the machine operator. Therefore another research project started in 2007, widening the ASUL System by the usage of throughput related model based loading methods.

Set up of model based loading control

Main components of the model based overloading system are parts of the ASUL-system like the determining of the relative position and the loading point control. The system is being supplemented by throughput-related loading strategies. With a potentiometer the distance between the intake rollers is measured. The throughput volume is forecasted by taking the geometry of the intake channel into account. The trailer can be

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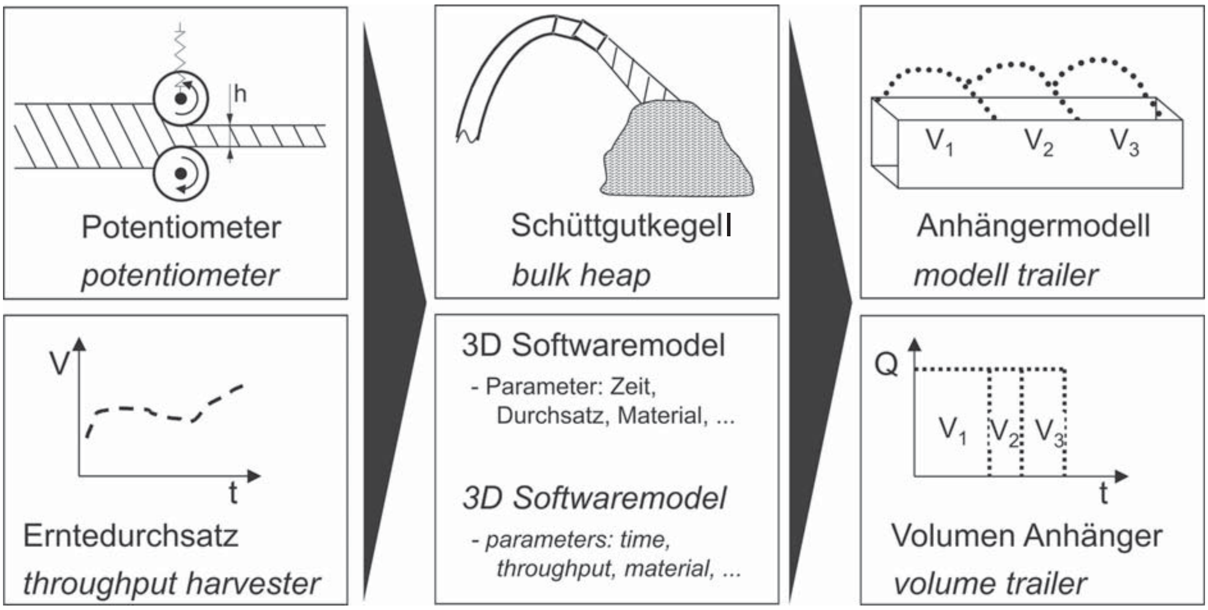
Fig. 1



Set up of model based loading of agricultural trailers

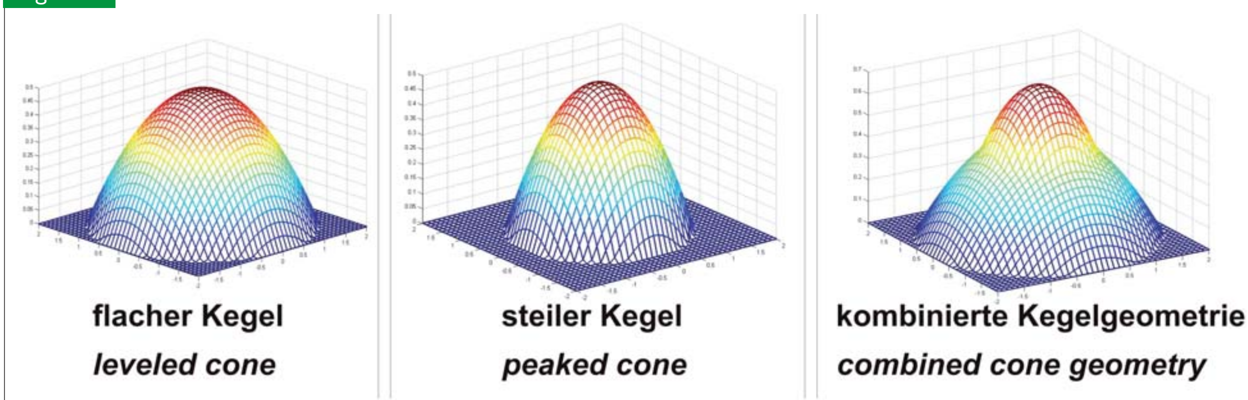
divided into several discrete volume spaces. By generating and achieving loading points the discrete spaces are to be filled up to the maximum load of the trailer. Regarding the throughput and the effective loading position a software model estimates the loading state inside the trailer, until it is filled at maximum rate. **Figure 1** depicts the set up principle.

Suitable models of bulk goods for mobile purposes

Main task in the research project 'model based loading of agricultural trailers' is the development of elementary software models of agricultural bulk goods. Therefore exemplary heaps of silage crops are examined in field trials as references. The all-important parameters which have to be implemented in the software model are the gradients at least in four orientations, the geometrical form of the bulk heaps, the build up process means the temporal alteration of single bulk heaps as well as the interaction of several bulk heaps.

According to Schulze and Landry in [7, 8] and considering the heterogeneity of the agricultural bulk goods, numerical methods – such as discrete element methods or computational fluid dynamics – have been desisted as model approaches for the automated loading. The solving of these approaches necessitates an enormous amount of computing power, which usually is not available on agricultural mobile machinery. During the research several model approaches have been analyzed regarding to the applicability for mobile machinery, whereby one has been elaborated in detail. The bulk heap software model concept is based on an approach using only elementary mathematical 3D functions. These ought to be e.g. hyperboloids, cones or hyperbolic paraboloids. The main advantages of this

Fig. 2



Example for the combination of cone models

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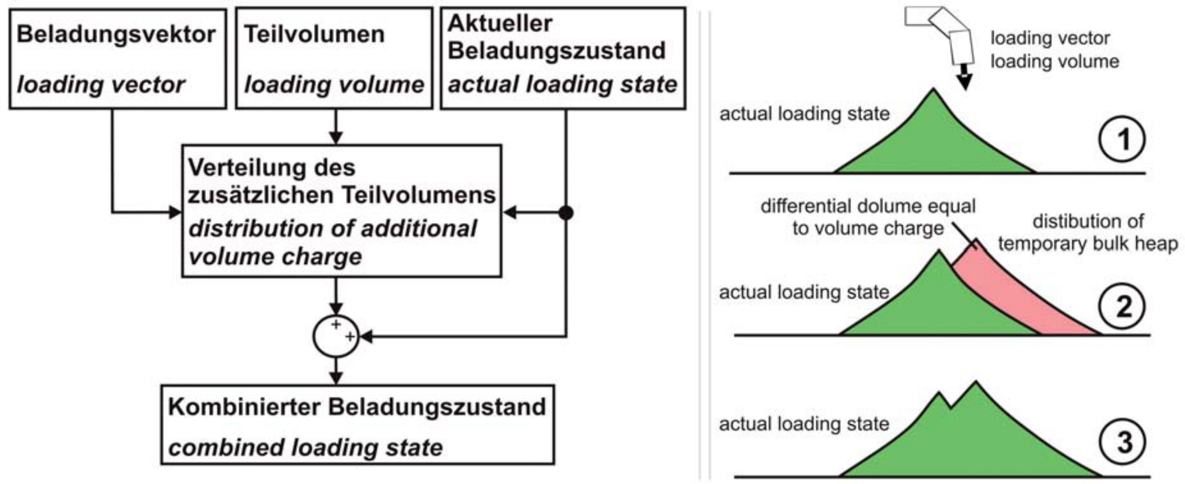
Fig. 3



Definition of the loading state

approach are as follows:

- The inherent functions are all well known and easy to be set up.
- The functions are easy to be implemented and to be varied.
- The functions are uniformly continuous; therefore the computing power as well as the computing time is low.
- The functions are exceedingly qualified to be combined, so that relatively complex geometry (e.g. interacting bulk heaps) can be compiled (**figure 2**).

Loading state definition of agricultural trailers

Besides the definition of the geometry the definition of the temporal loading state – which means the actual loading state during the loading process – is essential for an automated loading. The loading state definition considers the loading state build up, which means the temporal assembly of one heap as well as the interaction between several heaps **(figure 3)**.

By analyzing the orientation of the spout as well as the relative positions of the vehicles the loading vector of the crop stream is calculated. Otherwise a discrete loading volume – the loading charge – is predefined. For the modeling of a new – means actual – loading state the former loading state has to be taken into account, too. With regards to the given 3D-software model and the three parameter inputs the distribution of the additional loading charge can be calculated. The actual loading state as well as the distribution of the additional loading charge is defined via the particular surface in a 2D matrix. The matrix is designed to depict the base of the real transportation unit via predefined increments. The height of the loading state is allocated to every corresponding increment; the total of the particular heights describes the surface of the loading state.

Conclusions

An auxiliary system for loading agricultural goods in parallel process – the ASUL – has been developed at the Technische Universität Braunschweig. During the consecutive research project 'model based loading of agricultural trailers' especial models of bulk heaps and the loading state for agricultural trailers have been developed. These models meet the demands of applicability in state of the art mobile harvesting machinery. Currently field trials including automated loading processes are taking place. Besides the function of the automated loading process, the bulk heaps as well as the loading state models are consecutively verified.

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