Happich, Georg; Lang, Thorsten and Harms, Hans-Heinrich

Modelling agricultural crop for mobile applications

At the current state the performance of self propelled harvesting machines is still being improved. Accordingly the strain for the drivers of harvesting machines and transport units is rising. With the aim to relieve the driver's condition a model based approach has been analysed. The approach enables the automation of the loading process by the model based monitoring of the loading state. Concerning that the partly adverse harvesting conditions reduce the efficiency of computerized vision based monitoring, model based loading might have the ability to play a future key role. This paper derives an overview of the loading model 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, overloading process, bulk heap software model, loading process model, cooperating machinery

Abstract

Landtechnik 65 (2010), no. 6, pp. 460-463, 4 figures, 11 references

There is a trend in agricultural engineering towards increasing power of harvesting machines; working widths as well as throughput are rising. Additionally, this kind of machinery causes higher financial investments and relative high operating costs. To generate a maximum of harvesting profit, harvesting machines – as well as any other high performance machine – have to be run at the most efficient configuration as well as at a high amount of operating time per harvesting period.

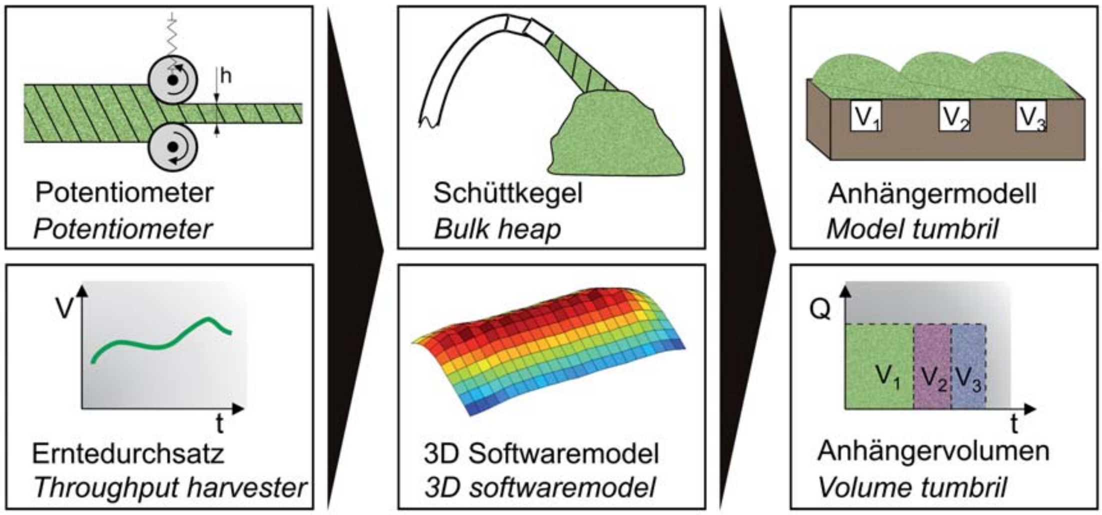
If harvesting and transport are combined in parallel operation, the overloading process is of another particular importance for the efficiency of the whole harvesting process. The working process and the loading process demand the driver's attendance concurrently. Constant vigilance and high concentration is required in order to avoid losses, overfilling or collisions between the vehicles. In Order to optimize the capacity of the machines, harvesting at night is necessary, and the risk of fatigue mistakes is rising. Supplementary the operators are ergonomically stressed, because the increasing size of the transportation units is worsen the visibility of the capacity [1; 2].

Model based loading control for agricultural crops

Continuously the amount of sensors being installed on harvesting machines is rising [3; 4]. Regarding to the automation of the spout control [5; 6] its a consecutive step to extend the current state-of-the-art loading point control by means of the complete automation towards a process which is not attended by the machine operator. According to Graefe [7] reasonable camera-based sensor systems in the agricultural environment are suitable only for a limited extend. Contrary first solutions are launched on the market in 2009 [6; 8]. To meet the demands the Institute of Agricultural Machinery and Fluid Power initiated a research project to develop and analyse the prospects of a throughput related extension of the loading point control. The model based loading system is based on the main components of the previously developed Assistance System for Overloading Agricultural Crops (ASUL); firstly the loading point control, and secondly the calculation of the relative position. The whole functional principle of the model-based loading control is depicted in **figure 1**.

Assuming that the relative position and orientation of the vehicles – self propelled forage harvester and a tractor – and the orientation of the loading spout are known, the calculation of the actual loading point inside the trailer is easily manageable. Using a potentiometer detecting the gap between the intake rollers the volumetric flow of the crops is calculated. A software model uses the given parameters to define the accumulation of the crop in the trailer. By cumulating the crop strategically – by means of different discrete loading spaces – the total volume is filled efficiently.

Fig. 1



Set up of model based loading of agricultural trailers

Suitable bulk heap and loading model

The development of a fundamental agricultural bulk heap model was the first main task during the research project. Therefore referential bulk heaps of agricultural crops had been analyzed, which were carried out in field trials during the harvesting campaigns. The results were used to formulate three rules qualifying the characteristics of bulk heap gradient and the heap formation [9]:

- Regarding the front of the bulk heap, the gradient is less depending on the impact vector than on the material constraints. The bulk heap gradient on the front slope ranges between 31° and 40°.
- On the reverted side of the bulk heap the gradient is influenced on both the material constraints and the impact vector. Whilst the impact vector is beyond 45°, the gradient is saturating in between 35° and 40°.
- The shifting of the bulk heap apex and the gradient are interdependent, therefore a combined geometric and loading model concept shall be aspired.

Due to the results of Schulze and Landry [10; 11] the usage of numerical simulation methods has not taken into account. Those modelling approaches usually consume enormous computing power, which is not available on harvesting machinery. During the research process a different concept has been pursued. The accumulation of the crop is represented via simple elementary geometric 3D-functions such as cones, paraboloids and hyperboloids. In [9] the main advantages of this approach are discussed in detail.

To meet the results and studies of the field trials two different functions are implemented. The first one calculates the geometry of single bulk heaps; the second function defines the assembling process as well as the interaction of the bulk.

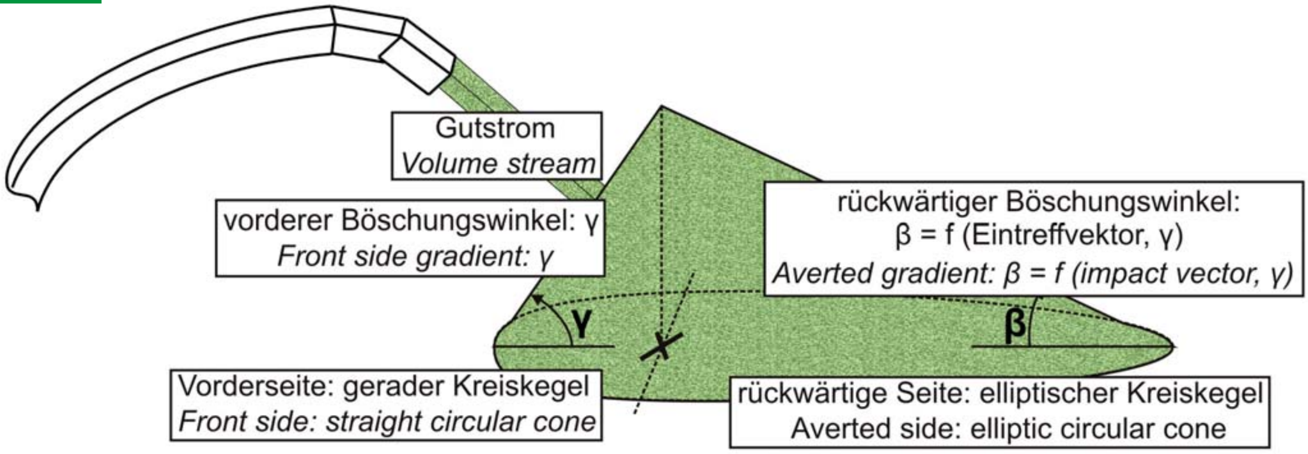
Single bulk heaps are represented as a split two phased cone. According the field trial results the single cone consists of a circular cone on the front side and an elliptic cone on the rear side (**figure 2**). The gradient at the reverted side is depending on the impact vector of the crop stream and the predefined gradient on the front side of the bulk heap.

The continuous crop flow is separated into discrete volumina, and the total loading state inside the trailer is fed stepwise by the discrete parts. The accumulation of the discrete part is calculated concerning the impact vector, the size of the volume part and the current loading state, with regards to the given 3D-function. The current loading state as well as the distribution of the incoming volume is represented via elevation profiles specified in matrices. Adding the matrices both are combined to establish a new current loading state (**figure 3**). The concept implies several advantages: Firstly the continuity of the assembly of the virtual bulk is independent of both the size of the discrete volume parts and the deviation of the discrete loading point.

Verification of the model

During the last harvesting periods newer field trials have been used to verify the model concept. Therefore the elevation profile of the model and the real distribution were identified. The highest deviation, the median as well as the standard deviation between the height of the real distribution and the model are calculated. Additionally, **figure 4** depicts the mean value averaged over the given results of all trials. In the given subset the maximum deviation concerning the height difference is 1.13 meters. Acting on the assumption that the maximal loading height is 1.5 m, the maximum deviation is in a range about 75 %. The mean value over the whole subset (ca. 60 cm) is equivalent to a mean maximum deviation of ca. 40 %. But regarding the mean value of the median and the standard deviation an adequate over all deviation is conjecturable. The standard deviation is averaged to 17 cm, which equates to slightly more than 10 %. The mean value of the median is 21 cm, means slightly below 15 %. Considering the relatively plain model concept using a split two phased cone, the given subset shows an impressive correlation of model and real accumulation.

Fig. 2



Geometrical definition of a single bulk heap

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. The first verification of the model has shown a impressive performance, regarding the plainness of the first approach.

Literature

[1] Buckmaster, D. R.; Hilton, J. W. (2005): Computerized cycle analysis of harvest, transport and unload systems. Computers and Electronics in Agriculture 47 (2), pp. 137–147

[2] Wallmann, G.; Harms, H.-H. (2002): Assistenzsystem zur Überladung landwirtschaftlicher Güter. Landtechnik 57 (6), S. 352–353

[3] Krallmann, J.; Foelster, N. (2002): Remote service systems for agricultural machinery. Automation for Offroad Equipment, Chicago, 2002. Proceedings Published by the American Society of Agricultural and Biological Engineers, St. Joseph, Michigan, US, pp. 59–68

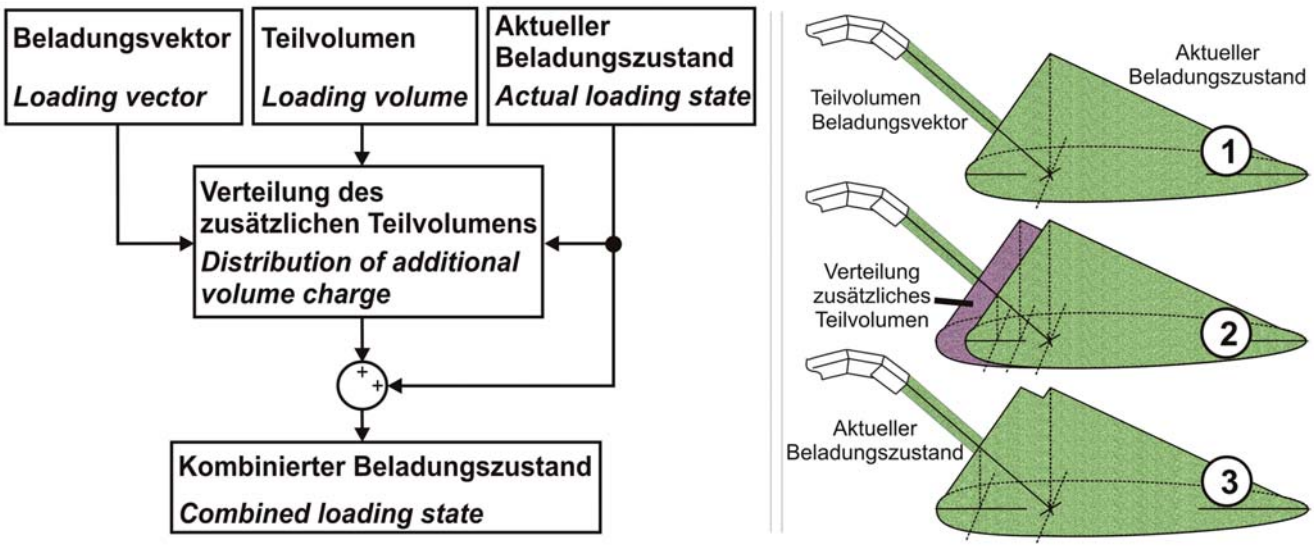
[4] Amiana, C.; Bueno, J.; Álvarez, C. J.; Pereira, J. M. (2008): Design and field test of an automatic data acquisition system in a self propelled forage harveste. Computers and Electronics in Agriculture, 61 (2), pp. 192–200

[5] Weltzien, C. (2009): Assistenzsystem für den Überladevorgang bei einem selbstfahrenden Feldhäcksler. Dissertation. Forschungsberichte des Instituts für Landmaschinen und Fluidtechnik, Shaker Verlag, Aachen

[6] Kirchbeck, A.; Lahmann, D. (2010): Automatisierungsbeispiel: Bildgebende Systeme im Feldhäcksler. KTBL-Tagung Automatisierung und Roboter in der Landwirtschaft, 21. bis 22. April 2010, Erfurt, S. 110–116

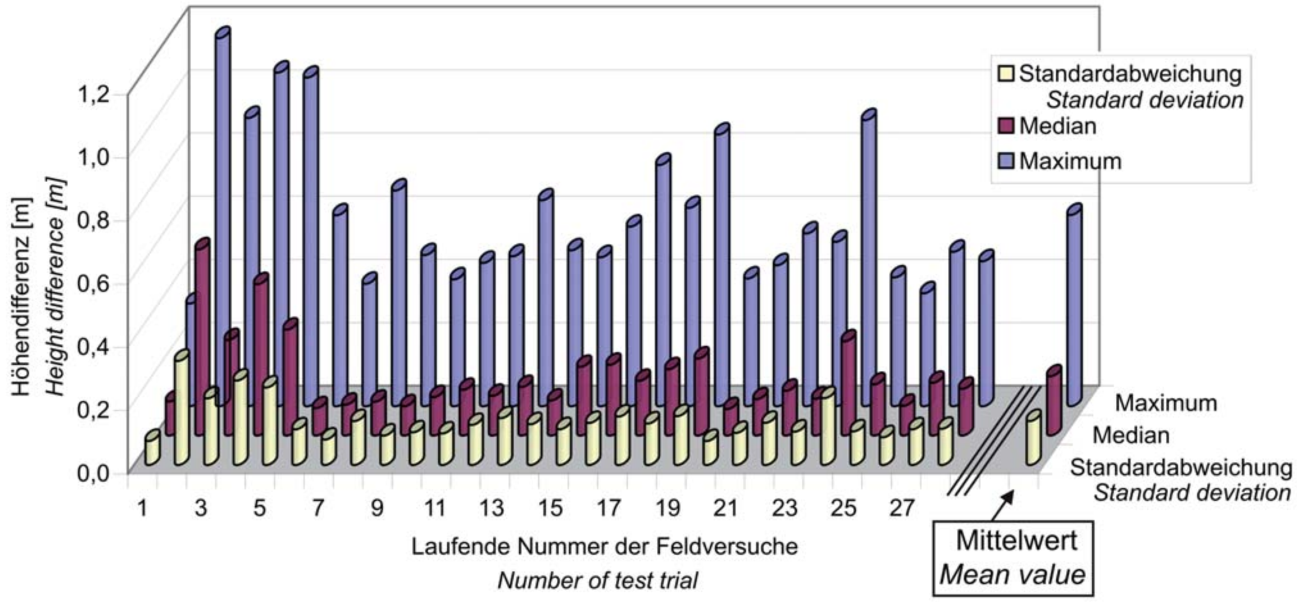
[7] Madsen, T. E.; Kirk, K.; Blas, M. R. (2009): 3-D-camera for forager automation. 67th Conference Agricultural Engineering LAND.TECHNIK AgEng

Fig. 3



Discrete loading state definition

Fig. 4



Maximum, median and standard deviation of the height differences

2009, VDI-Verlag, Düsseldorf, S. 147–152

[8] Graefe, F.; Schumacher, W.; Feitosa, R. Q.; Duarte, D. M. (2005): FILLED - A Video data based fill level detection of agricultural bulk freight, ICINCO 2005, Proceedings 3, pp. 439–442

[9] Happich, G.; Lang, T.; Harms, H.-H. (2009): Loading of Agricultural Trailers Using a Model-Based Method. Agricultural Engineering International: The CIGR E-Journal, 11, Manuscript no. 1187

[10] Schulze, D. (2002): Fließeigenschaften von Schüttgütern mit faser- und plättchenförmigen Partikeln. Schüttgut 8 (6), S. 538-546

[11] Landry, H.; Thirion, F.; Lagüe, C.; Roberge, M. (2006): Numerical modelling of the flow of organic fertilizers in land application equipment. Computers and Electronics in Agriculture 51 (1-2), pp. 35-53

Authors

Dipl.-Ing. Georg Happich is a scientist working at the Institute of Agricultural Machinery and Fluid Power (ILF) of the Technische Universität Braunschweig, Germany, **Prof. Dr.-Ing. Thorsten Lang** is the director of the Institute (former director: **Prof. Dr.-Ing. Dr. h.c. H.-H. Harms**), Langer Kamp 19a, D-38106 Braunschweig, E-Mail: g.happich@tu-bs.de