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Analysis of Human Factors on agricultural machines

For the economic operation of expensive mobile machines a high utilization rate is needed. To ensure a more efficient use of machines and to maintain the operability of increased machine sizes the number of automated functions steadiliy increases. For the operator these new developments will substantially change human-machine interactions. To ensure the safe and efficient operability of these machines, a human factors point of view is needed. The following article reports on the development of an approach to identify the relevant problem areas.

Keywords
Human Factors, work analysis, stress, strain, assistance

Abstract
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Some agricultural machines are used very intensively for special tasks during relatively short periods over the course of the year and are often part of a complex process chain like in the forage harvest, for example. Therefore, the integration of assistance systems is playing an increasing role. Fully automated machine guidance is already state of the art today.

As an extrapolation of the technical development of the past years, concepts of multiple machine operation are being frequently discussed as the next step. It seems to be a logical consequence that fully autonomous machine operation will be defined as a future goal. Regardless of challenges in view of the operational safety of autonomous machines in off-road use, for which no solution has yet been found, man seems replaceable. The left half of Figure 1 describes this development in an exemplary manner. In contrast to this development line, an alternative, less discussed view of future machine concepts can very specifically focus on the sustainable integration of man. This would mean that an intermediate step marked by demand-oriented, intelligent partial facilitation of the operator´s work could be followed by a highly integrated man-machine unit. Such a view by far exceeds the conventional design of man-machine interfaces. The development of reliable technical concepts requires extensive knowledge of the person involved, which is termed “human factors”.

Human factors describe the dependence of the use and the acceptance of machinery on human characteristics, for example. As a negative consequence, this means that technology often does not function like a developer imagined. Users or operators have their own expectations, experiences, and abilities, and their current fitness condition varies (e.g. relaxed, stressed, tired). The intended improvement of coordination raises questions, such as: How well does the available technology support the user in different situations depending on his current fitness condition, or could a new technical system or a better design of an existing system facilitate the work of the user?

In order to answer such questions, a pilot study was carried out at the Technical University of Braunschweig by cooperating engineers and psychologists and with the support of Maschinenfabrik Bernard Krone GmbH in order to provide an initial evalu-

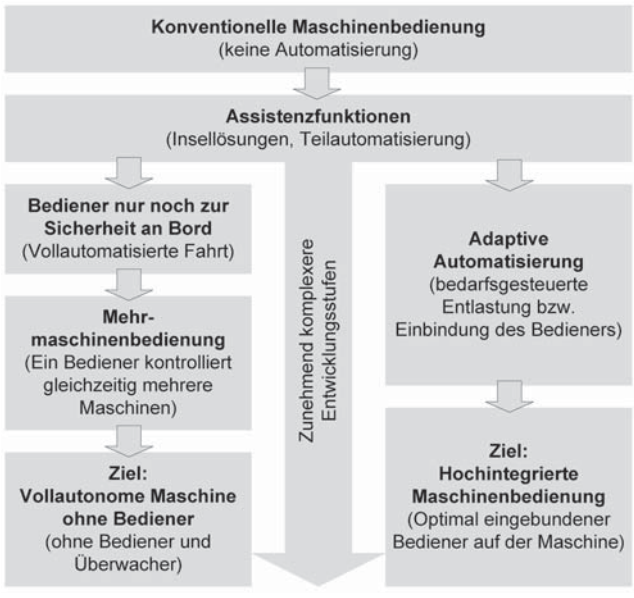
ation of relevant human factors in agricultural machinery. For this purpose, the operation of a self-propelled forage harvester was chosen (figure 3) because this work requires the fulfilment of very complex driving and operating tasks as well as coordination and communication within the forage harvesting chain.

Methodological approach

The goals of the pilot study were the identification of potential problems in the operation of existing technology and the determination of requirements for new technologies. For this purpose, the interview was chosen as a method. In addition to specific questions with fixed answer alternatives, interviews allow the subjectively important aspects of the driver´s work to be detected in a free conversation. This particularly applies to situations which are critical for safety and which should be described in detail in a free conversation in order to understand the development of the situation as precisely as possible.

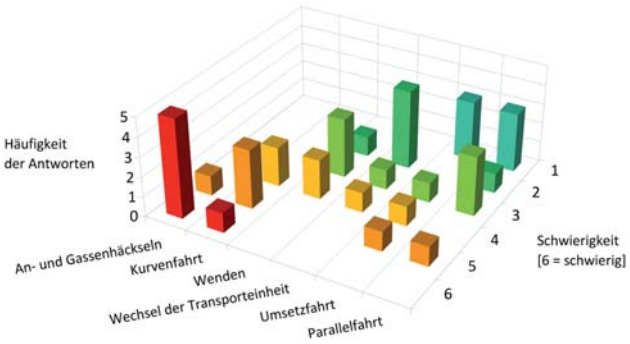
First, guidelines for the realization of the interview were developed. At the beginning, conversations with forage harvester drivers were held during several field visits in order to gain an overview of the complex driving and operating tasks on a self-propelled forage harvester. Afterwards, the driving and operating tasks were structured, and the required sub-tasks were identified. The insights gained from this process provided the basis for the interview guidelines. In addition to the guidelines, a questionnaire based on the short work analysis questionnaire according to PRÜMPER et al. [1] was developed for general workload assessment by the forage harvester drivers.

Fig. 1



Development objectives in mobile machines with and without users

Fig. 2



First results of the interview according to working situations and their level of difficulty

Application of the method

The interview begins with questions about the general working conditions. These questions refer to the organization of the operation (e.g. number of employees, service offer) as well as the individual training and professional experience of the driver. In addition, a distinction is made between the employees of a contractor and independent entrepreneurs. Moreover, the tasks of the drivers, the working conditions, and the processes on the field are considered. For this purpose, the material needs (e.g. the availability of the necessary work equipment), cooperation requirements (e.g. cooperation with customers and colleagues), as well as the external influences on work (e.g. weather influence) are registered. The effects of the individual factors on work execution are analyzed.

Afterwards, the individual work steps of the individual forage harvester driver on the field are analyzed. For several driving situations, the individual demands on the operator and the resulting strain are registered.

Another section of the interview deals with the ergonomic design of the forage harvester. This section focuses on the cockpit with its displays and operating elements as well as the evaluation of the safety of the forage harvester. Assistance systems are one area of concentration in the interview. The available assistance functions of the forage harvester are evaluated with regard to usefulness and functionality. Other questions address the need for more support from the drivers´ viewpoint. The operators are also confronted with the scenario of a completely autonomous machine and asked for their opinion about this topic.

After the end of the interview, the general workload questionnaire is handed to the interviewees, who are asked to answer the questions in writing. This questionnaire includes general workload assessment with a distinction between qualitative (e.g. difficulty of the tasks) and quantitative workload (e.g. number of the tasks). Moreover, the leeway of the drivers as well as the versatility and the holistic nature of the tasks are evaluated. In addition, social feedback and cooperation in the company are addressed. Since a set of given questions and answers is

used, this section is comparable for all forage harvester drivers.

Sample relevance

So far, six forage harvester drivers have been interviewed and questioned with the aid of the questionnaire. Since the interviews carried out thus far lasted approximately three hours, detailed, meaningful results have already been gained despite the seemingly small number of interviewees. Experiences from other fields of psychology show that a few persons are sufficient in order to identify important problems if the interviews are deep and detailed. For the more in-depth description and evaluation of overall work relevance, more studies will be necessary in the future, which can be limited and more focused on the problems identified in the interviews.

Initial results

The interview proved to be a very suitable method in order to obtain a description of the most important sub-tasks on the field and the resulting demands on the operator. The detailed evaluation of the interviews and questionnaires is still continuing. Different sub-tasks have been analyzed with regard to the role of man-machine interaction and the tasks which require additional support. Figure 2 provides an initial insight into the results. Here, the six potential driving situations are shown which the interviewees had to sort according to their difficulty. The results show that almost all those questioned in particular considered initial cutting and cutting alleyways as the most difficult driving situations. On average, the curve ride of the forage harvester and the transport unit during the cutting process is considered the second most difficult driving situation. With regard to the other driving situations, the results are far less clear. Other detailed evaluations will follow in order to explain the different assessments of the interviewees. The objective is a recommendation classified according to relevance for future work organization and the design of the forage harvester as a workplace.

Summary and outlook

As an alternative to the future fully autonomous operation of machines without operators, the development of a sustainable, highly integrated man-machine unit seems appropriate for several reasons. This requires extensive knowledge about man-machine interaction.

The investigations carried out so far serve to develop a method as part of a pilot study which allows problem areas in complex driving and operating tasks of mobile machines to be identified and defined. The example chosen for this purpose was the operation of a self-propelled forage harvester.

The problem areas identified in this pilot study after the evaluation of the results allow specific, in-depth investigations to be carried out in future studies in order to develop approaches towards a solution. The long-term objective is the development of adaptive assistance systems so that the degree of automation can be adapted to the individual driving situation and the current needs of the operator.

Literature

[1] Prümper, J., Hartmannsgruber, K. & Frese, M. KZFA. Kurzfragebogen zur Arbeitsanalyse. In: Zeitschrift für Arbeits- und Organisationspsychologie 39, Nr.3, S.125-132; 1995.

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Fig. 3

Self-propelled forage harvester in parallel operation