Stress-adaptive user interface for the networked agriculture

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The Institute of Mobile Machines (Mobima) of the Karlsruhe Institute of Technology (KIT) is researching innovative concepts and solutions for mobile working machines in cooperation with other partners from research and industry. As part of the "Fahrerkabine 4.0 | OnField" project, which is part of the "Agricultural Systems of the Future" funding program, an adaptive human-machine interface (HMI) is being developed with the help of an occupational psychology research approach, which enables the integration of the driver's workplace of an agricultural machine into other everyday farm processes through digital networking. The basis of the interface adaptation is the current stress level of the user.

Motivation

A well-managed, long-term agricultural business is essentially dependent on qualified and motivated farmers. However, the statistics of recent years show a significant decline in the number of new agricultural trainees. It is also evident that the number of younger farm owners has decreased considerably, indicating a structural change in the age structure of the workforce. The proportion of farm owners younger than 45 years fell by 32 % between 2010 and 2016. [1]

In addition, a decline in the agricultural workforce is apparent. In 2016, 10% fewer workers were employed on farms than in 2010. This is also reflected in the change in agricultural structure, with the number of farms decreasing by 17.1% between 2007 and 2019. This results in a significantly higher workload for the remaining employees in agriculture. For example, the annual number of hours increased by about 5% between 2017 and 2019. Only the use of modern technology could slow down this increase in workload slightly. [1; 2]

This trend cannot be countered by autonomous vehicles alone. In order to secure the next generation of farmers, it is necessary to provide them with an attractive working environment to help them perform their work effectively and efficiently. Only in this way is it possible to reconcile work with private and family life, for a healthy "work-life balance".

Project introduction

The driver of a combine harvester essentially has three tasks: He has to steer the machine, set the speed and adjust the machine's entire process technology. Particularly when threshing a new field, the driver's workload is high. The first lap around a new field requires the utmost attention, obstacles have to be recognized and avoided, and even with cutterbar widths of up to 14 meters, the machine must not get bogged down. At the same time, the threshing systems must be adjusted and monitored. After the headland has been threshed, the driver's workload is significantly lower. When using current assistance systems, the steering can be controlled via GPS and the speed and process technology of the machine can be automatically adjusted via the installed sensors and controls. At the same time, the driver still has to monitor the entire process. With increasing automation, as is to be expected in the coming years, this monitoring activity will decrease further and the machine will be able to master various situations autonomously [3].

Summarized over the harvest day, periods of high workload as well as many periods of low workload are spread out. This is exactly where the "Fahrerkabine 4.0" project comes in. As shown in **Figure 1** and proven by several studies, it is most comfortable for people to be at a medium stress level. Both overstraining and understraining have a negative effect on well-being and situational awareness. [4; 5]

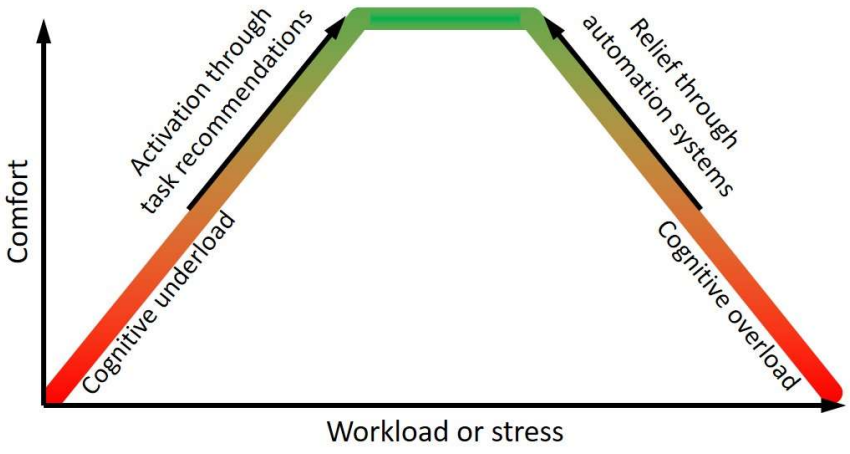

Figure 1: Impact of workload on well-being

Overload leads to the driver no longer being able to concentrate sufficiently on the essentials, things are overlooked and errors occur. By switching on additional assistance systems or by hiding information that is unimportant for him in this situation, the driver can concentrate on the essential issues and is relieved in the process. On the other hand, underload is also a problem. The resulting boredom leads to fatigue and situational awareness decreases [5]. On the one hand, this reduces the driver's well-being and at the same time increases the risk of errors, especially when the machine has to be

taken over from highly automated operation. In order to counteract this underload, the driver is given options for completing other activities on the machine via task recommendations. Task recommendations can come from a wide variety of areas and were divided into the categories of operational and farm management, machine, well-being, media and wiki.

With the help of the task recommendations, the driver's stress level will be kept at a medium level throughout the day. This promises improvements in ecological terms through the integration of further information into the harvesting process, improvements in economic terms through the parallel completion of internal tasks such as documentation duties, and improvements in social terms through better integration and better contact with the social environment.

Results from surveys and data analysis

Since the project and the resulting cabin are to be developed close to the farmer or the driver, various interviews and surveys were conducted at the beginning. This is an important step in order to be able to include all comments and ideas of potential future users in the further course of the project from the very beginning.

The content of the interviews included a description of a typical working day, activities and stress levels while driving the combine harvester. Furthermore, the interviewees could indicate which activities they would like to do on the combine harvester if the automated operation does not require their attention. From the initial results of these interviews, an online survey was launched for further experience and insight. A total of 26 people participated in the interviews and survey. All participants covered a wide range in both age and employment relationship. The interviews show that the respondents can envision additional tasks while driving, with freedom from defects and integrity of the machine, respectively, being the highest priority. The online survey conducted further illustrates this point. For example, the possibility of working on additional tasks was rated with an average of 4.31 (SD = 1.98; on a scale of 1 = "cannot imagine at all" to 7 = "can imagine very well"). Respondents were unsure whether concentration and attention might suffer. In particular, "checking weather forecasts" (M = 6.08; SD = 1.43) and "retrieving machine information" (M = 5.54; SD = 1.60) were rated as good possible activities. In addition, activities in the field of communication, management and office were mentioned.

A much more widespread survey via the magazine "profi" corroborates the results from the interviews and the online study. Of the 312 participants, 95% said they wanted to use assistance systems in the combine harvester. 84 % of the participants are also interested in the systems and the technical backgrounds [6]. This is also shown by the Situation Report 2021 from the German Farmers' Association (Deutscher Bauernverband e.V.). In 2020, for example, a survey revealed that 65% of German farmers see an opportunity in advancing digitization [1]. Half of the drivers from the "profi" survey state that they are underchallenged at various times when driving a combine harvester; at the same time, more than half of the respondents feel overburdened if several activities had to be completed at the same time. Nevertheless, two-thirds of all participants rate the possibility of being able to perform secondary tasks as positive or very positive. "Organizing the business" and "managing logistics and sales" are cited as beneficial. Skepticism is expressed about the dangers of a possible high continuous workload, which could increase the susceptibility to errors. [6]

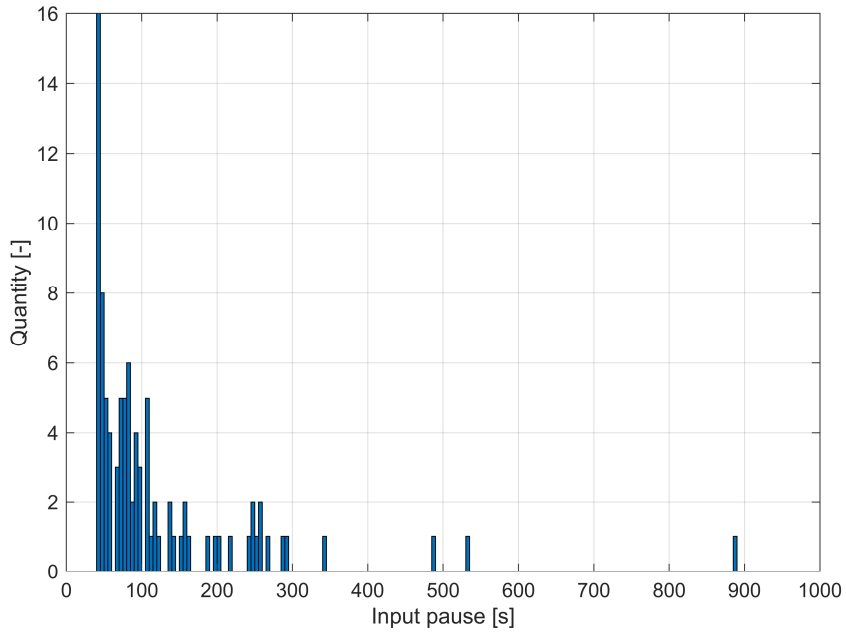

Figure 2: Times without driver input

The results of the surveys show that, especially during highly automated driving, there is a desire for further activity. To check whether and how often these situations occur, several machine data analyses were carried out. For this purpose, the CAN-Bus was read and analyzed for 5 hours during a usual working day. The worked fields are located in the northeast of Germany and had an average area of about 105 ha. **Figure 2** shows that there are many situations in which no input is made for up to 2 minutes. However, there are also occasional periods of time between 4 and 15 minutes in which no input was made. Periods without operator input of less than 40 seconds are not considered here. As can be seen in **Figure 3**, operation of the front attachment accounts for 80% of all recorded inputs and thus has a major influence on the frequency of operations. In the future, it is to be expected that the necessary user inputs will be significantly reduced by the progressive automation of the combine harvester and the front attachment.

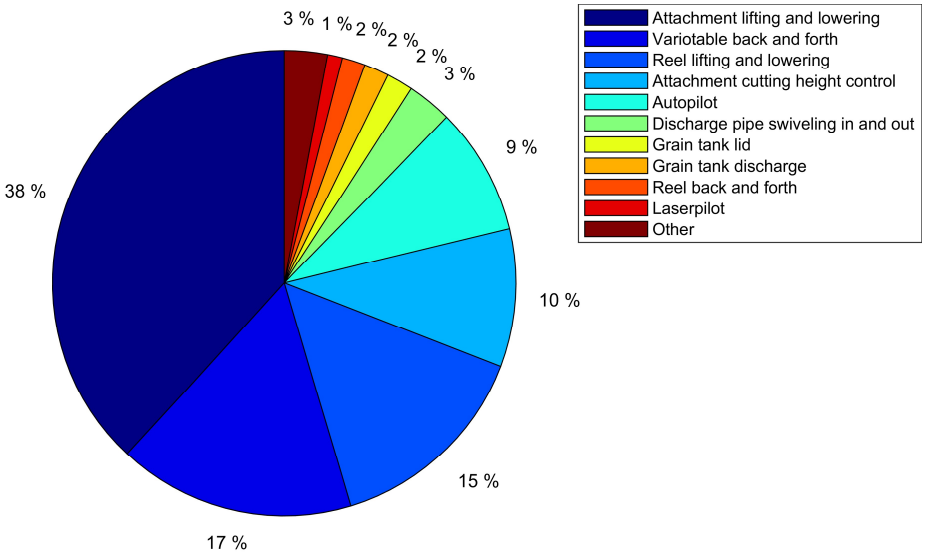

Figure 3: Most used functions of the driver

From the results of the surveys and interviews, it can be seen that machine integrity has the highest priority, especially among farm managers. Distraction of the driver is thus not desired, as this could impair attention. According to current scientific findings, however, this fear is unfounded. Situational awareness and the ability to react quickly and safely in

critical situations are greatly reduced by monotonous, cognitively undemanding work [5; 7]. Specific, not too demanding tasks, which are additionally given to the driver, can significantly increase performance [5]. This is where the concept of "Fahrerkabine 4.0" comes into play and enables an increase in performance and a reduction in stress with targeted and activating task recommendations. Concepts that enable the timely detection of critical situations are necessary for this. There are also studies that show that frequent smartphone use during work reduces situational awareness [8]. However, this reduction is due to uncontrolled use and thus too much distraction. This problem can be prevented by an algorithm which limits the maximum cognitive load of the additional task. Since the state of sustained observation, which is necessary for the adaptivity of the new user interface, also has an influence on the user state, it is important to investigate this as well. Backhaus concludes in 2019 that performance, by perception of monitoring alone, is increased by up to 14%, but trust and morale can suffer greatly. Therefore, it is particularly important to explain the reason for the monitoring well, to disclose it and to show the use of the data transparently. [9]

Outlook and summary

In summary, the concept of task recommendations including user state detection serves the goal of driver support and improving situational awareness. Participants in the interviews and surveys saw the potential of controlled task recommendations in times of cognitive underload. Analyses of operator input from current combine models show that periods of this under-challenge currently exist. As automation continues, these times are expected to increase significantly in the future. The doubts of the participants regarding an increased susceptibility to errors due to reduced attention can be scientifically refuted.

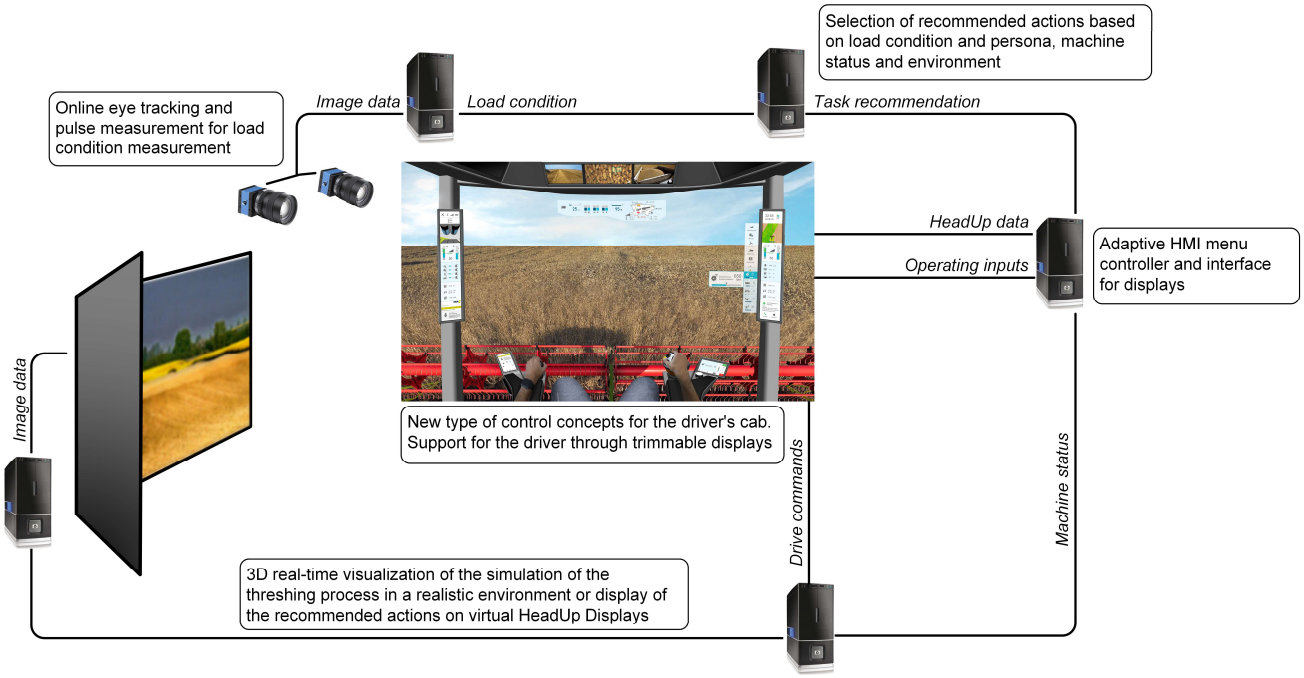

Figure 4: Overview of the overall system

The next step in the "Fahrerkabine 4.0" project involves the systematic construction of a cab demonstrator, including an environment simulation, as shown in **Figure 4**. This demonstrator will enable comprehensive testing of the whole system in the future.

Literature

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