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Modelling of operator's focusing scheme along working hours: harvesting operation

I. Szabó, M. Hushki, Z. Bártfai and L. Kátai*

Szent István University, Faculty of Mechanical Engineering, Institute of Mechanics and Machinery, Páter K. street 1, HU2100 Gödöllő, Hungary
*Correspondence: katai.laszlo@gek.szie.hu

Abstract. In consistent with the growing research activities regarding the Farm 4.0 concept, it is valuable to consider each possible chance of enhancement which is expected to contribute positively to the productivity and the safety of planned operations. Human centred design concept is becoming essential for the multitasking vehicles market, which promotes the research experiments aiming to understand the human behaviour inside the vehicle cabins to proceed with upgrading the design, planning and production procedures based on validated inputs leading to introducing reliable solutions for more productive and safety conduct of operations. The accurate and deep analysis of the operator behaviour inside the cabin will lead to a better understanding for the problems and issues need to be resolved in new designs in addition to providing the production planning (i.e. manpower planning and working shift period) with the necessary data to ensure achieving the maximum efficiency and effectiveness. In this research, the operator's glance behaviour inside the tractor cabin is studied during the harvesting operation to develop a model for the change of operator's focusing scheme along working hours.

Key words: off-road vehicle, operator's behaviour, eye tracking, focusing scheme, passive fatigue, precision farming.

INTRODUCTION

Herdovics (2013) mentioned a very important role of the academic sector improving the development of agricultural operations by problem resolving and developing the recommendations based on the advanced analysis of data to be used in advanced farming processes easily. To the purpose of assisting the decision-making activity during the planning phase (Man-power planning, operational procedures, …etc.) this research activity is conducted. Thereafter; the availability of such models will provide decision makers by a factual based method coming from deterministic data analysis, which is usually done based on managerial assumptions in the absence of validated models from research and development centres and/or academic sector.

In continuation of the research work done by Szabo et al. (2017) and Szabo et al. (2018) regarding Operator's behaviour measuring methodology inside off-road vehicle cabin and the developed two models for windrowing and cultivating agricultural operations, in which the passive fatigue is examined due to the nature of the said two operations requiring a continual physical movement to turn back and check for the rear attached tool. However; it is stated that the increasing mental load is inherent inside the resulted models.

This research activity depends on the validated methodology to develop a model representing the change on the resulted operator's focusing scheme along working hours in harvesting agricultural operation in which the operator doesn't need to physically turn back and check for a rear attached tool, but the operator is still requested to pay enough attention to the front mounted tool doing the necessary steering and monitoring.

Due to the operational nature of multi-tasking off-road vehicles, operators need to spend long working hours, which increases the level of mental workload leading to human error. (Li & Haslegrave, 1999) introduced similar conclusion of which the vehicle design should be human oriented in order to maximize comfort and ability to perform the driving task perfectly and safely by reducing the human error possibility.

In the in-road vehicles market, such a study is conducted more thoroughly to check for the distraction caused to the driver due to the increasingly added systems and technologies to the driving cabin. Indirect measures are usually applied to assess safety and attention of drivers due to complexity of definitions and criteria of safety and attention. That is why some studies such as (Alm & Nilsson, 1995; Hulst et al., 2001; Lai et al., 2001; Lee et al., 2001; Broy et al., 2006) commonly used measures of driver distraction related to secondary task interaction by primary task measures such as lateral control (e.g. measurement of lane keeping performance) and longitudinal control (e.g. speed maintenance).

Therefore, it is quite common to make inferences, such that higher driver workload when interacting with an in-vehicle system implies greater lateral movement and more frequent lane exceedances. It is interesting to note that a measure such as the number and length of lane exceedances during in-vehicle interaction is not considered primarily safety-relevant by everyone.

Cnossen et al. (2000) and Liua & Lee (2006) studies argue that if there are no other traffic users nearby, if the lane exceedance is small or of short duration, or if the lane exceedance or speed reduction reflects the driver's strategy for compensation and reducing workload during concurrent task execution, there is no safety implication at all.

It is a general aim to improve comfort and safety (Sheridan, 1992; Endsley, 1996; Fukunaga et al., 1997; Scheding et al., 1999; Shen & Neyens, 2017; Zewdie & Kic, 2017; S. Kumar et al., 2018), additionally, it is stated that, in the automated driving condition, driver responses to the safety critical events were slower, especially when engaged in a non-driving task. At the same time in their paper – dealing with driver visual attention (Louw & Merat, 2017) reached a conclusion shows that the drivers understanding of the automated system increases as time progressed, and that scenarios which encourage driver gaze towards the road centre are more likely to increase situation awareness during high levels of automation.

Operating an off-road vehicle is a complex task, requiring a concurrent execution of various cognitive, physical, sensory and psychomotor skills (Young & Regan, 2007), additionally to control attached tools to perform in-field productive tasks such as agricultural and industrial operations. Ensuring the comfortable ride is considered essential for any vehicle, as well as executing happily and safely requested operational tasks, to that end, the driver ergonomics comes to play as considered as an important parameter that can't be neglected in the design phase of the vehicle (Hsiao et al., 2005).

Driving is not only a physical task but also visual and mental tasks. The eyes of a driver are indispensable in performing visual tasks such as scanning the road and monitoring in-vehicle devices. Mental tasks are important during driving, and include such factors as understanding vehicle dynamics, making situation-dependent decisions, and judging time/space relationships (Kramer, 1990), (De Waard, 1996), (Brookhuis & De Waard, 2010) and (Marquart et al., 2015) were examined the eye-related measures of drivers' mental workload. The mental workload could be defined as the relation between demands resulted from various tasks to be performed on the operator and his ability to fulfil; with satisfactory; these demands. While (Sporrong et al., 1998) described the mentioned demands as multidimensional, as it involves tasks, operator and system demands together with other factors. Additionally; many studies showed that; the need for well fitted architectural space to the operator's dimensions is considered crucial. The mental workload level is found to be increasing with the time passing.

For the purpose of this research, the passive fatigue is investigated. This type of fatigue is characterized by being the indirect product of the human driver's exertion of a set of tasks whose demands are low, monotonous or repetitive (Saxby et al., 2013). These rules out any sort of physical fatigue or mental active fatigue.

MATERIAL AND METHODS

Tobii equipment and software packages

Tobii solutions were used to conduct the eye tracking and glance measuring of the operator inside the off-road vehicle cabin.

Tobii glasses 2 (Fig. 1) package was selected due to its mobility feature in addition to the powerful properties enable the operator to use it in the daylight and night in the field. A brief description of the package is illustrated in the figure below:

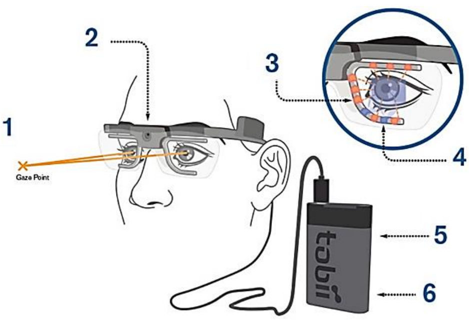


Figure 1. Tobii glasses 2 package.

1 – Eye tracker: consists of cameras, illuminators, and algorithms;
2 – Scene camera: a camera is recording what the operator is looking at;
3 – Illuminators: creates a pattern of near infrared light on the eyes;
4 – The cameras: take a high-resolution image of the user's eyes and patterns;
5 – The image processing algorithms: find specific details in the user's eyes and reflection patterns;
6 – The eye position and gaze point are calculated using a sophisticated 3D eye model algorithm based on the inputs and configurations mentioned previously.

MATLAB

The Curve Fitting Toolbox is used for modelling the resulted data of the change in operator's focusing scheme along working hours for the samples collected from harvesting agricultural operation.

Research methodology

Followed methodology is summarized in process map showed in (Fig. 2).

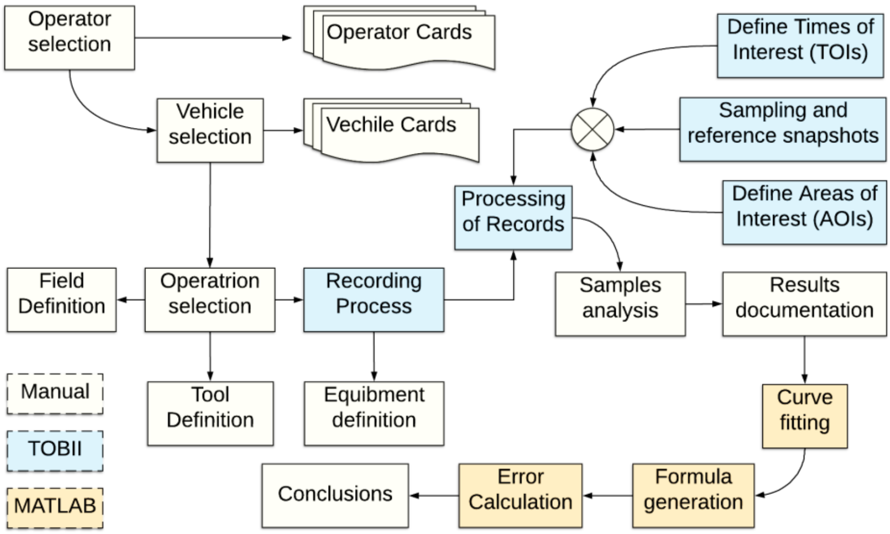


Figure 2. Methodology process map (Szabo et al., 2018).

The selected area of interest (AOI), to the purpose of this research, is the front mounted harvesting tool (Fig. 3). The operator needs to keep focusing on AOI for continuously monitoring and steering the vehicle into the right path, which requires more mental load than the additional physical passive fatigue for turning around and check a rear tool as an example.

A reference snapshot (Fig. 4) is taken for the selected AOI form videos recorded by the Tobii Glasses 2 equipment.

Figure 3. The front mounted tool for harvesting operation.

Figure 4. Reference snapshot for the harvesting tool.

The operator is requested to wear Tobii glasses and to go through the calibration process whenever a new recording is started. The glasses are connected wirelessly to the windows tablet which is running the Tobii controller software to register the recording information, monitor the real-time view of the operator, conduct the calibration process and to stop, pause and start the recording process.

Thereafter, the collected video recordings are transferred to the PC which is running the Tobii Pro Lab software to be analyzed using the real-time mapping and available filtering packages to obtain the accumulated times. Recorded videos are splitted out into number of recording samples, each one represents 600 seconds of the real-time recording of the operator's gaze during the windrowing operation.

Due to the differences between the planned and actual recoding time, each sample is normalized to represent the 600 seconds of recording with a factor (N). However, collected gaze time spent on the attached tool (X) is multiplied by the Normalization factor (N) according to the formula:

$$(X)_{\text{Normalized}} = (N) \cdot (X)_{\text{Actual}}$$

Cultivating operation

The experimental trials are conducted for harvesting the sunflowers field using the vehicle (CLAAS Dominator 202) (Fig. 5), in a field beside Gödöllői airport to the south west of Gödöllő city.

Figure 5. CLAAS Dominator 202.

RESULTS AND DISCUSSION

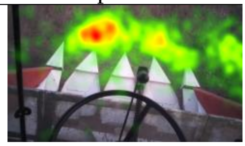
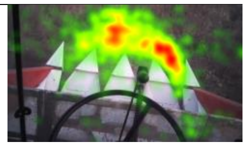
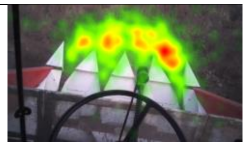
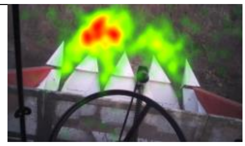
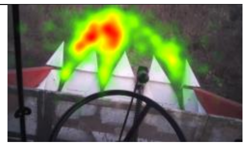
Measurements and analysis results

After recording the harvesting operation along one working day with calibration process conducted successfully whenever it was needed, the recorded samples were analyzed by Tobii Pro Lab analyzer software and exported to MS Excel sheet.

The samples were normalized in accordance to the mentioned normalization formula and the exported results (Table. 1) showed the following:

- The sample reference in the original video (column 1); which represents the reference of a certain sample inside the used analyzer software (Tobii Pro Lab).
- The sample serial number (X) (column 2); which will represent the X-Axis on the resulted curve.
- The tool gaze times in (X) sample (column 3); which will represent the accumulated time of operator's gaze inside the AOI on the Y-Axis on the resulted curve.
- The normalization factor (N) for the sample (X) (column 4).
- The Normalized tool gaze times (X*N) (column 5).
- The generated heat map for the sample (X) (column 6); which is a graphical representation for the operator's gaze distribution and accumulated time over the reference image along the sample recording time.

Table 1. Sample Experiment results of windrowing operation

Sample Reference	X value	Tool gaze time (Sec)	N Factor	Time (Normalized) (Sec)	Generated Heat map
1	1	481	0.90	245.52	
2	2	413.5	1.00	274.79	
3	3	500.05	1.00	369.99	
4	4	409.89	1.00	282.74	
5	5	440.73	1.00	362.42	

Putting the resulted data of accumulated time of each sample on the y-axis and the and the samples sequence on the x-axis, after the normalization of results based on the actual recording time to represent 600 seconds of recording for each sample, the results are shown in (Fig. 6).

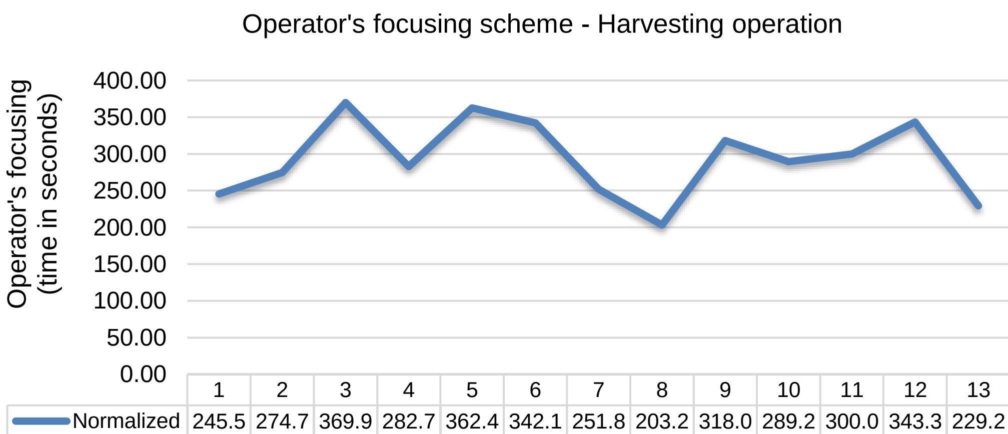


Figure 6. Accumulated time of operator's focusing scheme for each sample in harvesting agricultural operation.

Modelling results

The curve fitting operation is conducted using the MATLAB Curve Fitting Toolbox™, the resulted curve (Fig. 7) for the harvesting operation was processed selecting the Linear model (Poly 4) which generates a polynomial equation with the forth degree and using Bi-square robust method.

Where:

X-Axis represents the samples serial number (1 unit = 600 working seconds)

Y-Axis represents the OFS (Accumulated gaze time on the AOI in seconds)

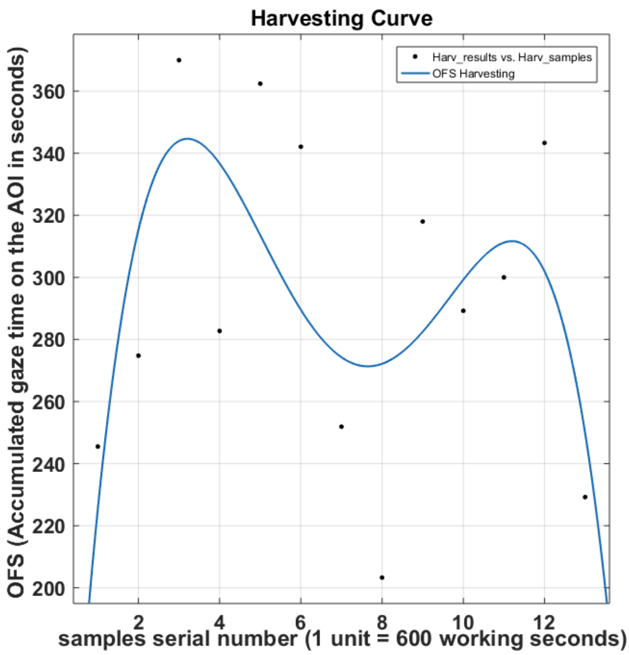


Figure 7. Curve fitting of results.

The results showed the operator's gaze on selected area of interest. The used equipment and supporting software packages easily defined the time in which the operator paid his attention to the front mounted tool during working time in the harvesting operation developing the model describing the change on the OFS along working hours X_{harv} (t):

$$X_{harv}(t) = 274.3 - 35.07t + 103.3t^2 + 18.12t^3 - 50.04t^4$$

Resulted models and the goodness of fit as per exported from MatLab Curve fitting toolbox:

Linear model Poly4:

f(x) = p1*x^4 + p2*x^3 + p3*x^2 + p4*x + p5

p1 = -50.04

p2 = 18.12

p3 = 103.3

p4 = -35.07

p5 = 274.3

Goodness of fit:

R-square: 0.2816

RMSE: 54.34

DISCUSSION

The used equipment and supporting software packages easily defined the time in which the operator paid attention to the defined areas of interest during the operations. All experimental trials were conducted in similar environmental and operational conditions. The daylight recording, use of closed cabin controlling the temperature and humidity inside the cabin, protection from dust and insects… etc.; all of it; are considered to be similar along executing all experimental trials in order to keep on consistency of environmental and operational conditions trying to include the same uncertainties sources along all developed models which is reflecting the routine duties conducting by the operator in agricultural operations.

The resulted models can be used to give an indication estimating the effort required by operators to conduct different agricultural operations based on deterministic data driven models.

The impact of the learning process on the operator's focusing scheme is subjected to be under more investigation in order to assess the contribution of the experience of the operator to the production phase in a certain agricultural operation which is proposed to be conducting by developing different models for the same operation executed by different operators with differentiated levels of operating experience.

The resulted models are developed to be used as a simple tool predicting the behaviour of an operator inside the off-road vehicle cabins based on deterministic data analysis. The contribution of the implemented models is expected to assist the decision-making process regarding many aspects (i.e. scheduling of breaking times, working hours and payment estimation). Which make it necessary not to exclude any uncertainties expected to accrue during the real-time implementation of the model.

Taking into consideration keeping on the simplicity of the model and not excluding of uncertainties, the resulted models are showing low R2 coefficient of determinization. This small number is resulted from the huge variation of accumulated operator's gaze from each sample to other samples. Each sample result represents summation of operator's gaze along the 10 minutes of the sample record analysis. Repeating some routine tasks require more operator attention to the AOI might be repeated twice in the same sample while it would not happen in next or previous sample (i.e. lifting the tool to turn over at the end of the field will be reflected twice in one sample and might not happen in the next recording sample).

However; the resulted models for the tested agricultural operations are found to be the first attempt to modelling the change on operator's focusing scheme along working hours, which is subjected to be improved on a continual base.

CONCLUSIONS

This work presents a method for measuring change of operator focusing scheme over time during an agricultural operation. The time is not the only factor affecting the operator focusing scheme. Other factors such as age, gender, experience, working conditions... etc. are not within the scope of this work and are left for future works.

The resulted model showed a notable decrement behaviour in operator's focusing scheme along working hours, which is correlated to the passive fatigue and mental load accumulated along working hours. However, the resulted trend of decrement is slower than it was in the previous experiments which require the operator contribution to monitor and control the rear attached tool on a continual base.

The resulted model is subjected for further development in term of the modelling quality. However; it is still usable to provide an indication for comparing different agricultural operations.

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