SZENT ISTVÁN UNIVERSITY

Operator's focusing scheme inside off-road vehicles

Thesis of PhD work

by

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Affirmation of supervisor Affirmation of head of school

CONTENTS

1. INTRODUCTION, OBJECTIVES

Human behavior inside workplace is considered an important factor for the productivity, safety and security aspects, the human factor issue is always considered as main contributing factor to be studied and analyzed. The resulted data from such research activities are normally translated into working models to be followed or implemented directly in the related field. Based on the criticality of human contribution for the studied field and the availability of research technology, the source data is extracted on probabilistic or deterministic basis. However; utilizing the right data will be reflected in the effectiveness of resulted model to correlate a specific human behavior or more to a unique result which will be transformed into decision or a contributing factor for decision making.

It is found in many literature that; human error has been documented as a primary contributor to more than 70 percent of commercial airplane hull-loss accidents. While typically associated with flight operations, human error has also recently become a major concern in maintenance practices and air traffic management. Research and development centres in the leading manufacturers made the human factor as a priority, developing the models representing the change on operator's behaviour inside workplaces, such as Boeing human factors professionals work with engineers, pilots, and mechanics to apply the latest knowledge about the interface between human performance and commercial airplanes to help operators improve safety and efficiency in their daily operations.

A notable momentum of research activities has been already taken place in the in-road vehicle field during the recent few years. Starting by simulators development for safety related research activities until developing the state-of-the-art technologies to support the in-road real-time researches.

For this research, accumulated knowledge from earlier researches will be used to develop the methodology of measuring the selected behavior and will be contributing to the design processes in the precision farming i.e. human resources, selection of the vehicle and time estimation of the production operation. According to the previous reviewed research, it has demonstrated that the research area of human behavior in the multitasking vehicles are not enough, comparing with the research activities in the other fields, despite of the importance of human factor contribution to ensure the productivity and safety of the executing of operations. Using the modern eye-tracking systems technology with a powerful analyzer software will be used in tractor cabin after designing of experiment procedure and documentation, the objectives of this research can be described as follow:

- Validating a method for measuring the operator's focusing scheme.
- Modeling the change on focusing scheme of the operator along working hours for a certain Area of interest (AOI) which is the attached tool in the windrowing agricultural operation.
- Modeling the change on focusing scheme of the operator along working hours for a certain AOI (the attached tool) in the cultivating agricultural operation.
- Comparing and analyzing the resulted models.
- Specifying the least AOIs inside tractor cabins in the baling agricultural operation based on deterministic data.

2. MATERIALS AND METHODS

The present chapter is introducing the materials and their preparations which used in my research in addition to the engineering and scientific methods involved experimental measurements, characteristics, methodological knowledge, and description of the test systems to achieve the research goals.

2.1. Tobii equipment and software package

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

Tobii glasses 2 package in Fig. 1 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:

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.

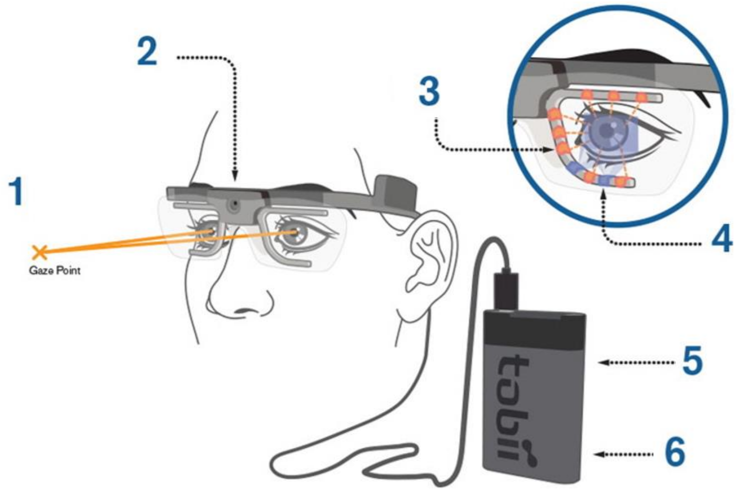

Fig. 1. Tobii glasses 2 package

2.2. Methodology testing

CLAAS tractor (Model: ARES 567 ATZ) in Fig. 2 is selected to the purpose of accommodating the number of experimental trials. For this part of research are conducted inside Szent István University Laboratories where the tractor is located. The operation part is limited to develop the operator's focusing scheme while exploring the cabin contents of the selected tractor. Spending several minutes as a familiarization process, the operator is introduced to the notification panel, main control panel and the side control panel components.

Fig. 2. CLAAS tractor (Model: ARES 567 ATZ)

The operator is tasked to go through the calibration process, start the recording process and get in the tractor cabin for several minutes to get familiarized with the cabin components paying attention to the selected AOIs while receiving verbal illustration regarding each component.

Thereafter, the recording process is stopped, and the recorded video is processed by the Tobii Lab pro software using the automatic real-world mapping tool, heat maps representing operator's focusing scheme during the recording time are generated by the software, which leads to generate the statistic readings using MS Excel software.

2.3. Field works

Outdoor experimental trials are conducted on different agricultural fields using different tractors and combined tools. All selected tractor models have covered cabin for the operator, which is helpful to control some of experimental conditions (i.e. temperature and humidity inside the cabin) keeping on the consistency of those parameters and conditions.

2.3.1. Windrowing operation

Windrowing agricultural operation is selected to be the studied operation in this research to produce the model of the change on operator's focusing scheme along working hours. After hay cutting in the agricultural field, windrowing operation is conducted to sort hay into lines in the field. The operation is conducted by specific tools attached to tractors generating hay lines to prepare for the hay baling operation. To the purpose of this research, the used attached tool to the CLAAS tractor (Model: ARES 567 ATZ) is CLAAS LINER 450T in Fig. 3.

Fig. 3. ARES 567 ATZ tractor with CLAAS LINER 450T used for windrowing

Experimental trials are conducted under the supervision of Szent István University management in a field called Babat-völgy to the north west of Gödöllő city shown in Fig. 4.

Fig. 4. Location of windrowing and baling experimental trials (Babat-völgy field)

The selected area of interest is the attached tool CLAAS LINER 450T in Fig.5. Reference snapshot is taken for the item in the AOI form the video recorded by the Tobii Glasses 2 equipment.

Fig. 5. Reference snapshot

2.3.2. Baling operation

Baling agricultural operation is selected to study and obtain the least used equipment inside a tractor cabin. After windrowing operations are conducted to sort hay into lines in the field. Thereafter; the baling operation is conducted by specific tools attached to tractors generating hay bales in different shapes. To the purpose of this research, the used attached tool to the John Deere 6600 tractor is CLAAS ROLLANT 62S shown in Fig. 6.

Fig. 6. John Deere 6600 tractor with CLAAS ROLLANT 62S rear tool

Experimental trials are conducted under the supervision of Szent István University management in a field called Babat-völgy to the north west of Gödöllő city as previously shown in Fig. 4.

Several areas of interest are selected to measure the operator's focusing to each AOI during the experimental execution time as listed in Table.1. Reference snapshots are taken for the items in the areas of interest form the video recorded by the Tobii Glasses 2 equipment.

Table. 1. AOI's with reference snapshots

AOI Num.	AOI	Reference snapshot	Item of interest
1	Front dashboard		
2	Side panel		
3	Left mirror		
4	Right mirror		
5	Attached tool		

Automatic real-world mapping tool is used along the time of interest (about 1478 seconds) to measure the operator's gaze on the selected items of interest in the reference snapshots.

2.3.3. Cultivating operation

The experimental trials are conducted for cultivating the sunflowers field using the vehicle (CASE 7210) with attached cultivating tool shown in Fig. 7.

Fig. 7. CASE 7210 with attached cultivating tool

Experimental trials are conducted under the supervision of Szent István University management in a field beside Gödöllői airport to the south west of Gödöllő city shown in Fig. 8. The attached rear tool is the selected AOI to be under studying along two working days.

Fig. 8. Experiment field beside Gödöllői airport to the south west of Gödöllő city

2.3.4. Harvesting operation

The experimental trials are conducted for harvesting the sunflowers field using the vehicle (CLAAS Dominator 202) with front mounted harvesting tool shown in Fig. 9 in a field beside Gödöllői airport to the south west of Gödöllő city as shown previously in Fig. 8.

Fig. 9. CLAAS Dominator 202 with front mounted harvesting tool

The front-mounted tool is the selected AOI to be studied, along 13 recording samples each for 600 seconds (in total 7800 seconds).

2.4. Experimental procedure

2.4.1. The process map for the experimental procedure

The followed methodology is summarized in process map showed in Fig. 10.

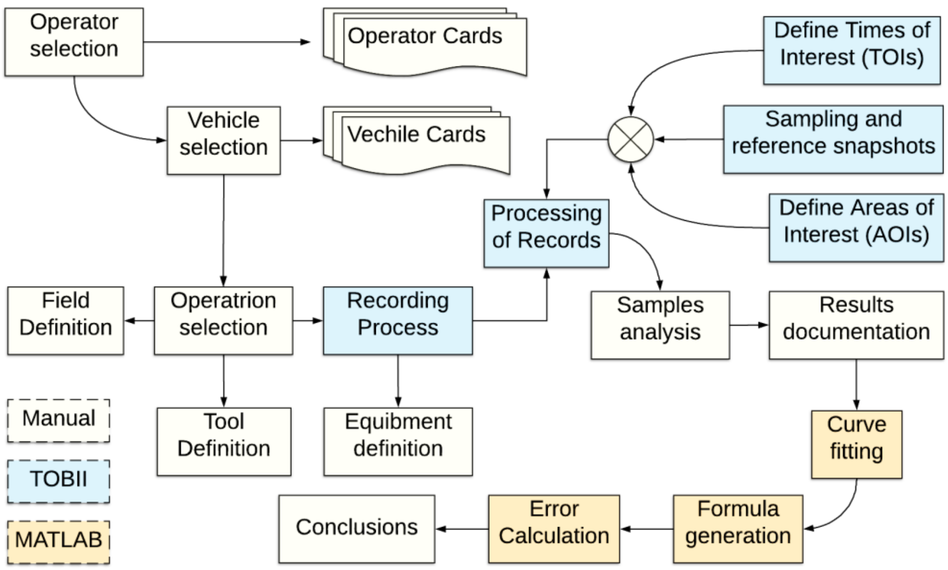

Fig. 10. Methodology process map

The operator is mandated 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.

2.4.3. Sampling

To measure the operator's focusing on the AOI during the experimental samples of execution times recording samples are used. Each recording sample (X) represents 600 seconds of the real-time recording of the operator's gaze during the all tested agricultural operations.

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). the shortest recorded sample was less than the planned recording time by 17%. However, collected snap times on the attached tool is multiplied by the Normalization factor (N) according to the formula:

$$X_{Normalized} = (N) * (X_{Actual}).$$

To the purpose of this research, automatic real-world mapping tool is used along the time of interest (about 6600 seconds) to measure the operator's gaze on the selected area of interest in the reference snapshot.

Turing over at the field edges requires a special attention by the operator to the attached tools and the used panels and monitors inside the cabin, mainly for steering purposes and to de-attach the tool from the working field avoiding any unexpected or unnecessary to be treated obstacles.

Such special process if happened more than once during the sample (600 seconds) the resulted values will be obviously distinguished from previous and following samples results in which there were no turnovers, or it happened once during the sample.

The samples were not manipulated to uniformly split the turnover cases over samples due to the randomization found in each sample length, however; the results were treated at later stages by the curve fitting techniques developing the model of operator's focusing scheme change along working hours for each agricultural operation.

The samples which were excluded from the records were limited to the following cases:

- Familiarization process
- Due being out of the vehicle for a limited time to conduct an unrelated to the experiments results tasks such as:
  - Being out of the vehicle to conduct a quick maintenance operation.
  - Changing the battery of the recording unit.
  - Conducting the recalibration process after starting new recording session.
  - Stopping for eat or drink.
- Samples with less than 6 minutes of recording.

2.5. MATLAB curve fitting toolbox

Curve Fitting Toolbox™ provides an app and functions for fitting curves and surfaces to data. The toolbox lets you perform exploratory data analysis, pre-process, and post-process data, compare candidate models, and remove outliers. The application can be used to conduct regression analysis using the library of linear and nonlinear models provided or specify custom equations. The library provides optimized solver parameters and starting conditions to improve the quality of your fits. The toolbox also supports nonparametric modelling techniques, such as splines, interpolation, and smoothing.

The Curve Fitting Toolbox is used to give the Model of the change on operator's focusing scheme along working hours for the samples collected from agricultural operations.

3. RESULTS

The present chapter displays the most important achieved results and their discussion.

3.1. Methodology testing and validation

In order to ensure the completeness and functionality of the proposed mechanism to obtain the change of operator’s focusing scheme change along working hours, the indoor testing process is conducted inside SZIE laboratory to obtain readings of operator’s focusing scheme on two different areas of interest.

In prior to start recording, the calibration process is done successfully and confirmed automatically by the Tobii controller software and the special calibration card.

Two AOIs are selected inside the tractor cabin in Fig. 11, as follows:

- AOI1: the notification panel in the tractor dashboard and the Air conditioning rotary switch.
- AOI2: the side control panel in the tractor right side.

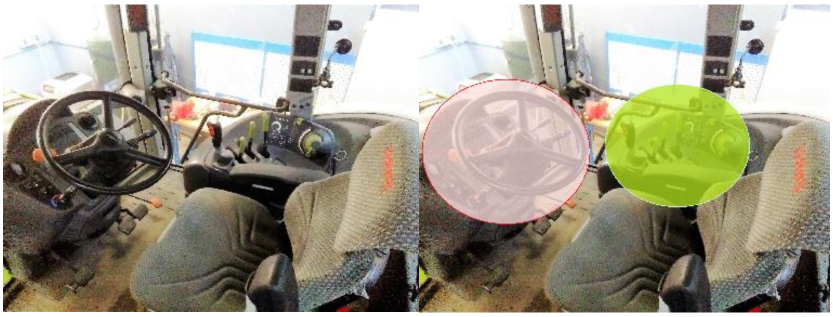

Fig. 11. Tractor cabin and the selected AOIs locations

The recorded video is processed using the Tobii Lab Pro software. The full recording time was about 520.53 seconds.

The AOI1 is represented into two components in the front dashboard. The air conditioning rotary switch and the notification panel. From the variety of available data which the Tobii Lab Pro software is capable to provide, main collected data from AOI1 was limited to the accumulated gaze time spent on the selected components “in seconds” and the counts representing the number of times in which each component is scanned by the operator in Table. 2 and the heat map is generated as shown in Fig. 12.

Fig. 12. AOI1 the notification panel and AC rotary switch with the heatmap generated

Table. 2. AOI (1) collected data

Total Visit Duration	AC Rotary switch	Front Dashboard	Sum	Total Time of Interest Duration	Total Recording Duration
Time (seconds)	0.67	100.11	100.78	290.13	520.53
Counts	4	239	243		

The AOI2 is represented into side control panel components in the tractor cabin. From the variety of available data which the Tobii Lab Pro software is capable to provide, main collected data from AOI2 was limited to the accumulated gaze time spent on the selected components "in seconds" and the counts representing the number of times in which side control panel components are scanned by the operator in Table. 3 and the heat map is generated as shown in Fig. 13.

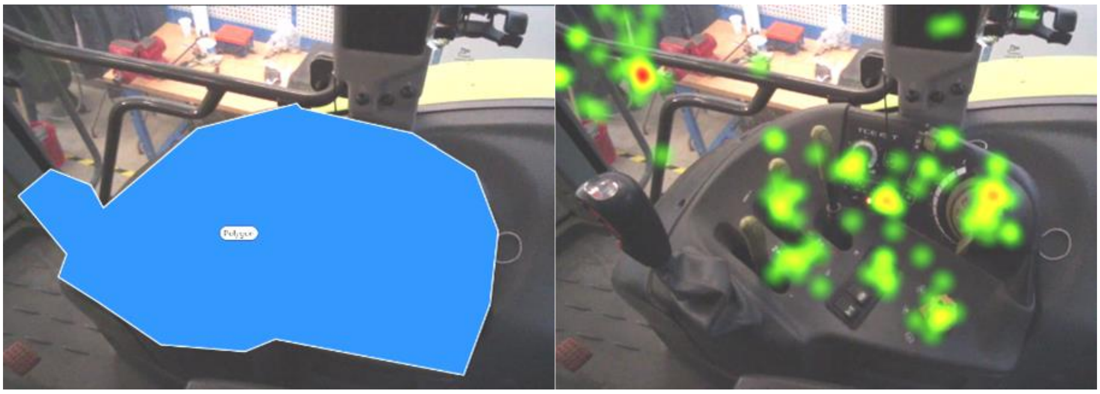

Fig. 13. AOI (2) the side control panel with the heatmap generated

Table. 3. AOI (2) collected data

Total Visit Duration	Side control panel	Sum	Total Time of Interest Duration	Total Recording Duration
Time (seconds)	33.88	33.88	54.94	520.53
Counts	77	77		

3.2. Windrowing operation results

The windrowing operation trials were conducted along two normal summer days in June 2017 by the operator using the CLAAS tractor (Model: ARES 567 ATZ) in a field called Babat-völgy to the north west of Gödöllő city. By selecting the attached rear tool (CLAAS LINER 450T) as an AOI. The experimental trials were conducted successfully and results are obtained and analysed accordingly.

4.2.1 Windrowing operation recording results

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. 14.

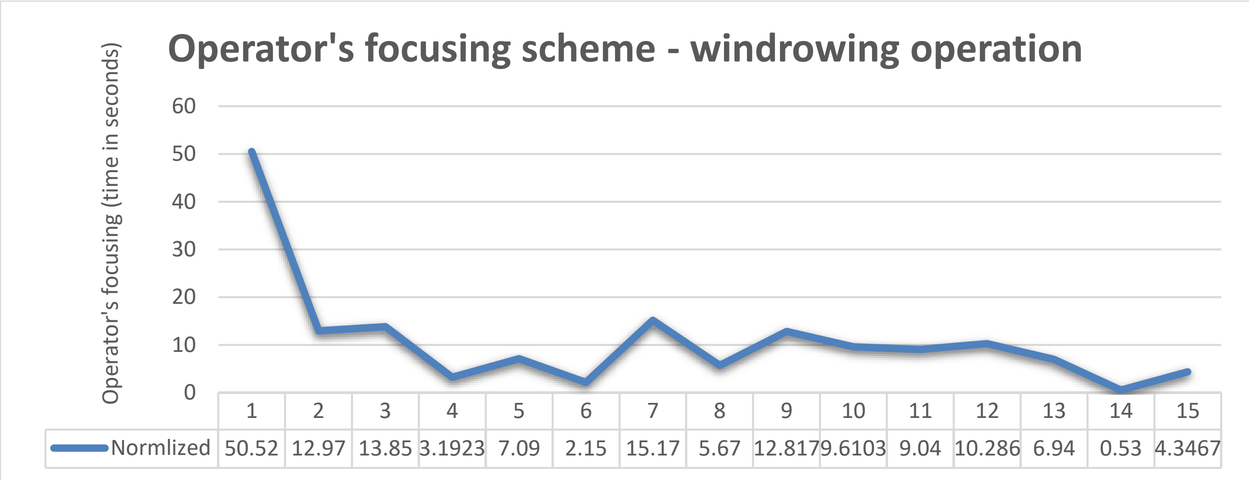

Fig. 14. Accumulated time of operator's focusing scheme for each sample in the windrowing operation

4.2.2 Excluded samples

Because it was the first real-time recording experience for the selected operator, the first four samples are excluded from the modelling scope to avoid any misleading inputs due to the familiarization process of the operator with the system configuration. Which required joining the operator in the tractor cabin to explain the mechanism and the target behavior.

4.2.3 Curve fitting results

The curve fitting operation is conducted using the MATLAB Curve Fitting Toolbox™, the resulted curves for the windrowing operation as shown in Fig. 15.

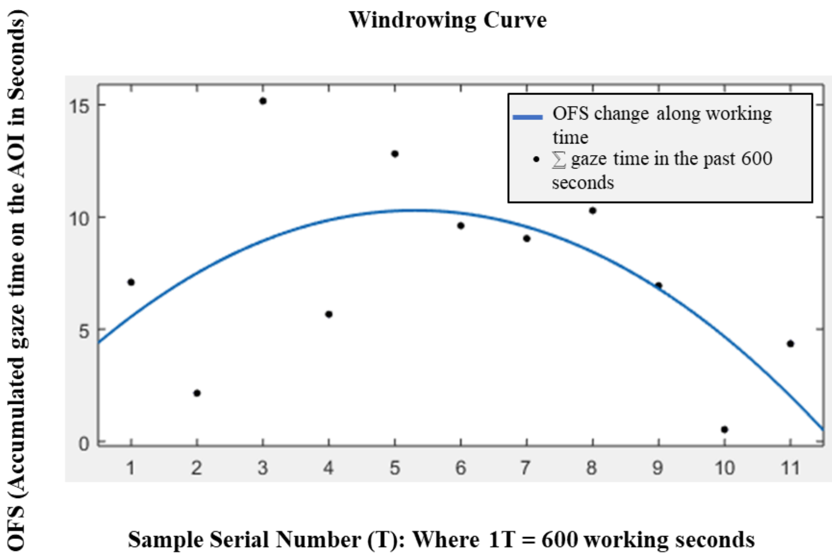

Fig. 15. Results of curve fitting for windrowing agricultural operation

4.2.4 Modelling results

The resulted data was processed selecting the Linear model (Poly 2) which generates a polynomial equation with the second degree and using Bi-square robust method.

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 attached windrowing tool during working time in the windrowing operation developing the model describing the change on the OFS along working time Xwindr (T) where T is the sample number and represents the past 600 working seconds:

$$Xwindr(T) = 3.103 + 2.71T - 0.2554T^2$$

3.3. Cultivating operation results

The cultivating operation trials were conducted along two days in October 2017 by the operator using the CASE tractor (Model: 7210) in a field beside Gödöllői airport to the south west of Gödöllő city.

By selecting the attached rear tool as an AOI, the experimental trials were conducted successfully and results are obtained and analysed accordingly.

4.3.1 Cultivating operation recording results

Putting the resulted data of accumulated time of each sample on the y-axis 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. 16 for the first day and in Fig. 17 for the second day.

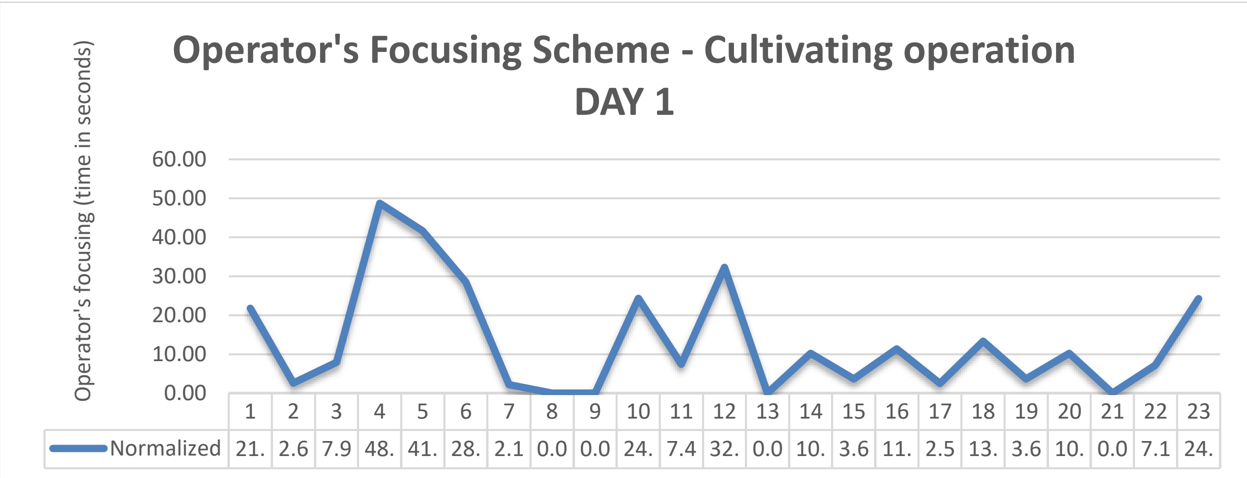

Fig. 16. Accumulated time of operator's focusing scheme for each sample in cultivating agricultural operation – Day1

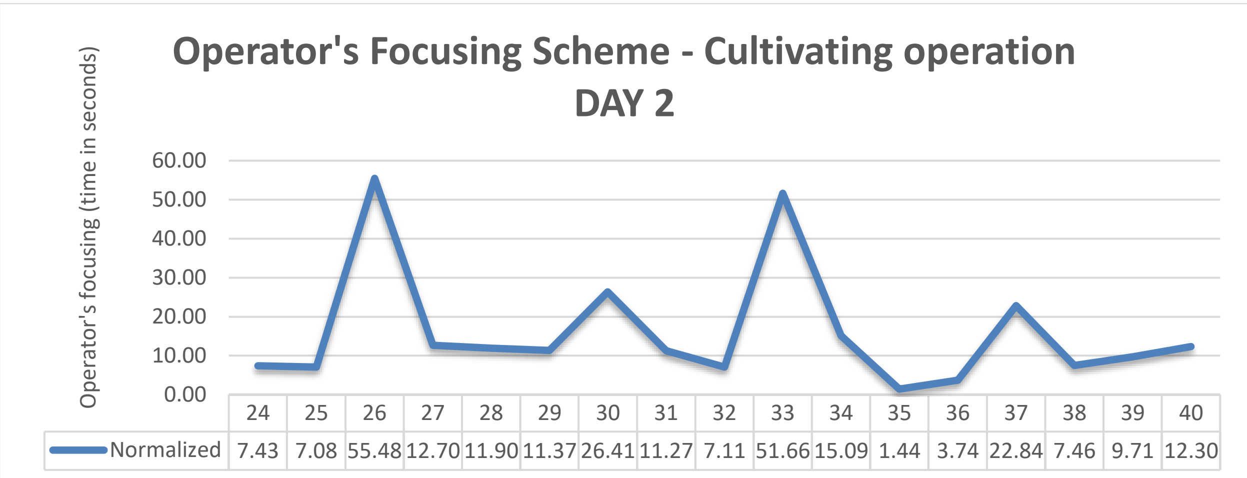

Fig. 17. Accumulated time of operator's focusing scheme for each sample in cultivating agricultural operation – Day2

4.3.2 Curve fitting results

The curve fitting operation is conducted using the MATLAB Curve Fitting Toolbox™, the resulted curves for the cultivating operation for the first and the second day as shown in Fig. 18.

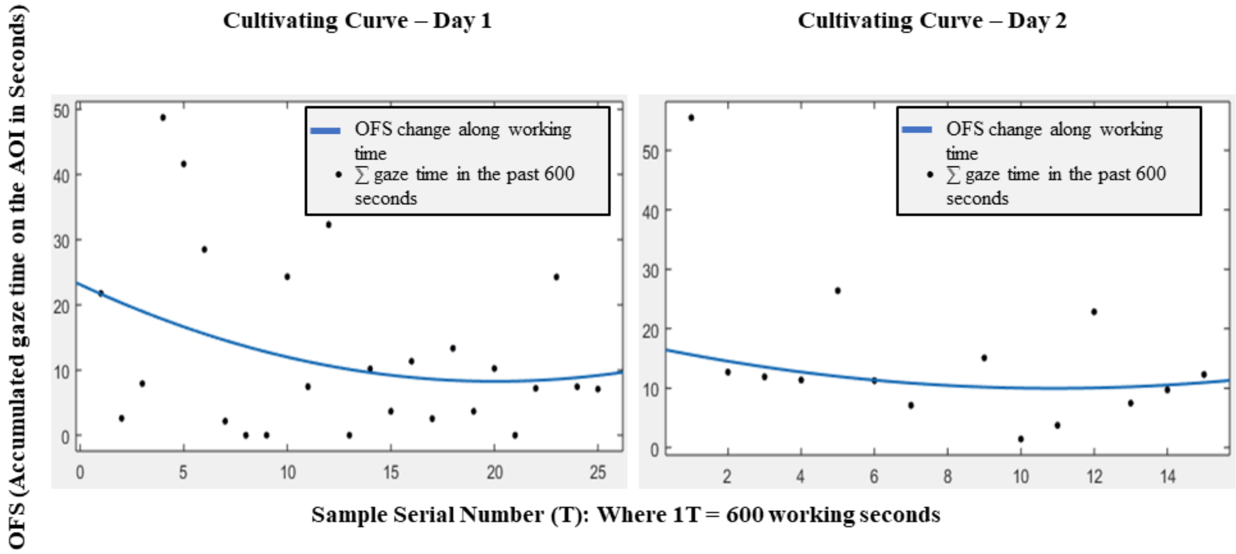

Fig. 18. Results of curve fitting for cultivating agricultural operation – day 1 and 2

4.3.3 Modelling results

The resulted data was processed selecting the Linear model (Poly 2) which generates a polynomial equation with the second degree and using Bi-square robust method.

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 attached windrowing tool during working time in the cultivating operation developing the model describing the change on the OFS along working time Xcult (T) where T is the sample number and represents the past 600 working seconds:

Day 1 resulted model: $Xcult(T) = 23.10 - 1.480T + 0.03691T^2$

Day 2 resulted model: $Xcult(T) = 16.81 - 1.256T + 0.05763T^2$

3.4. Harvesting operation results

The harvesting operation experimental trials were conducted along one day in October 2017 by the operator using the CLAAS Dominator 202 in a field beside Gödöllői airport to the south west of Gödöllő city.

By selecting the attached front harvesting tool as an AOI, the experimental trials were conducted successfully and results are obtained and analysed accordingly.

4.4.1 Harvesting operation recording results

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. 19.

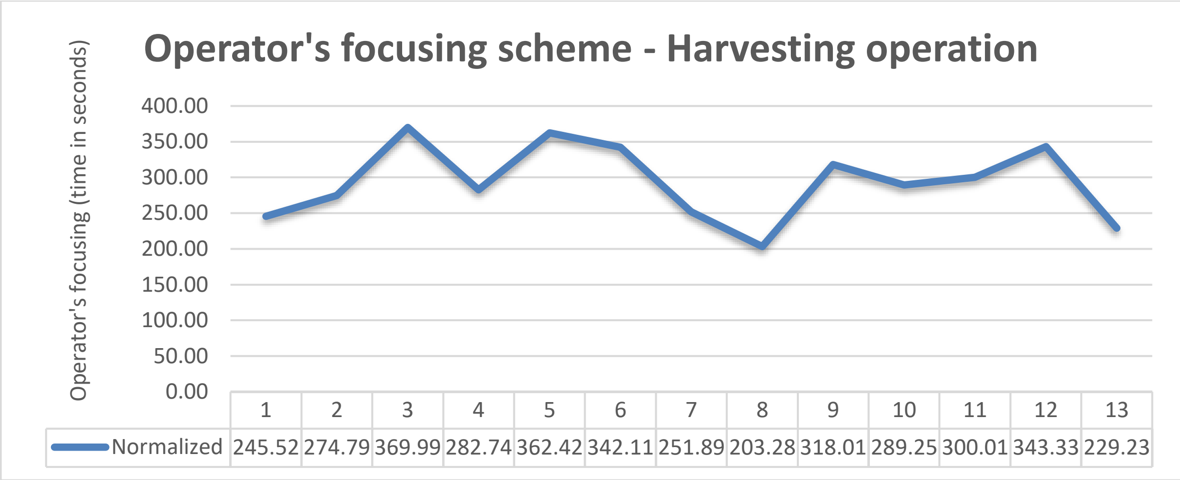

Fig. 19. Accumulated time of operator's focusing scheme for each sample in harvesting agricultural operation

4.4.2 Curve fitting results

The curve fitting operation is conducted using the MATLAB Curve Fitting Toolbox™, the resulted curves for the harvesting operation as shown in Fig. 20.

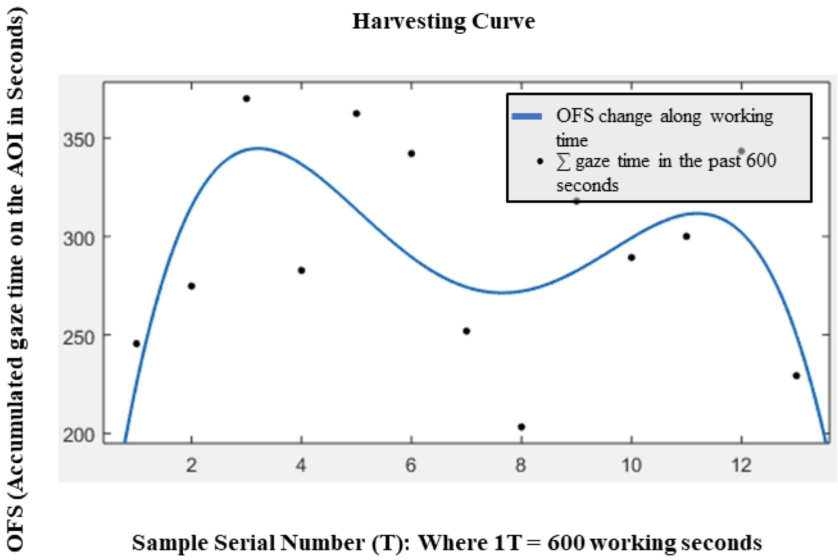

Fig. 20. Results of curve fitting for harvesting agricultural operation

4.4.3 Modelling results

The resulted data was processed selecting the Linear model (Poly 4) which generates a polynomial equation with the fourth degree and using Bi-square robust method.

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 time Xharv (T) where T is the sample number and represents the past 600 working seconds:

$$Xharv(T) = 43.6 + 239.2T - 63.58T^2 + 6.397T^3 - 0.2175T^4$$

3.5. Developed models of the selected agricultural operations

The curve fitting operation is conducted using the MATLAB Curve Fitting Toolbox™, the resulted curves for the windrowing in Fig. 15, cultivating in Fig18 and harvesting operations in Fig. 20

The resulted models and the goodness of fit is shown in Table. 4.

Table. 4. Resulted models and the goodness of fit

Windrowing operation model	**Cultivating operation model (day 1)**	**Cultivating operation model (day 2)**	**Harvesting operation model**
Linear model Poly2: f(x) = p1*x^2 + p2*x + p3 p1 = -0.2554 p2 = 2.71 p3 = 3.103 Goodness of fit: R-square: 0.2598 RMSE: 4.221	Linear model Poly2: f(x) = p1*x^2 + p2*x + p3 p1 = 0.03691 p2 = -1.48 p3 = 23.1 Goodness of fit: R-square: 0.0713 RMSE: 13.62	Linear model Poly2: f(x) = p1*x^2 + p2*x + p3 p1 = 0.05763 p2 = -1.256 p3 = 16.81 Goodness of fit: R-square: 0.5506 RMSE: 11.61	Linear model Poly4: f(x) = p1*x^4 + p2*x^3 + p3*x^2 + p4*x + p5 p1 = -0.2175 p2 = 6.397 p3 = -63.58 p4 = 239.2 p5 = 43.6 Goodness of fit: R-square: 0.2816 RMSE: 54.34

The selection criteria considered the common nature of agricultural operations, the AOI, the use of vehicles, the use of same operational conditions regarding the covered cabin and the use of same operator. Which all contributes to accomplish unified inputs keeping on the realistic implementation behaviour of the operator.

The nature of the selected agricultural operations includes the routine tasks; in which the operator needs to be involved is adding on the mental load due to monitoring of the vehicle track and the accumulated physical fatigue due to checking and monitoring the rear attached and the front mounted tools.

All resulted readings are represented in the modelling part which makes it beneficial to describe some sources of uncertainties. Studying the operator’s behaviour requires to take all readings as to reflect the real situation as much as practically possible.

During the experimental trials the operator used his cell phone listen to some music, making phone calls and even texting. However; being looking to the mobile phone screen with a tool or a dashboard in the background makes it notable for the operator to shuffle his attention when it is required.

High values of the root mean square error (RMSE) are noted for some developed models, the justification to such values are related to mission specific issues. The main cause of big differences between the sample value and the next or previous sample is paying an extra attention by the operation to the attached tool and steering at the field edges, in where the operator needs to disengage the attached tool from the operation temporary to make the turn and to steer toward the next bath and thereafter; to re-engage the tool to the operation mode again.

The accumulated gaze time which operator is paying continuously to the tool will be reflected in some samples twice while it is not taken place in the next or the previous sample.

In addition to having different numbers of situations requires more attention from the operator per sample, a notable increase in the accumulated gaze time after the short break time which the operator takes to change the battery of the recording unit and stretch out during the recalibration process.

Additionally, some operations have some break time for the operator during the process, just like the harvesting agricultural operation during transferring the harvested load to a container emptying the vehicle internal tank.

In the differences in the resulted models in Fig. 21 where the orange arrows are representing the decreasing nature of the operator's focusing scheme along working hours which is clearly showing the difference of the harvesting operation on the other resulted three curves (two days for cultivating operation and the windrowing operation).

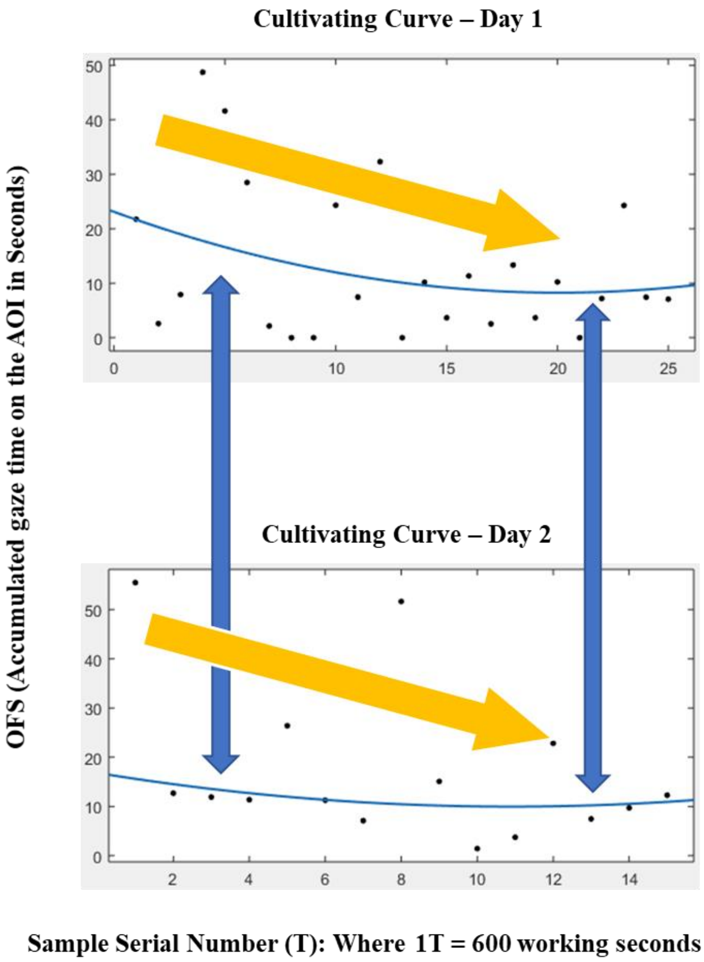

Fig. 21. The cultivating models for the 2 working days

At the beginning of the resulted curves for the windrowing and harvesting models are showing an increment area in prior to starting the decreasing nature of the resulted curves.

While it is noted that, the cultivating operation started in decremental nature for the first few samples of the two resulted models of the same operation along the two working days. Which is shown in Fig. 22 where the blue shaded areas are presenting the increment of operator's focusing scheme along the few early recorded samples in the windrowing and harvesting agricultural operations, while it is not the situation in the two resulted models for the same agricultural operation of cultivating.

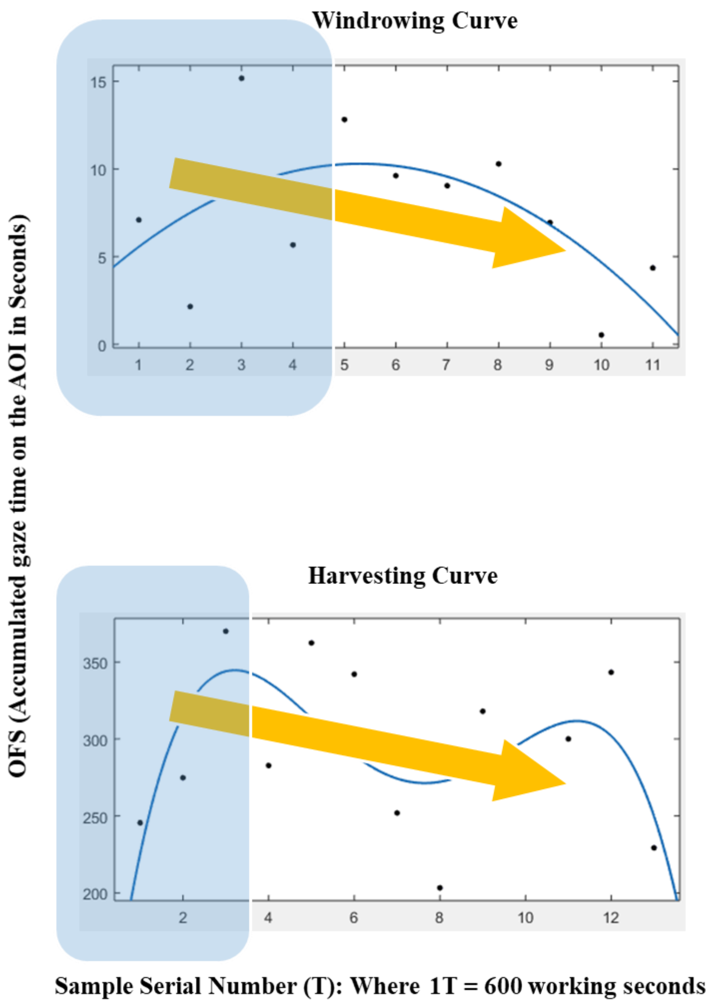

Fig. 22. The windrowing and harvesting models

3.6. Least spotted equipment in baling operation

The exported results in Table. 5 showed the duration along which the operator paid attention to each area of interest.

Table. 5. Experiment results

AOI	Duration in Seconds
Front dashboard	12.01
Side panel	31.69
Left mirror	110.23
Right mirror	143.24
Attached tool	139.64

The analysis of the recorded sample from baling agricultural operation showed that; clearly; the operator spent the most of his time, after the main task of driving and keeping the way on the planned track, in checking the attached tool using the side mirrors and direct check of the attached tool (139.64 + 143.24 + 110.23) which is presenting 26.6% of the total recording time.

In accordance to the validated method, the deterministic data showed; clearly; the least areas of interest equipped the attention of the operator as the percentages showed in Fig. 23 which shows that the dashboard and the side panel AIOs the least Areas of interest during the baling operations.

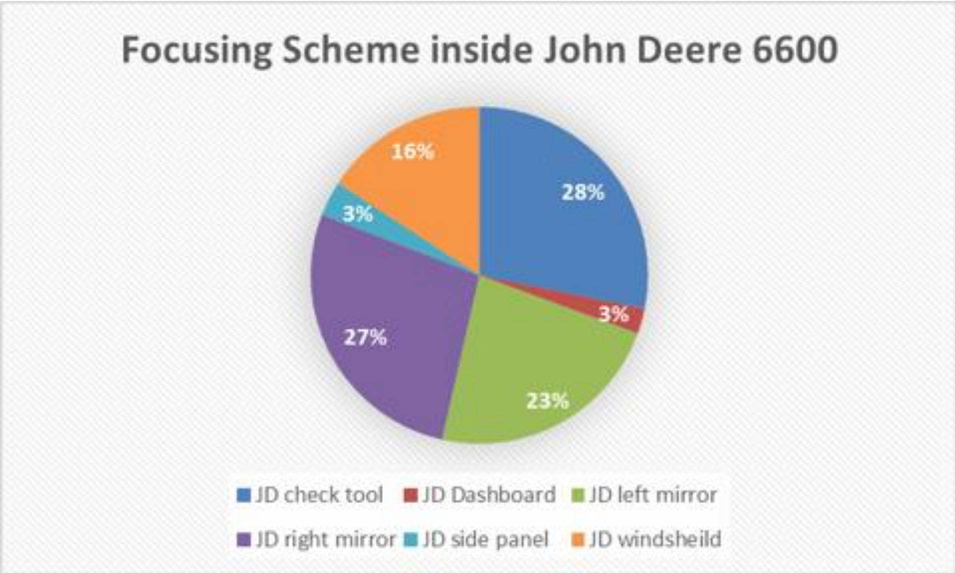

Fig. 23. The resulted AOIs percentages for operator's focusing scheme inside John Deere 6600 tractor during baling operation

The methodology of this research is proven to be utilized when and where it is necessary to ensure the safety and productivity of the conducted operation.

The human factor impact on the safety and productivity of the operation is considered very crucial to the success achievement of the planned targets. Aviation field is an obvious example on the importance of the human factor as an essential part of the work mechanism success. Starting of the pilot and cabin crew readiness to handle the accumulated fatigue issue passing through aviation maintenance organizations and the implementation of the right procedure and correctly accomplish all planned activities by technicians and engineers.

4. NEW SCIENTIFIC RESULTS

In this section, the unique results; which represent a new contribution to the literature; are presented.

1. Design and validation of the method for measuring the operator's focusing scheme

I have designed the method including procedures and process maps to measure the operator's focusing scheme, and I have utilized the results to create different models for operator's focusing scheme change along working hours in several agricultural operations.

2. The change of operator's focusing scheme along working hours in the windrowing operation

I have collected the results of the operator's gaze on the rear attached windrowing tool, as a selected area of interest, along full working day in the field. I have developed the model describing the change on the OFS along working time in the windrowing agricultural operation, Xwindr (T) where T is the sample number and represents the past 600 working seconds:

$$X\text{windr}(T) = 3.103 + 2.71T - 0.2554T^2$$

3. The change of operator's focusing scheme along working hours in the cultivating operation

I have collected the results of the operator's gaze on the rear attached cultivating tool, as a selected area of interest, along full two working days in the field. I have developed the model describing the change on the OFS along working time in the cultivating agricultural operation, Xcult (T) where T is the sample number and represents the past 600 working seconds:

Day 1 resulted model: $Xcult(T) = 23.10 - 1.480T + 0.03691T^2$

Day 2 resulted model: $Xcult(T) = 16.81 - 1.256T + 0.05763T^2$

4. The change of operator's focusing scheme along working hours in the harvesting operation

I have collected the results of the operator's gaze on the front mounted harvesting tool, as a selected area of interest, along full working day in the field. I have developed the model describing the change on the OFS along working time in the harvesting agricultural operation, Xharv (T) where T is the sample number and represents the past 600 working seconds:

$$Xharv(T) = 43.6 + 239.2T - 63.58T^2 + 6.397T^3 - 0.2175T^4$$

5. The numerical representation of operator's focusing scheme along working hours

I have analyzed the recorded sample from windrowing and cultivating agricultural operation, and I proved the evidential fact, based on deterministic approach, that the operator focusing scheme is decreasing along working hours which is related to the increment of physical and mental load as the time of the agricultural operation conducting. I have demonstrated by numeric representation the trends of operator's focusing scheme change along working hours and its differences based on the nature of the agricultural operation.

6. Defining the least spotted equipment in the baling operation

I have used the developed method to spot the least areas took the attention of the operator inside the tractor cabin in the baling agricultural operation to the purpose of current cabin designs evaluation as well as for comparison purposes following a deterministic approach to support the decision-making process in enhancing current cabins with new technological solutions and for considering that approach during the early design stages of new cabins.

5. CONCLUSIONS AND SUGGESTIONS

In conclusion, 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 behavior 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 R^2 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.

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.

The method of research is providing the decision-making process with deterministic data regarding the least and most AOIs sportified by the operator along working hours. Such results are expected to be used to estimate many things including a comparison tool between prototypes of new cabin designs, workload of different operations, operating different vehicles… etc., based on deterministic measures. Additionally; the feasibility of improving cabin designs with new technological solutions based on deterministic data (i.e. cameras and screens instead of mirrors and/or rear cameras to watch the attached tools) in order to reduce the accumulated passive fatigue. Moreover; such a method of research is expected to be used to find out the suitable place to host new components inside the cabin based on the analysis of gaze counts and concentration.

6. SUMMARY

OPERATOR'S FOCUSING SCHEME INSIDE OFF-ROAD VEHICLES

In summary, I have designed the experimental procedures and process maps to execute the full scope of the experimental trials. Firstly; I checked for the required validation for assessing the operator's focusing scheme method before it is used to conduct the real-time experimental trials. And then I developed the extended procedures and process map to manage the results and build the regression models for different agricultural operations.

I have executed the documented experimental procedure along one full day in the field and I developed the model of which representing the change on the OFS along working hours for the windrowing agricultural operation. I have selected the attached rear windrowing tool as an area of interest due to the required physical interaction by the operator to check and steer on a continuous base. I found that; the OFS is decreasing along working hours.

I have developed two models of which representing the change on the OFS along working hours for the cultivating agricultural operation during two working days. Selecting the attached rear cultivating tool as an area of interest due to the required physical interaction by the operator to check and steer on a continuous base. It is found that; the OFS is decreasing; with a similar behavior comparing the two days generated models; along working hours.

I have developed the model of which representing the change on the OFS along working hours for the harvesting agricultural operation. Selecting the front mounted harvesting tool as an area of interest due to the required interaction by the operator to check and steer on a continuous base. It is found that; the OFS is decreasing (in a slower and different behavior than the previous two agricultural operations) along working hours.

I have conducted the analysis of the recorded sample from windrowing and cultivating agricultural operation and it is showed that, clearly, the operator focusing scheme is decreasing along working hours which is related to the increment of physical and mental load as the time of the agricultural operation conducting. While the nature of the harvesting agricultural operation showed a different change on the behavior in which the tool is front mount, however the operator's focusing scheme showed decreasing behavior in slower trend than other operations in which the rear attached tool which requires relatively more physical effort to turn back and check the rear tool on a continual base, that is correlated to the change in the increment of physical fatigue.

In accordance to the validated method, I have determined; clearly; the least areas of interest equipped the attention of the operator as percentages based on the deterministic data in the baling agricultural operation as an example. And I proved that the developed method is readily to be implemented to the purpose of current cabin designs evaluation as well as for comparison purposes following a deterministic approach to support the decision-making process in enhancing current cabins with new technological solutions and for considering that approach during the early design stages of new cabins.

7. THE MOST IMPORTANT PUBLICATIONS RELATED TO THE THESIS

Refereed papers in foreign languages:

1. **Hushki, M.,** Kátai, L., Szabó, I. (2016): Experimental study: operator's behavior measuring inside off-road vehicle cabin (operator's focusing matrix and response time), Mechanical Engineering Research, Vol. 14. 2016., pp. 160-169. HU ISSN 2060-3789 .
2. El-Hagary, E., **Hushki, M.,** Szabo, I. (2017): Fuzzy logic model approaches for water saving in irrigation systems, European Journal of Academic Essays, Vol. 4(4). 2017., pp. 157-165. ISSN 2183-3818
3. Szabó, I., **Hushki, M.,** Bártfai, Z., Kátai, L. (2017): Operator's behavior measuring methodology inside off-road vehicle cabin, operator's focusing scheme, Agronomy Research, Estonia, Vol. 15(5), 2172-2182, 2017. ISSN 1406-894X (Q2).
4. Szabó, I., **Hushki, M.**, Bártfai, Z., Kátai, L.: Operator's focusing scheme measuring inside a multi-tasking off-road vehicle. In: Hungarian Agricultural Engineering, Vol. 33. 2018., pp. 30-37. HU ISSN 0864-7410 (Print) / HU ISSN 2415-9751(Online) https//:doi.org/10.17676/HAE.2018.32.30
5. Szabó, I., **Hushki, M.,** Bártfai, Z., Lágymányosi, A., and Kátai, L.: Modelling of operator's focusing scheme along working hours: windrowing and cultivating operations, Agronomy Research, Estonia, Vol. 16(4), 1885-1895, 2018. ISSN 1406-894X (Q2). https://doi.org/10.15159/AR.18.155.
6. Szabó, I., **Hushki, M.,** Bártfai, Z., Lágymányosi, A., and Kátai, L.: Modelling of operator's focusing scheme along working hours: harvesting operation, Agronomy Research, Estonia, 2019. ISSN 1406-894X. (Q2). https://doi.org/10.15159/AR.19.026.

International conference abstracts:

7. Szabó, I., **Hushki, M.,** Bártfai, Z., Kátai, L. (2017): Operator's focusing Scheme measuring inside a multi-tasking off-road vehicle. V. SYNERGY International Conference, V. International Conference of CIGR Hungarian National Committee and the Szent István University, Faculty of Mechanical Engineering and the XXXVIII. R&D Conference of Hungarian Academy of Sciences, Committee of Agricultural and Biosystems Engineering. Gödöllő 16-19. October 2017. Abstracts, p. 83. ISBN 978-963-269-680-5
8. Szabó, I., **Hushki, M.,** Bártfai, Z., Kátai, L. (2017): Operator's behavior measuring methodology inside off-road vehicle cabin, Operator's focusing scheme, Book of Abstracts. 8th International Conference on Biosystems Engineering, Estonian University of Life Sciences, Estonia, p. 102. ISBN: 978-9949-536-81-8
9. Szabó, I., **Hushki, M.**, Bártfai, Z., Kátai, L., Lágymányosi, A. (2018): Examination of the driver's focusing scheme during precision agriciultural operation. In Jakab G., Tóth Ané, Csengeri E.: Alkalmazkodó Vízgazdálkodás: Lehetőségek és kockázatok. Víztudományi Nemzetközi Konferencia. 326 p. Konferencia helye, ideje: Szarvas, Magyarország, 2018.03.22 Szarvas: Szent István Egyetem Agrár- és Gazdaságtudományi Kar, 2018. pp. 1-6. ISBN:978-963-269-736-9

Book chapter in foreign languages:

10. Szabó, I., **Hushki, M.**, Bártfai, Z., Kátai, L. (2017): Design aspects of flat plate solar collectors used for drying applications, Towards sustainable agricultural and biosystems engineering, /ed. by A. Nyéki, A.J., Kovács, G. Milics/, Universitas-Győr Nonprofit Ltd, 2017, pp. 191-206, ISBN 978-615-5776-03-8