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Human online reliability estimation applied to real driving maneuvers

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***Abstract*—Traffic safety is mainly affected by human factors and related human reliability. During the driving process, effects of human factors, such as fatigue and vigilance, on driving safety have been widely discussed. Human reliability is less considered, especially in situated driving context. Human reliability is a commonly used concept in probability assessment context. Many approaches have been developed in human reliability analysis (HRA). Cognitive reliability and error analysis method (CREAM) provides a human cognitive model called contextual control mode (COCOM) and a method to describe and evaluate the most significant factors in context as common performance conditions (CPCs). Based on CREAM, reliability of human operators can be evaluated. However, due to the application limits of CPCs in CRERAM, it is advised to generate a new list of CPCs for the application domain, if the CREAM approach is applied to other domains. In this contribution, a new approach defining a situated and dynamical human reliability measure is established as no approach exists for a dynamic context. The approach is based on the well-known CREAM approach, which is modified with respect to the use in dynamical context. The new list of CPCs is generated to illustrate the features of situated driving context. Furthermore the reliability estimation is understood as a dynamic task with changing conditions leading to a dynamical change of reliability properties. Driving data collected by driving simulator are processed, the effects of experimental sequences and scenarios on reliability of human drivers are analyzed. Reliability of human drivers in situated driving context can be estimated by the newly introduced human performance reliability score (HPRS). The results indicate the applicability of the proposed approach. The new approach first time realizes the evaluation of human online reliability in situated driving context.**

***Index Terms*—human online reliability, modified CREAM, driving simulator, HPRS, situated driving context**

I. Introduction

Driving safety is always within the focus of transportation administration and related researchers due to the requirement of decrement of traffic accidents and traffic density [1]. Meanwhile, constantly complex road traffic system makes the driving context complicated. Increasing traffic flow induces the increase of drivers' workload, which continuously effects human reliability of driving maneuvers. Although some advanced driver assistance systems (ADAS), such as forward collision warning system and lane keeping assistance system, have been developed to assist human driver and therefore to make driving safer, human driver is still the key to ensure driving safety [2]. The idea of this contribution is to understand the reliability of human drivers as to be defined in real-time, so that - as example - some warnings or suitable information can be given to the driver when the reliability is below a predefined threshold. The key idea of this paper is therefore the definition of a suitable reliability property which can be calculated and used online.

The concept of human reliability has been widely used in industrial settings by human factors experts to optimize the human-task fit [3]. Human reliability analysis (HRA) is the risk analysis concerned with identifying, analyzing, and quantifying the causes, contributions, and occurrence of human failures. The so called 'first generation methods' have been developed with features broadly to task analysis and probabilities for human errors. The so called 'second generation' aims more on shaping factors and operation environment, and less on individual errors [4].

However, no approach exists for a dynamic context. To transfer the notion to the measurement of human reliability into situated driving context, the following components are necessary: elements for the definition of driving context, levels for the description of driving context and their corresponding effects on human reliability. Based on these features, the cognitive reliability and error analysis method (CREAM) is considered as it provides a cognitive model and an easy contextual description for the estimation of human reliability [5].

In assisted mode, evaluated driver reliability can be used as input to determine whether driver's behavior is equivalent to the driving and traffic situation or not. If not, corresponding maneuver suggestions may be given to effect the awareness with the goal to enable situated safe behavior. In some cases, the automated system may takeover driving tasks if driver's reliability is consistently low. In addition, driver reliability may be inputted to proved action performance assistance to driver(e.g. braking support) [6]. Therefore, a method to evaluate drivers' reliability online is promising.

This contribution is organized as follows: in Section II, an overview of original CREAM is given. The modified CREAM including a new concept of human performance reliability score (HPRS) to calculate human reliability over time is also introduced in detail in this section. The driving simulator experiment and the results are illustrated in Section III. The conclusion is provided in Section IV.

II. Modified CREAM approach

A. Original CREAM

The CREAM approach is a practical approach for performance analysis as well as attendant prediction. This approach is able to conduct a retrospective analysis of historic events and a prospective analysis for the design of high-risk systems or processes. The core idea of CREAM is that human error is shaped by both context and human nature. The context is described in terms of control mode which is the degree of control that the operator has over the situation [7].

- Contextual control mode
  The cognitive model used in CREAM is denoted as contextual control mode (COCOM). It is assumed that the degree of control can be determined by the context under which human operators perform their tasks. Four control modes are defined in COCOM for the description of degree of control, which are scrambled control, opportunistic control, tactical control, and strategic control. Each control mode corresponds to different human reliability interval in which strategic control has the highest reliability and scrambled control is related to lowest reliability.
- Common performance conditions
  Nine common performance conditions (CPCs) are defined as the most significant factors representing the operation context. These nine CPCs are adequacy of organization, working conditions, adequacy of MMI and operational support, availability of procedures/plans, number of simultaneous goals, available time, time of day (circadian rhythm), adequacy of training and experience, and crew collaboration quality. Each CPC has several different levels, and corresponding expected effect on performance reliability.

When the effect on performance reliability of each CPC is determined, CPC score can be identified as [$\sum$reduced, $\sum$improved], where $\sum$reduced represents the sum of reduced effects on performance reliability and $\sum$improved means the sum of improved effects on performance reliability. The control mode is then identified with a relation map between CPC score and control modes which is shown in Fig.1.

From the CPCs in the original CREAM approach, this approach is primarily applied in the human reliability analysis in industry, such as spaceflight application [8], process industry [9], and marine engineering [10]. It is advised to generate a new CPCs list adequate for application domain, if CREAM approach needs to be applied to another domain [11].

In driving processes, the situated driving context is continuously changing, and the changing context can then revise driver's behavior and reliability in real time. So new CPCs should be identified to characterize the situated driving context.

B. Selection of new CPCs

The CPCs provide a comprehensive and well-structured basis for characterizing the conditions under which the performance is expected to take place. To characterize the domain features of situated driving context, nine new CPCs are identified. The new list of CPCs is shown in Table I.

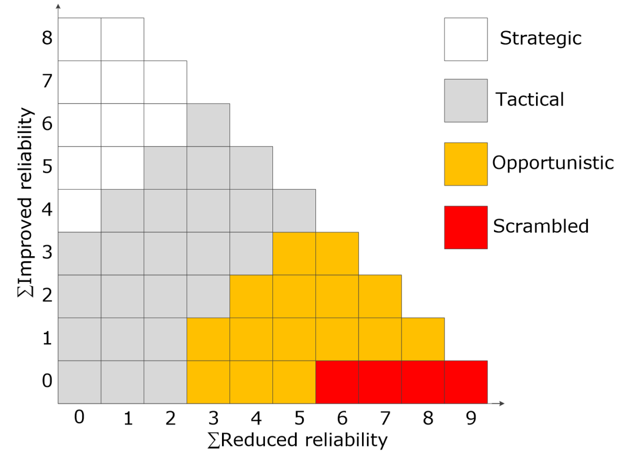

Fig. 1. Relations between CPC score and control modes (adapted from [5])

- Number of surrounding vehicles
  The behavior of ego-vehicle is affected by surrounding vehicles as driving context could be more complex when more vehicles are surrounded. Surrounding vehicles can be defined as vehicles that the time to collision (TTC) of front/rear vehicles, and vehicles in the adjacent lanes to ego-vehicle is less than 1.5 s [12].
- Time to collision (TTC)
  Time to collision (TTC) is an important parameter to indicate the time it would take a following vehicle to collide with a leading vehicle [13]. This parameter can be used to characterize the safety of vehicle following and lane changing. When TTC $\geq$ 5.5 s, human driver has enough time to complete different operations, like lane changing, or braking, so the effect on performance reliability is improved. The case TTC of 2.5 s could be regarded as the lower threshold that should be avoided in normal traffic conditions [14]. When TTC $\leq$ 2.5 s, abilities of the driver to handle the situation are limited, so the effect on performance reliability is reduced.
- Ego-vehicle speed
  Ego-vehicle speed is important to characterize driving behavior in driving safety issues. Some human physiological characteristics, which could influence performance reliability of drivers, are affected by driving speed. Thresholds of 80 km/h and 110 km/h can separate speed into three levels. Effect on performance reliability is improved when speed is less than 80 km/h, while is reduced when speed is larger than 110 km/h.
- Longitudinal acceleration
  Acceleration, which can be divided into longitudinal and lateral acceleration, is fundamental to define the behavior of the driver as it describes the motion of the vehicle. Acceleration is closely related to driving speed for safety driving. The relationship between longitudinal

TABLE I
NEW CPCS AND PERFORMANCE RELIABILITY

CPC name	Level/description		Expected effect on performance reliability
Number of surrounding vehicles (N)	N=0		Improved
	1⩽N⩽3		Not significant
	N⩾4		Reduced
Time to collision (TTC)	TTC>5.5 s		Improved
	2.5⩽TTC⩽5.5 s		Not significant
	TTC<2.5 s		Reduced
Ego-vehicle speed	V⩽22 m/s		Improved
	22<V⩽30 m/s		Not significant
	V>30 m/s		Reduced
Longitudinal acceleration	V⩽22 m/s	a⩽1.60 m/s²	Improved
		1.60<a⩽2.32 m/s²	Not significant
		a>2.32 m/s²	Reduced
	22<V⩽30 m/s	a⩽1.13 m/s²	Improved
		1.13<a⩽1.60 m/s²	Not significant
		a>1.60 m/s²	Reduced
	V>30 m/s	a⩽1.13 m/s²	Not significant
		a>1.13 m/s²	Reduced
Lateral acceleration	V⩽22 m/s	a⩽1.48 m/s²	Improved
		1.48<a⩽2.15 m/s²	Not significant
		a>2.15 m/s²	Reduced
	22<V⩽30 m/s	a⩽1.05 m/s²	Improved
		1.05<a⩽1.48 m/s²	Not significant
		a>1.48 m/s²	Reduced
	V>30 m/s	a⩽1.05 m/s²	Not significant
		a>1.05 m/s²	Reduced
Traffic density	Low (⩽7)		Improved
	Medium (8-14)		Not significant
	High (⩾15)		Reduced
Number of available lanes	One lane		Improved
	Two lanes		Not significant
	Three lanes		Reduced
Actual lane	The first lane (The right lane)		Improved
	The second lane (The middle lane)		Not significant
	The third lane (The left lane)		Not significant
General visibility conditions	Daytime with sunny weather		Improved
	Early morning or nightfall with sunny weather		Not significant
	Evening or foggy or rainy or snowy		Reduced

acceleration and vehicle speed has been concluded in [15], [16].

- Lateral acceleration
  The relationship between longitudinal acceleration and lateral acceleration is explained in [15], as the longitudinal acceleration is 0.925 times the lateral acceleration.
- Traffic density
  Traffic density defines the average number of vehicles occupying one kilometer of traffic lane. Driving behavior and drivers' emotion are affected by traffic density. Higher traffic density (approximately 15 vehicles per kilometer) could result in higher workload and demand compared to lower traffic density situations (approximately 7 vehicles per kilometer) [17], [18].
- Number of available lanes
  Number of available lanes represents the complexity of traffic situations. More available lanes give drivers more safety redundancy that drivers have more choice when emergency events are encountered.
- Actual lane
  Following the traffic rules in Germany, vehicles should keep running at the most right lane. It is only allowed to overtake from the left lane. Vehicles need to return to the right lane after overtaking, long-term use of the left lane is not allowed. These traffic rules will affect driving behavior of drivers in different lanes.
- General visibility conditions
  General visibility conditions affect perception level of drivers on surrounding context. With low visibility conditions, many context information could not be captured by drivers, which may have high risk on vehicle driving.

C. Calculation of human reliability score

In modified CREAM, after the identification of levels of CPCs, the CPC score could be determined as [$\sum$reduced, $\sum$improved]. The control mode can be identified. This method is valid when used for reliability assessment of operation as a whole, or major segments of the operation in situated context.

In this contribution, a new concept of defining human performance reliability score (HPRS) is introduced to continuously calculate the performance reliability of human operators in dynamic context. The equation is

$$HPRS = \lambda_1 \cdot \sum reduced + \lambda_2 \cdot \sum improved, \quad (1)$$

where λ denoting related weights. Here λ = 1, denotes improving effects, which λ = -1 reducing effects.

Combining the control modes corresponding to CPC score in orginal CREAM, HPRS could be identified into four levels. They are strategic level (4≤HPRS≤9), tactical level (-1≤HPRS≤3), opportunistic level (-5≤HPRS≤-2), and scrambled level (HPRS≤-6). Each level represents the corresponding reliability of human driver, where HRS in strategic level has the highest reliability, and HRS in scrambled level has the lowest reliability. In the same levels, larger HRS means higher reliability. In this case, the reliability of human driver in every time spot (depending on time slot of data acquisition) could be identified, so reliability of human driver could be evaluated continuously with time.

III. EXPERIMENTAL RESULTS

A. Description of data generation platform

A professional driving simulator SCANeR^{TM} studio as shown in Fig. 2 is used to collect data. The simulator realize a 270° view of the driving environment, a rear view mirror, and two side mirrors. For controlling ego-vehicle, there is a base-fixed driver seat, steering wheel, and pedals are used. Data describing ego-vehicle dynamics (e.g. speed, steering angles, etc.) and surrounding interacting vehicle status (e.g. lateral shift, TTC, etc.) relative to ego-vehicle are collected allowing evaluation driver interaction behaviors also to be used for reliability analysis.

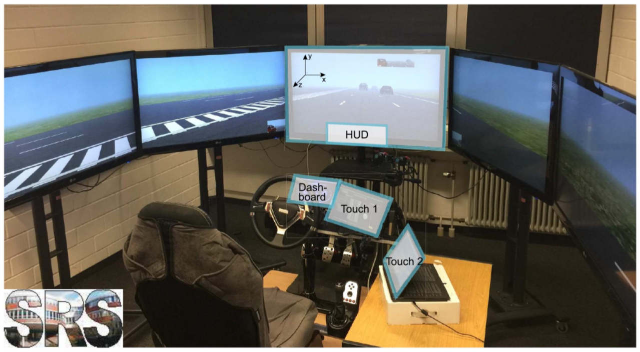

Fig. 2. Driving simulator laboratory, Chair of Dynamics and Control, U DuE

B. Scenarios description

Driving scenarios are set on a three-lane dual carriage highway. Fog, curves, and undulations are introduced to generate the real driving environment. In addition to ego-vehicle, interacting vehicles are introduced to generate situated driving context which can continually stimulate ego-vehicle driver to perform various maneuvers. Driver may change lanes, decelerate, maintain relative speed as deemed appropriate in accordance with Germany's driving rules. Therefore, participants are required to drive on right lane unless overtaking or moving at approximately the same speed as other vehicles present in other lanes. With dynamically changing driving context and corresponding to change driving maneuvers, driver's reliability varies over time.

Roads in highway scenario have their own characteristics differing from other roads, like urban roads. Highway roads are usually in closed road design, wide, flat, and less changed road conditions. These features could induce some driving issues that differ from other roads. For example, the braking distance will be extended with high speed driving. It is also easy to be fatigue with the monotonous road conditions. So the levels for the assessment of highway features are different from other driving scenarios. For instance, vehicle speed with 120 km/h is allowed in highway scenario, but it is not allowed in urban roads.

In this contribution, 4 scenarios containing two levels of level I and level II are experienced by participants. For each scenario, the main differences are the number of vehicles on the road and if there is a single lane. For scenario 2, it starts with a single lane, and for scenario 4, there is a single lane at the end of the driving. The number of vehicles on the road for different scenarios can be find in Table II. For level I and level II in the same scenario, the number of vehicles are basically the same except scenario 4. The differences in scenarios may have effects on the drivers' reliability which will be discussed later. To increase the complexity during manual driving process, drivers are asked to exit the highway and then return back. With the dynamically changing situations in driving, drivers' reliability will also fluctuate, which can be evaluated online by the proposed method.

TABLE II
NUMBER OF VEHICLES ON THE ROAD

Scenario	Number of vehicles on the road
scenario 1_ I	10
scenario 1_ II	9
scenario 2_ I	8
scenario 2_ II	9
scenario 3_ I	5
scenario 3_ II	5
scenario 4_ I	5
scenario 4_ II	12

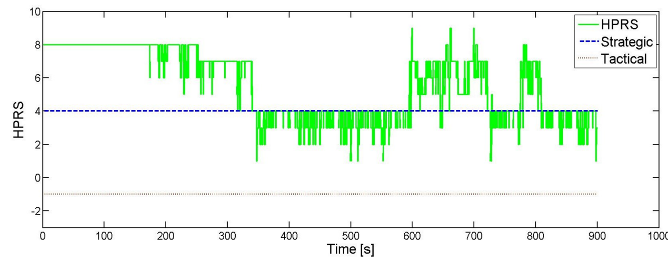

Fig. 3. The HPRS of scenario 1_II

C. Results analysis

For a principle first demonstration of the approach, six participants are involved in the simulator driving experiment, each participant needs to complete 3-4 scenarios in random sequence. The data obtained from different driving scenarios are processed based the modified CREAM approach, so drivers' reliability is evaluated by HPRS. The results of participant 6 in scenario 1_II and scenario 2_I are explained into detail as an example to illustrate how human reliability is changed. The results are shown in Fig. 3 and Fig. 4. It can be detected that driver's reliability dynamically changes with time. Meanwhile, HPRS fluctuates within the score greater than -1, which is related to tactical level. It shows that the driver has a relatively high reliability in these two scenarios. The fluctuation of HPRS denotes the changes of human reliability of the driver encountering different situations.

For the reason of the fluctuation of HPRS, the changes of each CPC in the situations should be considered. Take the

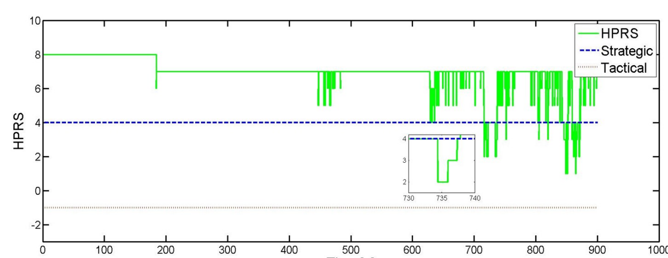

Fig. 4. The HPRS of scenario 2_I

situation at time of 734.43 s to 737.37 s in scenario 2_I as example. At 734.43 s, HPRS decreases from 4 to 2, and at 735.97 s, HPRS increases to 3, which increases to 4 again at 737.37 s.

- Example 1: Passing by a right front vehicle (t=734.43 s) At 734.43 s, the changed CPCs are number of surrounding vehicles and number of available lanes. At this time spot, the number of surrounding vehicles increases from 0 to 1 (a right front vehicle), which leads to the effect on performance reliability from improved to not significant. At the same time, the number of available lanes decrease from 2 to 1, which induces the effect on performance reliability from not significant to reduced. Other CPCs have no change. So the corresponding CPC score changes from [1,5] to [2,4] which means that the HPRS is calculated as 2.
- Example 2: Passing by a right front vehicle (t=735.97 s) At 735.97 s, the number of available lanes increase from 1 to 2, which leads the effect on performance reliability from reduced to not significant. The number of surrounding vehicles is still 1 as the right front vehicle becomes the right behind vehicle, so the number of surrounding vehicles does not change, but the number of available lanes increases. The corresponding CPC score, therefore, can be counted as [1,4] which relates to HPRS of 3.
- Example 3: Passing by a right front vehicle (t=737.37 s) At time spot of 737.37 s, the number of surrounding vehicle decreases to 0, which leads the effect on performance reliability from not significant to improved, and other CPCs are still in the same level. So the corresponding CPC score is counted as [1,5] which relates to HPRS as 4. In this case, the fluctuation of human reliability in the situation of an overtaking maneuver is recorded and evaluated.

To clearly show the effects of changing control modes and human reliability level of different maneuvers with time, the HPRS of driver with time can therefore be transformed into control modes-divided HPRS. The Fig. 3 and Fig. 4 can be transformed into Fig. 5 and Fig. 6. This can be a good indicator for drivers in assisted driving mode. When human reliability is in strategic mode or tactical mode, it means that drivers' performance is efficient and robust, so human drivers have high reliability on the situations, and the state of human reliability is monitored in real time giving drivers and the assisted driving system the feedback to check if drivers are robust in the situations. It can be considered that drivers are lack of understanding of the situations when HPRS is in opportunistic mode. In this case, some actions, such as steering wheel vibration, or audio warning, can be triggered from the assisted driving system to improve the situation awareness of drivers and get drivers back to the loop. Takeover operation could be taken by the assisted driving system directly when HPRS is in scrambled mode as drivers at scrambled mode have lower reliability than assisted driving system.

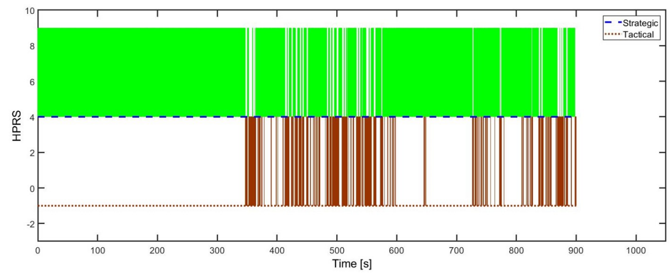

Fig. 5. Control modes-divided HPRS of scenario 1_II

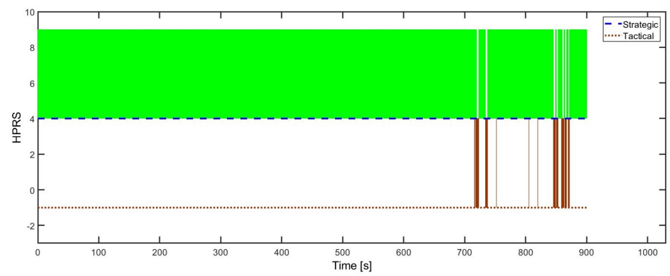

Fig. 6. Control modes-divided HPRS of scenario 2_I

D. Impact of scenarios on HPRS

From Fig. 3, it can be also obtained that in scenario 1_II, HPRS stays about 138 s in tactical mode, which accounts for 15.38 % of the total 900 s time, while HPRS is in tactical mode for 21 s in scenario 2_I, which accounts for 2.35 % of the total 900 s time. From the HPRS in this two scenarios, it can be obtained that different scenarios may have different degrees of impact on HPRS. To study the relationship between scenarios and human reliability, the experimental data of the six participants are concluded in Table III.

Based on Table III, to evaluate the impact of scenarios on HPRS, the average time percentage of level I and level II are calculated, which are 7.46 %, and 8.76 %, respectively. It can be concluded that level I and level II have almost the same impact on HPRS. The average time percentage for different scenarios from 1 to 4 are also calculated, which is shown in Fig. 7. It can be obtained that drivers in scenario 1 and scenario 4 have more time staying in tactical mode than the other two scenarios.

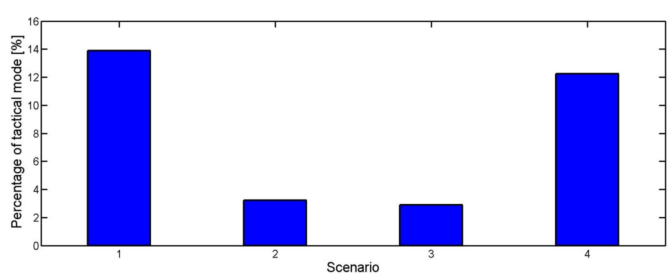

Fig. 7. Average percentage of tactical level in different scenarios

TABLE III
PERCENTAGE OF TACTICAL LEVEL IN DIFFERENT SCENARIOS

Participant	Scenario	Percentage of tactical mode [%]
P1	scenario 2_II	2.03
	scenario 1_I	19.38
	scenario 3_I	0.27
	scenario 4_II	13.99
P2	scenario 2_II	6.18
	scenario 3_I	3.55
	scenario 1_II	11.38
	scenario 4_I	20.79
P3	scenario 3_I	3.26
	scenario 1_II	7.88
	scenario 2_I	1.58
P4	scenario 2_I	0
	scenario 1_II	13.01
	scenario 4_II	5.34
	scenario 3_II	1.33
P5	scenario 4_II	9.11
	scenario 3_II	0.10
	scenario 1_I	16.25
	scenario 2_II	7.26
P6	scenario 3_I	0
	scenario 1_II	15.38
	scenario 2_I	2.35
	scenario 4_II	12.02

It can be also obtained that the experimental sequences of different scenarios have no obvious effect on human performance reliability, especially the last scenario driven by each participant. In general, when participant drives the last scenario in the experiment, participant may be fatigue or feel boring, and the situation awareness may decrease, which will leads to reduced HPRS, and the higher time percentage of weaker control mode. But in these experiments, participants did not experience this. The reason may be that the impact of different scenarios on HPRS is different as scenario 1 and scenario 4 have stronger negative effect on HPRS. Another reason may be related to the experiment process. When participants finished each scenario, they have 5-10 minutes to relax, this kind of fragmented driving enables participants restore their human reliability.

IV. Conclusion

In this contribution, a new approach defining a situated and dynamical human reliability measure is established. The approach is based on the well-known CREAM approach, which is modified with respect to the use in dynamical context. A new list of CPCs describing the main features of situated driving context are determined, their corresponding levels and effects on performance reliability are also identified. A new concept indicating the human performance reliability over time is introduced, which is HPRS. Four levels for the evaluation of HPRS are identified, which are consistent with the control modes in original CREAM. Experiments have been conducted using driving simulator, and experimental data have been collected. Results analysis indicates the applicability of the proposed method in evaluation of human drivers' reliability in real time. The impact of scenarios on HPRS is also discussed. The approach can assist drivers to drive safety in assisted mode by constantly supervising human reliability in driving process. In the next step, a sensitivity analysis could be conducted to reduce the number of considered features to reduce the complexity of the approach.

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References

[1] J. Wang and D. Söffker, "Bridging gaps among human, assisted, and automated driving with DVIs: a conceptional experimental study," *IEEE Transactions on Intelligent Transportation Systems*, vol. 20, no. 6, pp. 2096–2108, 2018.

[2] T. A. Dingus, F. Guo, S. Lee, J. F. Antin, M. Perez, M. Buchanan-King, and J. Hankey, "Driver crash risk factors and prevalence evaluation using naturalistic driving data," *Proceedings of the National Academy of Sciences*, vol. 113, no. 10, pp. 2636–2641, 2016.

[3] H. Gstalter and W. Fastenmeier, "Reliability of drivers in urban intersections," *Accident Analysis & Prevention*, vol. 42, no. 1, pp. 225–234, 2010.

[4] Q. Zhou, Y. D. Wong, H. Xu, V. Van Thai, H. S. Loh, and K. F. Yuen, "An enhanced CREAM with stakeholder-graded protocols for tanker shipping safety application," *Safety science*, vol. 95, pp. 140–147, 2017.

[5] E. Hollnagel, *Cognitive reliability and error analysis method (CREAM)*. Elsevier, 1998.

[6] M. Q. Khan and S. Lee, "A comprehensive survey of driving monitoring and assistance systems," *Sensors*, vol. 19, no. 11, p. 2574, 2019.

[7] Z. Sun, Z. Li, E. Gong, and H. Xie, "Estimating human error probability using a modified CREAM," *Reliability Engineering & System Safety*, vol. 100, pp. 28–32, 2012.

[8] J. Calhoun, C. Savoie, M. Randolph-Gips, and I. Bozkurt, "Human reliability analysis in spaceflight applications," *Quality and Reliability Engineering International*, vol. 29, no. 6, pp. 869–882, 2013.

[9] E. Akyuz and M. Celik, "Application of CREAM human reliability model to cargo loading process of LPG tankers," *Journal of Loss Prevention in the Process Industries*, vol. 34, pp. 39–48, 2015.

[10] S.-T. Ung, "A weighted CREAM model for maritime human reliability analysis," *Safety science*, vol. 72, pp. 144–152, 2015.

[11] H. Taga, K. Furuta, and T. Kanno, "Human reliability analysis of car drivers in urban intersections," *Cognition, Technology & Work*, vol. 14, no. 4, pp. 365–377, 2012.

[12] F. Bella and R. Russo, "A collision warning system for rear-end collision: a driving simulator study," *Procedia-social and behavioral sciences*, vol. 20, pp. 676–686, 2011.

[13] V. E. Balas and M. M. Balas, "Constant time to collision platoons," *Int. J. of Computers, Communications and Control*, vol. 3, pp. 33–39, 2008.

[14] R. Van Der Horst and J. Hogema, "Time-to-collision and collision avoidance systems," *6th ICTCT Workshop Salzburg*, pp. 129–143, 1993.

[15] L. Eboli, G. Mazzulla, and G. Pungillo, "Combining speed and acceleration to define car users' safe or unsafe driving behaviour," *Transportation research part C: emerging technologies*, vol. 68, pp. 113–125, 2016.

[16] A. S. Zeeman and M. J. Booysen, "Combining speed and acceleration to detect reckless driving in the informal public transport industry," in *16th International IEEE Conference on Intelligent Transportation Systems (ITSC 2013)*, pp. 756–761, 2013.

[17] C. Gold, M. Körber, D. Lechner, and K. Bengler, "Taking over control from highly automated vehicles in complex traffic situations: the role of traffic density," *Human factors*, vol. 58, no. 4, pp. 642–652, 2016.

[18] N. A. Stanton and M. S. Young, "Driver behaviour with adaptive cruise control," *Ergonomics*, vol. 48, no. 10, pp. 1294–1313, 2005.