General

<table>
<tr><td>ID[1]</td><td colspan="3"></td></tr>
<tr><td>Use case name</td><td colspan="3">AI Components for Vehicle Platooning on Public Roads</td></tr>
<tr><td>Context</td><td colspan="3">Transportation</td></tr>
<tr><td>Application domain</td><td colspan="3">Self-driving vehicles</td></tr>
<tr><td>Status</td><td colspan="3">Prototype</td></tr>
<tr><td rowspan="2">Contributor</td><td>Name</td><td>Affiliation</td><td>Contact</td></tr>
<tr><td>Zielke</td><td>HSD, Germany</td><td></td></tr>
<tr><td>Scope[2]</td><td colspan="3">Trains of vehicles that drive very close to each other at nearly equal speed (platoons) on public roads, in particular platooning trucks on motorways.</td></tr>
<tr><td>Objective(s)</td><td colspan="3">The objectives of truck automation are energy saving and enhanced transportation capacity by platooning, and eventually possible reduction of personnel cost by unmanned operation of following vehicles. In a variant of this concept, platoons of passenger cars follow a truck autonomously.</td></tr>
<tr><td rowspan="2">Narrative</td><td>Short description (not more than 150 words)</td><td colspan="2">The overall concept of automated platooning is that the lead vehicle will be driven as normal by a trained (professional) driver, and the following vehicles will be driven fully automatically by the system, allowing the drivers to perform tasks other than driving their vehicles. The EU roadmap for truck platooning (EU project ENSEMBLE) envisions market introduction of multi-brand platooning by 2025 [12]. Several pilot projects have been carried out since about the year 2000 [8,9,10,13,14]. While a few AI components are already used in the pilot projects (e.g. lane keeping), future products are likely to incorporate AI solutions on several functional levels.</td></tr>
<tr><td>Complete description</td><td colspan="2">A major development in research on Intelligent Transportation Systems (ITS) is Cooperative Adaptive Cruise Control (CACC). It takes Adaptive Cruise Control (ACC) to the next level by adding direct communication between vehicles. Directly communicating accurate state information allows vehicles to drive much closer to each other without compromising safety. This is the basis of platooning: trains of vehicles that drive very close to each other at nearly equal speed. By CACC, platoons become string stable: changes in the acceleration or deceleration are reduced by the following vehicles instead, of getting amplified. This property is expected to greatly improve the throughput of vehicles on highways, because it is exactly the amplification of acceleration and deceleration that causes many traffic jams. R&D on truck platooning is driven partially by the potential fuel savings and the expectation of an attractive return on investment.
Implementations of platooning are complex cyber-physical systems [3]. In freight transportation, for example, a typical system architecture consists of the fleet layer, the cooperation layer, and the vehicle layer. AI components are already used on the vehicle layer (e.g. lane keeping), future products are likely to incorporate AI solutions on several functional levels and all system layers.
Lane keeping is an established AI technology in the automotive industry [6]. Some examples for other potential AI components in platooning systems are:</td></tr>
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		• Prediction of behavior of surrounding traffic [4] • Controllers for platooning strategies [1,3] • Road surface recognition [2] • Driver state assessment [7,11] • Safe control and safety regions [5]		
Key performance indicators (KPIs)	ID	Name	Description	Reference to mentioned use case objectives
		Efficiency, environmental and economic benefits	• improved on-road safety • greater fuel efficiency and reduced emissions • ease of driving • increased operational efficiency • additional road capacity • reduced labor costs	see above
		Societal Acceptance	Safety testing, reporting, benefits analyses, and demonstrations of automated platooning are needed and should be available to the public	see above
		Safety	The system must be safe, secure, and reliable	
AI features	Taks(s)	Lane keeping, environment perception, prediction, driver monitoring, planning and optimization		
	Method(s)[3]	machine learning, computer vision, logical decision making, pattern recognition, multimodal event detection, multi-agent planning and scheduling, probabilistic predictive modeling, evolutionary algorithm		
	Hardware[4]	commercial road vehicles, positioning sensors, environment sensors (radar, LIDAR, electro-optical cameras, infrared cameras), GPS, V2V communication (UMTS,4/5G, 802.11 networks)		
	Terms and concepts used[5]	autonomous vehicle guidance, environment perception, self perception, planning and scheduling, optimization, human-machine interaction, cyber-physical system		
Challenges and issues	highly unpredictable traffic environment, legislative situation, standardisation, stress and comfort of human drivers involved			
Societal concerns	Stress or boredom for the drivers, Big Brother and constant monitoring, Safety, system security, and reliability, Risk of hacking and hijacking a long-haul freight truck poses great danger, Trust over system reliability when driving next to a computer-controlled platoon.			

Data (optional)

Data characteristics	
Description	
Source[6]	
Type[7]	
Volume (size)	
Velocity (e.g. real time)[8]	
Variety (multiple datasets)[9]	
Variability (rate of change)[10]	
Quality[11]	

Process scenario (optional)

Scenario conditions					
No.	Scenario name	Scenario description	Triggering event	Pre-condition[12]	Post-condition[13]

Training (optional)

Scenario name	Training				
Step No.	Event[14]	Name of process/Activity[15]	Primary actor	Description of process/activity	Requirement
Specification of training data[16]					

Evaluation (optional)

Scenario name	Evaluation				
Step No.	Event[17]	Name of process/Activity[18]	Primary actor	Description of process/activity	Requirement
Input of evaluation[19]					
Output of evaluation[20]					

Execution (optional)

Scenario name	Execution				
Step No.	Event[21]	Name of process/Activity[22]	Primary actor	Description of process/activity	Requirement
Input of Execution[23]					
Output of Execution[24]					

Retraining (optional)

Scenario name	Retraining				
Step No.	Event[25]	Name of process/Activity[26]	Primary actor	Description of process/activity	Requirement
Specification of retraining data[27]					

References

References						
No.	Type	Reference	Status	Impact on use case	Originator/organization	Link

[1] W. van Willigen, E. Haasdijk, and L. Kester, "A multi-objective approach to evolving platooning strategies in intelligent transportation systems," in *Proceedings of the 15th annual conference on Genetic and evolutionary computation*, 2013, pp. 1397–1404.
[2] M. Aki *et al.*, "Road Surface Recognition Using Laser Radar for Automatic Platooning," *IEEE Transactions on Intelligent Transportation Systems*, vol. 17, no. 10, pp. 2800–2810, Oct. 2016.
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[4] I. Cara and J.-P. Paardekooper, "THE POTENTIAL OF APPLYING MACHINE LEARNING FOR PREDICTING CUT-IN BEHAVIOUR OF SURROUNDING TRAFFIC FOR TRUCK-PLATOONING SAFETY," in *25th ESV Conference Proceedings (International Technical Conference on the Enhanced Safety of Vehicles)*, 2017 [Online]. Available: http://indexsmart.mirasmart.com/25esv/PDFfiles/25ESV-000292.pdf
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[7] T. Heffelaar, R. Landman, M. Merts, J. M. van Hemert, A. Stuiver, and L. Noldus, "Driver state estimation: from simulation to the real world," in *Proceedings of Measuring Behavior 2014, Wageningen, The Netherlands*, 2014 [Online]. Available: https://www.measuringbehavior.org/files/2014/Proceedings/Heffelaar%20T%20-%20MB2014.pdf
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[9] M. Maurer, J. C. Gerdes, B. Lenz, and H. Winner, Eds., *Autonomous Driving*. Springer Berlin Heidelberg, 2016.
[10] T. Robinson and E. Coelingh, "Operating Platoons On Public Motorways: An Introduction To The SARTRE Platooning Programme," Jul. 2018 [Online]. Available: https://www.researchgate.net/publication/268300380_Operating_Platoons_On_Public_Motorways_An_Introduction_To_The_SARTRE_Platooning_Programme
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[12] K. Sjöberg, "Status of Truck Platooning in Europe," in *9th ETSI Workshop on Intelligent Transport Systems (ITS)*, 2018 [Online]. Available: https://docbox.etsi.org/Workshop/2018/20180306_ITS_WORKSHOP/S04_ACCIDENT_FREE_AUTOM_DRIV/TRUCK_PLATOONING_SCANIA_SJOBERG.pdf
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Footnote

[1] Leave this cell blank.

[2] The scope defines the limits of the use case.

[3] AI method(s)/framework(s) used.

[4] Hardware system used.

[5] Terms and concepts listed here can be used to extend the work of WG 1 (AWI 22989 and AWI 23053) as necessary.

[6] Origin of data, which could be from instruments, IoT, web, surveys, commercial activity, or from simulations.

[7] Structured/unstructured Images, voices, text, gene sequences, and numerical. Composite: time-series, graph-structured

[8] The rate of flow at which the data is created, stored, analysed, or visualized.

[9] Data from a number of domains and a number of data types. The wider range of data formats, logical models, timescales, and semantics complicates the integration of the variety of data.

[10] Changes in data rate, format/structure, semantics, and/or quality.

[11] Completeness and accuracy of the data with respect to semantic content as well as syntactical of the data (such as presence of missing fields or incorrect values)

[12] Describe which condition(s) should have been met before this scenario happens.

[13] Describe which condition(s) should prevail after this scenario happens. The post-condition may also define "success" or "failure" conditions.

[14] The event that triggers the step. This might be completion of the previous event.

[15] Action verbs should be used when naming activity.

[16] Training data can be further specified.

[17] The event that triggers the step. This might be completion of the previous event.

[18] Action verbs should be used when naming activity.

[19] Specify input of evaluation.

[20] Specify output of evaluation.

[21] The event that triggers the step. This might be completion of the previous event.

[22] Action verbs should be used when naming activity.

[23] Specify input of evaluation.

[24] Specify output of evaluation.

[25] The event that triggers the step. This might be completion of the previous event.

[26] Action verbs should be used when naming activity.

[27] Retraining data can be further specified.