

Achieving a positive user experience through user-friendly design of the vehicle interior for automated driving functions



Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Driving behaviour and performance objectification

1 Motivation & goals

Assessment of driving

behaviour & performance for different drivers and driving systems



Subjective rates based on evaluators \rightarrow potentially biased and/or inconsistent, harder to replicate (e.g. evaluators mood, evolution of evaluators rating process)



2 Experimental setup & metrics

Experimental setup



Objective rates (metrics) based on **measurements** \rightarrow well defined, consistent, easier to replicate (e.g. vehicle) speed, steering angle, GPS data)

Goal: consistent & replicable assessment of driver behaviour & performance via objetive metrics

3 Computed metrics & first statistics

Examples for computed metrics







Three **driving** systems with different lateral and longitudinal control



Driving of 6 maneuvers with focus on specific vehicle dynamical characteristics

List of computed metrics (grouped by vehicle dynamics)

General/total dynamics	Lateral dynamics	Longitudinal dynamics		
1 Mean percentage	2 Max. abs. grad. lat. acc.	2 Max. abs. grad. long. acc.		
deviation lane center	2 Max. abs. device angular	2 Std. dev. veh. speed error		
1 Total no. track violations	speed	2 Integral veh. speed error		
1 Max. dist. track violations	2 Max. abs. peak-2-peak	2 Settling time vehicle		
1 Wrong lane (evasive)	device angle	speed error		
1 Mean dist. track violations	2 Integral device angle	2 Braking time veh. stops		

Examples for first statistical analysis of computed metrics



1 Total dist. track violations 2 Max. abs. target rack **2** Max. abs. grad. throttle position activity 2 Maneuver duration **2** Max. abs. torsionbar 2 Integral throttle activity **2** No. of stops during 2 Max. abs. grad. brake torque maneuver activity **3** Lateral driving 3 Steering behavior 2 Integral brake activity **3** Throttle/brake behavior 2 Throttle activity right **3** General/overall driving device **2** Brake activity right device **3** Longitudinal driving **3 Subjective ratings** from vehicle supervisor **1** Path-based (GPS) metrics **2** Non path-based (non GPS) metrics

4 Outlook metric selection & modelling

Goal: Modelling of driving performance based on objective ratings

Metric selection for modelling based on

correlation cofficient magnitude ("importance")

Metric	rSpe Metric	rSpe Metric	rSpe Metric	rSpe	Val
I stored show	Question nr. 1 (Int. Entrop	y = 4.3)	Tesise	de au alana	
Lateral class	Longitudinal class	General class	Trajec	clory class	
Get US Lat MaxSteerAngver	0.43 Get 11 Long MeasureSpeedErrorDistribution StoSpeedError	0.45 Get 24 General MeasureDrivingPerformance MaxAbsBeta	0.32 Get 33 Trajectory	0.51	
Get 39 Lat MaxSteerAngle	0.40 Get 10 Long MeasureVenLongGuidance MaxGradAccLong	0.41 Get 20 General MeasuremanPerormance ManDuration	0.22 Get 47 Trajectory	0.49	
Get 07 Lat MeasureSteeringAngle PK2PKMaxSteerAngle	0.39 Get 19 Long MeasurebreakUse IntegraiPercent	0.40 Get 22 General Understeer MaxPer	Nalv Get 48 Trajectory	0.49	
Get U2 Lat Measure venLongGuidance MaxGradAccLat	0.34 Get 50 Long MeasureBreakUse IntegraiPercentOverManDuration	0.39 Get 23 General Oversteer MaxPer	INalN Get 32 Trajectory	0.42	
Get 40 Lat MaxSteer Lorque	0.05 VGet 10 Long MeasureBreakUse MaxGradPercent	0.20	Get 26 Trajectory	0.30	
Get us Lat MeasureSteeringEffort IntegralAbsSteerAngle	0.05 Get 16 Long Measure Infottieuse MaxGradPercent	0.25	Get 34 Trajectory	0.01	
	Get 17 Long Measure I nrottieuse integramercent	0.14			
	Get 49 Long Measure Infottieuse IntegralPercentUverManDuration	0.10			
	Question nr. 2 (Inf. Entrop	y = 4.3)			
Lateral class	Longitudinal class	General class	Trajec	ctory class	
Get 05 Lat MaxSteerAngVel	0.46 'Get 11 Long MeasureSpeedErrorDistribution StdSpeedError'	0.49 'Get 24 General MeasureDrivingPerformance MaxAbsBeta'	0.36 'Get 33 Trajectory'	0.42	
Get 07 Lat MeasureSteeringAngle Pk2PkMaxSteerAngle'	U.40 'Get 19 Long MeasureBreakUse IntegralPercent'	0.42 'Get 28 General MeasureManPerofmance ManDuration'	0.28 'Get 48 Trajectory'	0.42	
Get 39 Lat MaxSteerAngle'	0.40 'Get 10 Long MeasureVehLongGuidance MaxGradAccLong'	0.40 'Get 22 General Understeer MaxPer'	NaN 'Get 47 Trajectory'	0.41	
Get 02 Lat MeasureVehLongGuidance MaxGradAccLat	0.32 'Get 50 Long MeasureBreakUse IntegralPercentOverManDuration'	0.40 'Get 23 General Oversteer MaxPer'	NaN 'Get 32 Trajectory'	0.37	
Get 40 Lat MaxSteerTorque'	0.15 'Get 16 Long MeasureThrottleUse MaxGradPercent'	0.25	'Get 26 Trajectory'	0.35	
Get 08 Lat MeasureSteeringEffort IntegralAbsSteerAngle	0.09 'Get 18 Long MeasureBreakUse MaxGradPercent'	0.25	'Get 34 Trajectory'	0.03	
	'Get 17 Long MeasureThrottleUse IntegralPercent'	0.14			V.
	'Get 49 Long MeasureThrottleUse IntegralPercentOverManDuration'	0.10			r -
	Question nr. 3 (Inf. Entrop	y = 4.0)			Cot 47 Trajectory $c = 0.163$
Lateral class	Longitudinal class	General class	Trajec	ctory class	Get_47 majectory ≤ 0.103
Get 05 Lat MaxSteerAngVel	0.19 'Get 10 Long MeasureVehLongGuidance MaxGradAccLong'	0.38 'Get 28 General MeasureManPerofmance ManDuration'	0.28 'Get 48 Trajectory'	0.27	antropy = 0.751
Get 40 Lat MaxSteerTorque'	0.17 'Get 19 Long MeasureBreakUse IntegralPercent'	0.36 'Get 24 General MeasureDrivingPerformance MaxAbsBeta'	0.17 'Get 33 Trajectory'	0.27	encropy = 0.751
Get 39 Lat MaxSteerAngle'	0.14 'Get 50 Long MeasureBreakUse IntegralPercentOverManDuration'	0.35 'Get 22 General Understeer MaxPer'	NaN 'Get 26 Trajectory'	0.26	samples – 79
Get 07 Lat MeasureSteeringAngle Pk2PkMaxSteerAngle'	0.14 'Get 11 Long MeasureSpeedErrorDistribution StdSpeedError'	0.32 'Get 23 General Oversteer MaxPer'	NaN 'Get 47 Trajectory'	0.26	samples – 75
Get 02 Lat MeasureVehLongGuidance MaxGradAccLat	0.06 'Get 18 Long MeasureBreakUse MaxGradPercent'	0.27	'Get 32 Trajectory'	r 0.23	value = $[17, 62]$
Get 08 Lat MeasureSteeringEffort IntegralAbsSteerAngle'	0.03 'Get 16 Long MeasureThrottleUse MaxGradPercent'	0.17	'Get 34 Trajectory'	0.02	Value – [17, 02]
	'Get 17 Long MeasureThrottleUse IntegralPercent'	0.13			class = good
	'Get 49 Long MeasureThrottleUse IntegralPercentOverManDuration'	0.07			cluss – good
	Question nr. 4 (Inf. Entrop	y = 4.0)			
Lateral class	Longitudinal class	General class	Trajec	ctory class	
Get 05 Lat MaxSteerAngVel	0.21 'Get 10 Long Measure/VehLongGuidance MaxGradAccLong'	0.46 'Get 28 General MeasureManPerofmance ManDuration'	0.31 'Get 33 Trajectory'	0.32	
Set 40 Lat MaxSteerTorque'	0.18 'Get 19 Long MeasureBreakUse IntegralPercent'	0.40 'Get 24 General MeasureDrivingPerformance MaxAbsBeta'	0.18 'Get 48 Trajectory'	0.31	
Get 07 Lat MeasureSteeringAngle Pk2PkMaxSteerAngle'	0.16 'Get 50 Long MeasureBreakUse IntegralPercentOverManDuration'	0.39 'Get 22 General Understeer MaxPer'	NaN 'Get 47 Trajectory'	0.30	
Get 39 Lat MaxSteerAngle'	0.14 'Get 11 Long MeasureSpeedErrorDistribution StdSpeedError'	0.37 'Get 23 General Oversteer MaxPer'	NaN 'Get 26 Trajectory'	0.28	
Set 02 Lat MeasureVehLongGuidance MaxGradAccLat'	0.08 'Get 18 Long MeasureBreakUse MaxGradPercent'	0.31	'Get 32 Trajectory'	0.27	
Set 08 Lat MeasureSteeringEffort IntegralAbsSteerAngle'	0.03 'Get 16 Long MeasureThrottleUse MaxGradPercent'	0.17	'Get 34 Trajectory'	0.01	
	'Get 17 Long MeasureThrottleUse IntegralPercent'	0.10			
	'Get 49 Long MeasureThrottleUse IntegralPercentOverManDuration'	0.05			
	Question nr. 5 (Inf. Entrop	y = 3.7)			
Lateral class	Longitudinal class	General class	Trajec	ctory class	
Get 05 Lat MaxSteerAngVel	0.30 'Get 11 Long MeasureSpeedErrorDistribution StdSpeedError'	0.40 'Get 24 General MeasureDrivingPerformance MaxAbsBeta'	0.24 'Get 33 Trajectory'	0.45	
Get 39 Lat MaxSteerAngle'	0.30 'Get 19 Long MeasureBreakUse IntegralPercent'	0.39 'Get 28 General MeasureManPerofmance ManDuration'	0.24 'Get 48 Trajectory'	0.43	
Get 07 Lat MeasureSteeringAngle Pk2PkMaxSteerAngle'	0.29 'Get 50 Long MeasureBreakUse IntegralPercentOverManDuration'	0.38 'Get 22 General Understeer MaxPer'	NaN 'Get 47 Trajectory'	0.43	
Set 02 Lat MeasureVehLongGuidance MaxGradAccLat'	0.21 'Get 10 Long MeasureVehLongGuidance MaxGradAccLong'	0.31 'Get 23 General Oversteer MaxPer'	NaN 'Get 26 Trajectory'	0.37	
Get 40 Lat MaxSteerTorque'	0.06 'Get 18 Long MeasureBreakUse MaxGradPercent'	0.24	'Get 32 Trajectory'	0.35	
Get 08 Lat MeasureSteeringEffort IntegralAbsSteerAngle'	0.01 'Get 16 Long MeasureThrottleUse MaxGradPercent'	0.22	'Get 34 Trajectory'	0.12	
	'Get 17 Long MeasureThrottleUse IntegralPercent'	0.14			0.52
	'Get 49 Long MeasureThrottleUse IntegralPercentOverManDuration'	0.09			entropy = 0.52
					samples = 60
					$1 \times 2 \times 2 = [7 \times 52]$



amples = alue = [17 lass = ba

Metric value over participants for all maneuvers (here: very large values for "extreme" maneuver Evasive)

Cumulative distributions show simlar behaviour between two driving systems and difference for one system ("extreme" maneuver Evasive observable)

Decision tree based on selected metrics to classifiy "good"/"bad" driving performance for specific maneuver

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