



Design Optimization of Driver Control and Uncertainty Study on Dynamic Performance of a Robot Vehicle







Dynamic Vehicle Simulation "E-Class Sedan" in CarSim







Driver Control in Simulink by Co-Simulation with CarSim







Design Automation Workflow in OptiY







Design Parameters of Driver Control







Multi-Objective Design Goals



Steering wheel angle in time domain





Steering wheel angle in frequency domain

Design Objectives:

- Driving road: Minimize integral of lateral error
- Driving comfort: Minimize maximal amplitude of high frequency

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Integral of Lateral Distance Error





Multi-Objective Design Optimization



Lx = 15; Ga = 10; GI = 30





Some Selected Uncertainties and Errors of a Passenger Vehicle



Uncertainties and errors are varying depending on weather, temperature and environment





Uncertainties as Stochastic Parameters in OptiY

1					
Name	Nominal		Tolerance		Distribution
Lx_Sensor	15		0.2		Normal Distribution
Gain Area Error	10		0		Normal Distribution
Gain Lateral Error	30		0		Normal Distribution
Vehicle Speed	100		0.2		Normal Distribution
Road Friction	0.85		0.1		Normal Distribution
Air Mass Density	1.206		0.12		Normal Distribution
Transfer Torsional Stiffness	80		8		Normal Distribution
Transfer Torsional Damping	0.8		0.08		Normal Distribution
Front Differantial Stiffness	100		10		Normal Distribution
Front Differantial Damping	1		0.1		Normal Distribution
Rear Differantial Stiffness	80		8		Normal Distribution
Rear Differantial Daping	0.8		0.08		Normal Distribution
Steering Column Damping	0.002		0.0002		Normal Distribution
Steering Column Hysteresis	0.3		0.03		Normal Distribution
Front Steering Damping	4		0.4		Normal Distribution
Front Steering Hysteresis	200		20		Normal Distribution
Steering Torsion Bar Stiffness	2		0.2		Normal Distribution
Tire Effective Roll Radius	365		5		Normal Distribution
Tire Spring Rate	278		27		Normal Distribution
Tire Rolling Resistance Moment	3e-005		3e-006		Normal Distribution
Tire Transition Factor	1.1		0.11		Normal Distribution
Front Suspension Spring	34		3		Normal Distribution
Front Suspension Friction	20		2		Normal Distribution
Rear Suspension Spring	46		4		Normal Distribution
Rear Suspension Friction	20		2		Normal Distribution



Normal Distribution:

- Nominal
- Tolerance





Monte-Carlo Dynamic-Simulation for Meta-Modeling





3D- Response Surface



Meta-Model of Driving Comfort on Some Selected Parameters



2D- Section Diagram

Meta-Model = mathematical relationship between driving comfort and uncertainty parameters www.optiy.eu





Sensitivity Analysis on Driving Comfort



Driving Comfort = min. Amplitude of High Frequency (>0.1221 Hz) for steering wheel angle

Depending on 7 important Parameters/Uncertainties

- Road Friction = 22,97%
- Aerodynamics = 21,13%
- Driver Sensor =12,9%
- Rear Suspension Spring = 12,24%
- Steering Torsion Bar Stiffness = 10,76%
- Front Suspension Spring = 10,32%
- Vehicle Speed = 7.54%

Max High Frequency						
Road Friction	22.97 %					
Ale Marco Describe	22.97 %					
Air Mass Density	21.13 %					
Lx_Sensor	12.9 %					
	12.9 %					
Rear Suspension Spring	12.24 %					
Steering Torsion Bar Stiffness	10.76 %					
	10.76 %					
Front Suspension Spring	10.32 %					
March Course	10.32 %					
venicie speed	7.54 %					
Tire Rolling Resistance Momen	t 0.6 %					
	0.6 %					
Tire Transition Factor	0.41%					
Front Steering Hysteresis	0.22 %					
	0.22 %					
Rear Suspension Friction	0.18 %					
Tire Offertive Bell Bedive	0.18%					
The Effective Koll Kadlus	0.11%					
Tire Spring Rate	0.11%					
	0.11%					
Front Suspension Friction	0.11%					
Rear Differantial Daping	0.1 %					
	0.1 %					
Front Differantial Stiffness	0.07 %					
Transfer Torsional Stiffness	0.07 %					
mansfer forsional summess	0.04 %					
Steering Column Damping	0.02 %					
Tree for Tree in 10 miles	0.02 %					
Transfer Torsional Damping	0.02 %					
Front Differantial Damping	0.01 %					
	0.01 %					
Rear Differantial Stiffness	0.01%					
Gain Area Error	0 %					
	0 %					
Steering Column Hysteresis	0%					
Gaia Lateral Error	0%					
Gain Lateral Error	0%	Total Effect				
		Main Effect				





Dynamic Sensitivity on Lateral Error







Cut-Sensitivities on Lateral Error







Dynamic Sensitivity on Steering Wheel Angle







Cut-Sensitivities on Steering Wheel Angle

1D Steering Wheel Angle						1D Steering Wheel Angle			
Vehicle Speed	87.29 %					Vehicle Speed	19.72 %		
	87.28 %						19.66 %		
Tire Rolling Resistance Momen	t 1.85 %					Kear Suspension Spring	13.47 %		
Road Friction	1.83 %					Road Friction	11.6 %		
Noad median	1.03 %						11.55 %		
Steering Torsion Bar Stiffness	0.97 %					Air Mass Density	8.36%		
In Course	0.94 %					Steering Torsion Bar Stiffness	7.54 %		
LX_Sensor	0.96 %						7.49 %		
Front Suspension Spring	0.95 %	1				Tire Rolling Resistance Moment	6.66%		
	0.94 %					Front Suspension Spring	5.96 %		
Front Steering Hysteresis	0.93 %						5.92 %		
Front Differantial Stiffness	0.87 %					Front Steering Hysteresis	5.53 %		
	0.86 %					Transfer Torsional Stiffness	3.97 %		
Steering Column Hysteresis	0.81%						3.92 %		
Rear Suspension Spring	0.75 %					Front Steering Damping	2.75%		
	0.74 %					Ly Sensor	2.08 %		
Air Mass Density	0.65 %					EX_SENSO	2.34 %		
Tire Spring Rate	0.6%					Rear Suspension Friction	1.88 %		
	0.59 %					Front Differential Stiffness	1.81%		
Transfer Torsional Stiffness	0.55 %					Tront Dimenantial Scimess	1.8 %		
Rear Differential Stiffness	0.35%		-			Steering Column Hysteresis	1.65 %		
Near officialitation settings	0.38 %		Cut	A-A		Front Succession Existing	1.62 %		
Rear Suspension Friction	0.39 %		our			From Suspension Friction	1.46 %		
Frank Standard Damaian	0.38%					Rear Differantial Stiffness	1.45 %		
Front Steering Damping	0.34 %					Station Column Densities	1.32 %		
Steering Column Damping	0.25 %					Steering Column Damping	1.08 %		
Time Effective Roll Reading	0.2 %					Tire Transition Factor	0.96 %		
The Effective Koll Kadius	0.09 %						0.94 %		
Front Suspension Friction	0.09 %					Tire Spring Rate	0.83 %		
	0.08 %					Front Differantial Damping	0.73 %		
Kear Differantial Daping	0.08 %						0.7 %		
Front Differantial Damping	0.07 %					Transfer Torsional Damping	0.45 %		
	0.06 %					Rear Differantial Daping	0.13 %		
Transfer Torsional Damping	0.06 %						0.11%		
Tire Transition Factor	0.06 %					Tire Effective Roll Radius	0.09 %		
	0.05 %					Gain Area Error	0%		
Gain Area Error	0%				Tatal Effe at		0 %	Total Effect	
	0.76				Main Effect			Main Effect	
					maincriett				





Summary

- Detailed simulation of dynamic performance of a robot vehicle is performed in CarSim and the driver control by co-simulation in Matlab/Simulink. The design workflow for both processes is build in OptiY for automation and optimization.
- Finding optimal control parameters of the driver model automatically, a multi-objective optimization is used to increasing the driving comfort and minimize the lateral error of driving road.
- The dynamic performance of a passenger vehicle is affected by many uncertainties and errors as friction, stiffness, damping of components etc.. They are varying depending on weather, temperature and environment. The uncertainty study takes these uncertainties and errors into consideration. It uncovers the relationships between driving comfort, lateral error on these uncertainty parameters. With sensitivity analysis, almost important parameters can be identified for driving comfort and lateral error.