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Fault tolerant generic vehicle control

Johannes Edrén

Daniel Wanner

KTH Vehicle Dynamics

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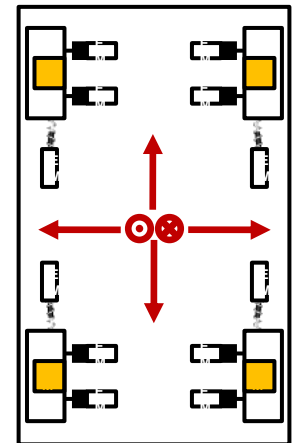
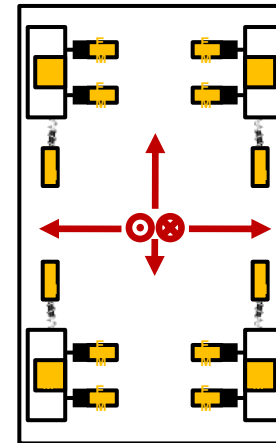
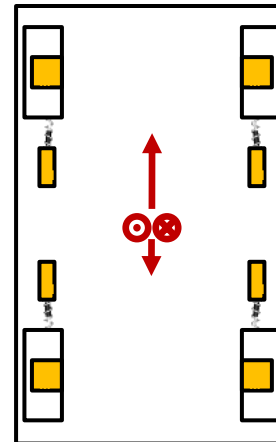
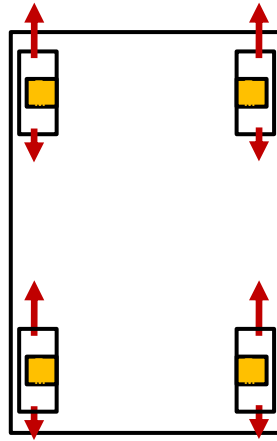
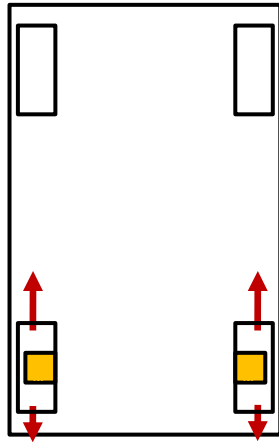
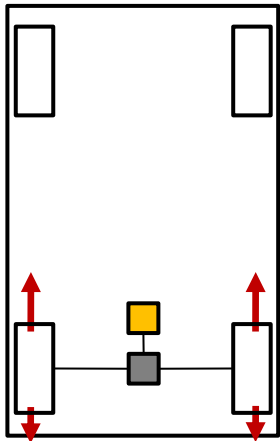


What do you think about electric cars?

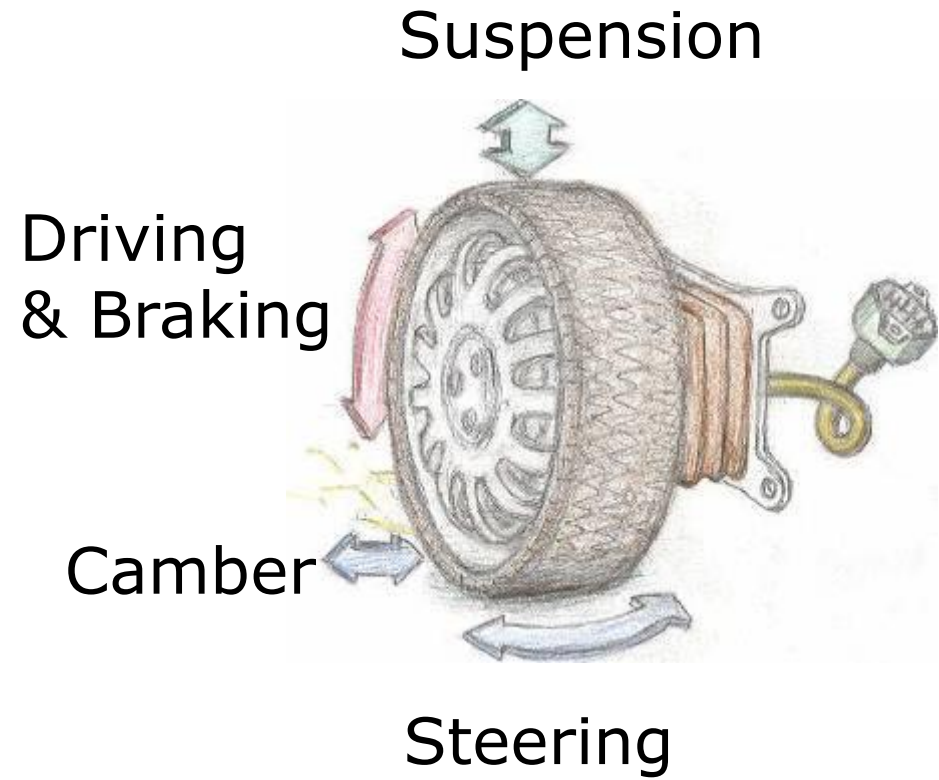
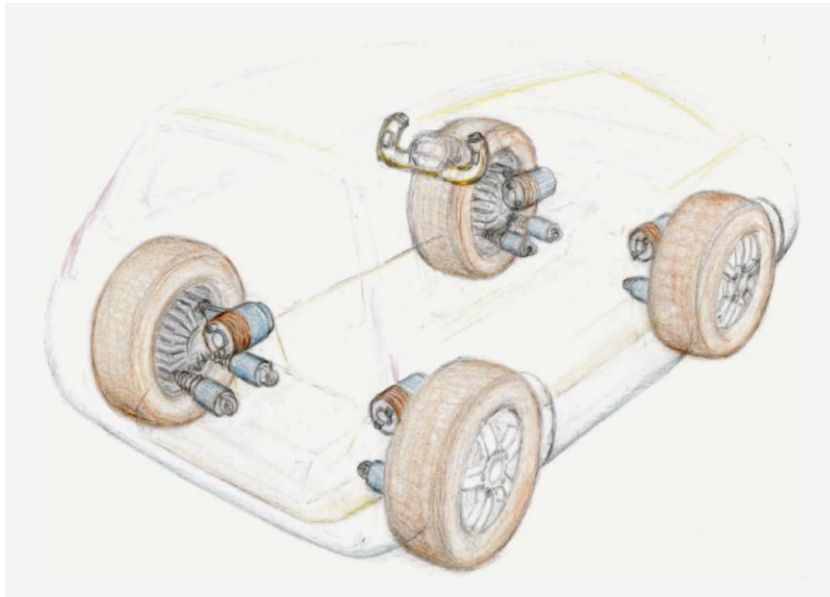


Possibilities

Over-actuation levels

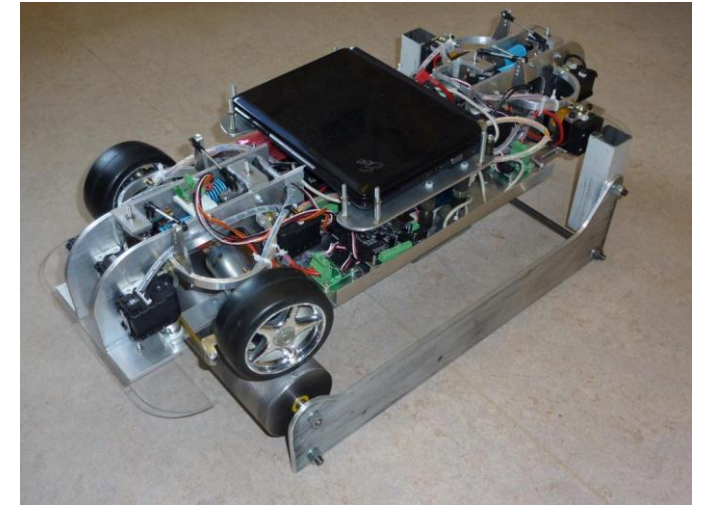
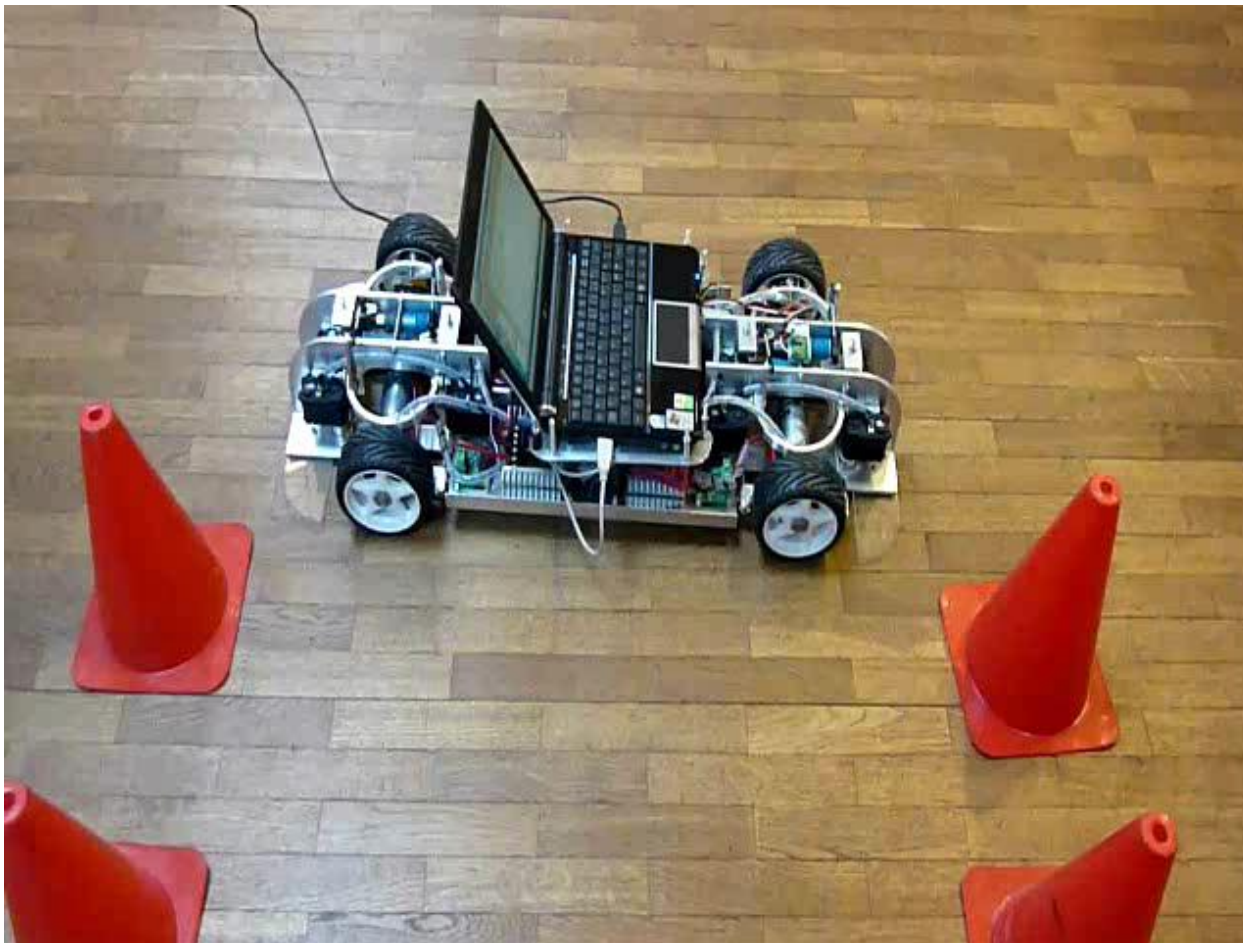


Possibilities Over-Actuation



Possibilities

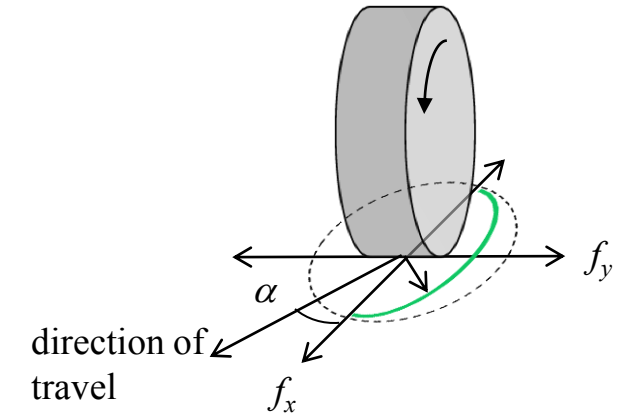
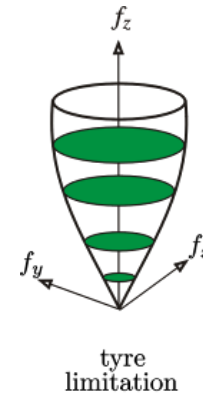
Concept vehicle Hjulia



- Steering
- Drive/Brake
- Camber
- Vertical

Possibilities

Force allocation

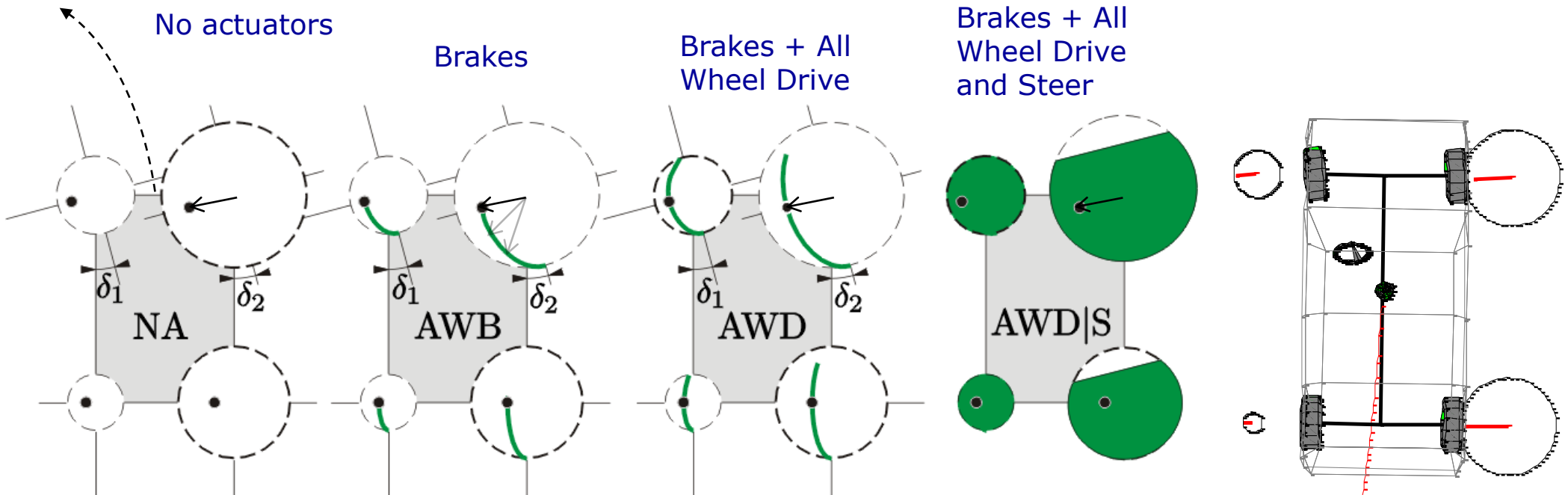


No actuators

Brakes

Brakes + All
Wheel Drive

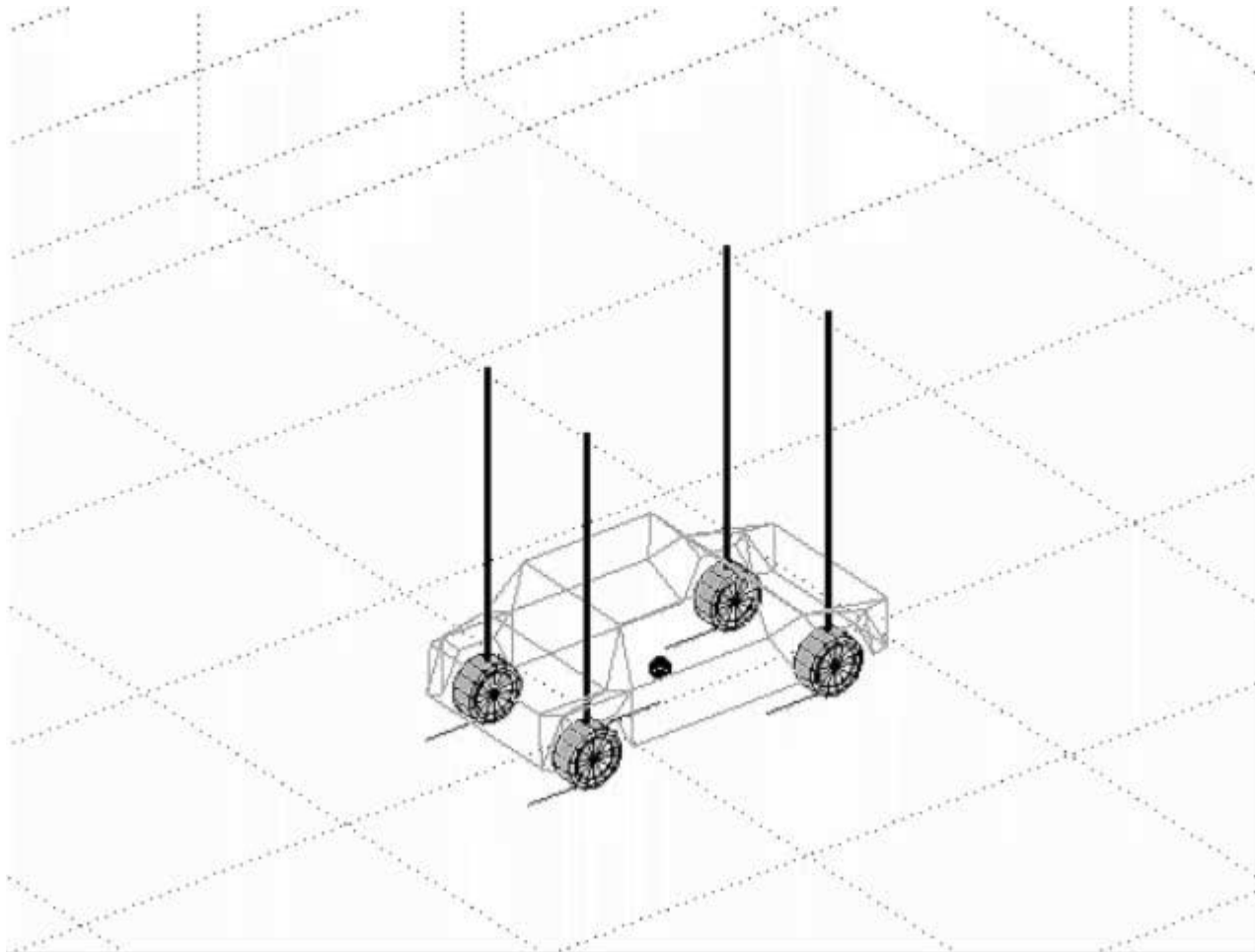
Brakes + All
Wheel Drive
and Steer



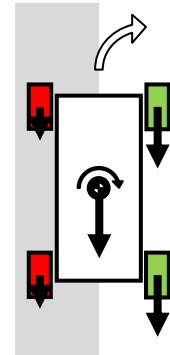
Green regions = Attainable tyre forces

Possibilities

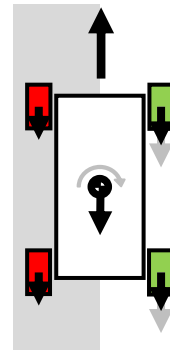
Force allocation μ -split



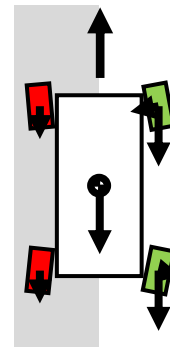
Vehicle A
5.37 m



Vehicle B
5.96 m



Vehicle C
5.27 m



Possibilities

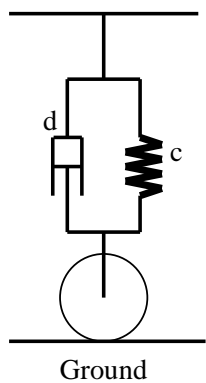
Active suspension during braking

Passive 41.43 m

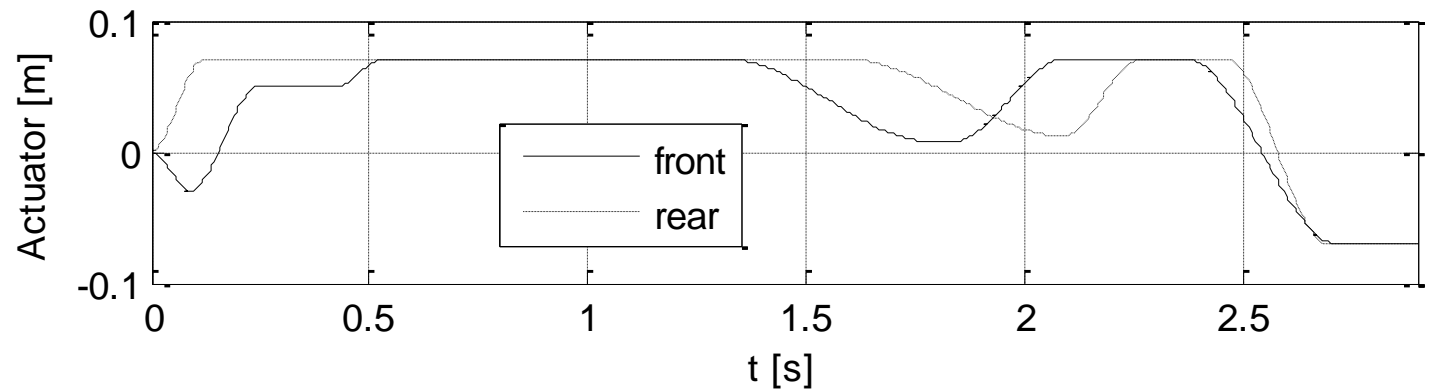
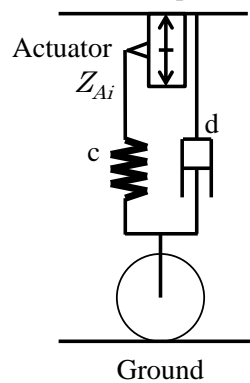
Active 40.64 m



a)
Passive suspension

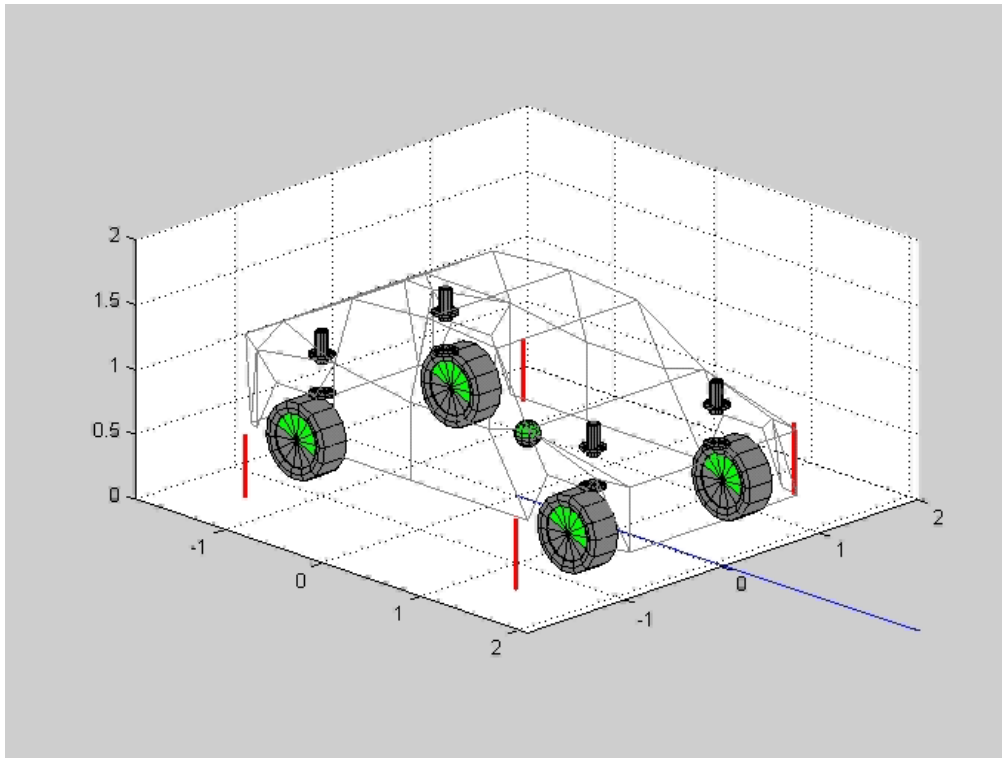


b)
Active suspension

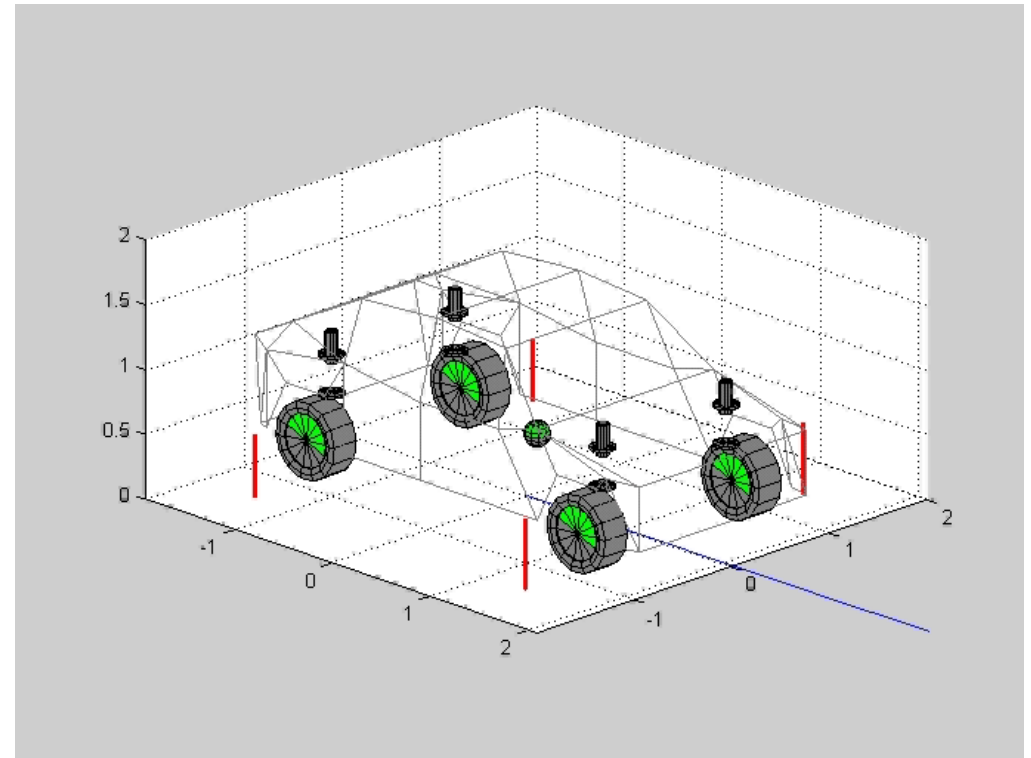


Possibilities

Active suspension



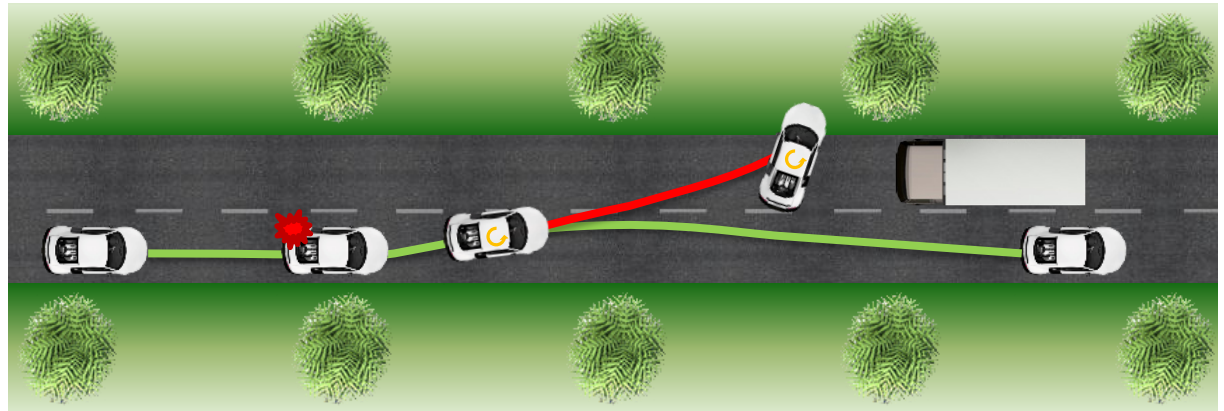
Passive 69.8 km/h



Active 71.1 km/h

Challenges

What happens if electrified vehicles fail?



Uncontrolled vehicle

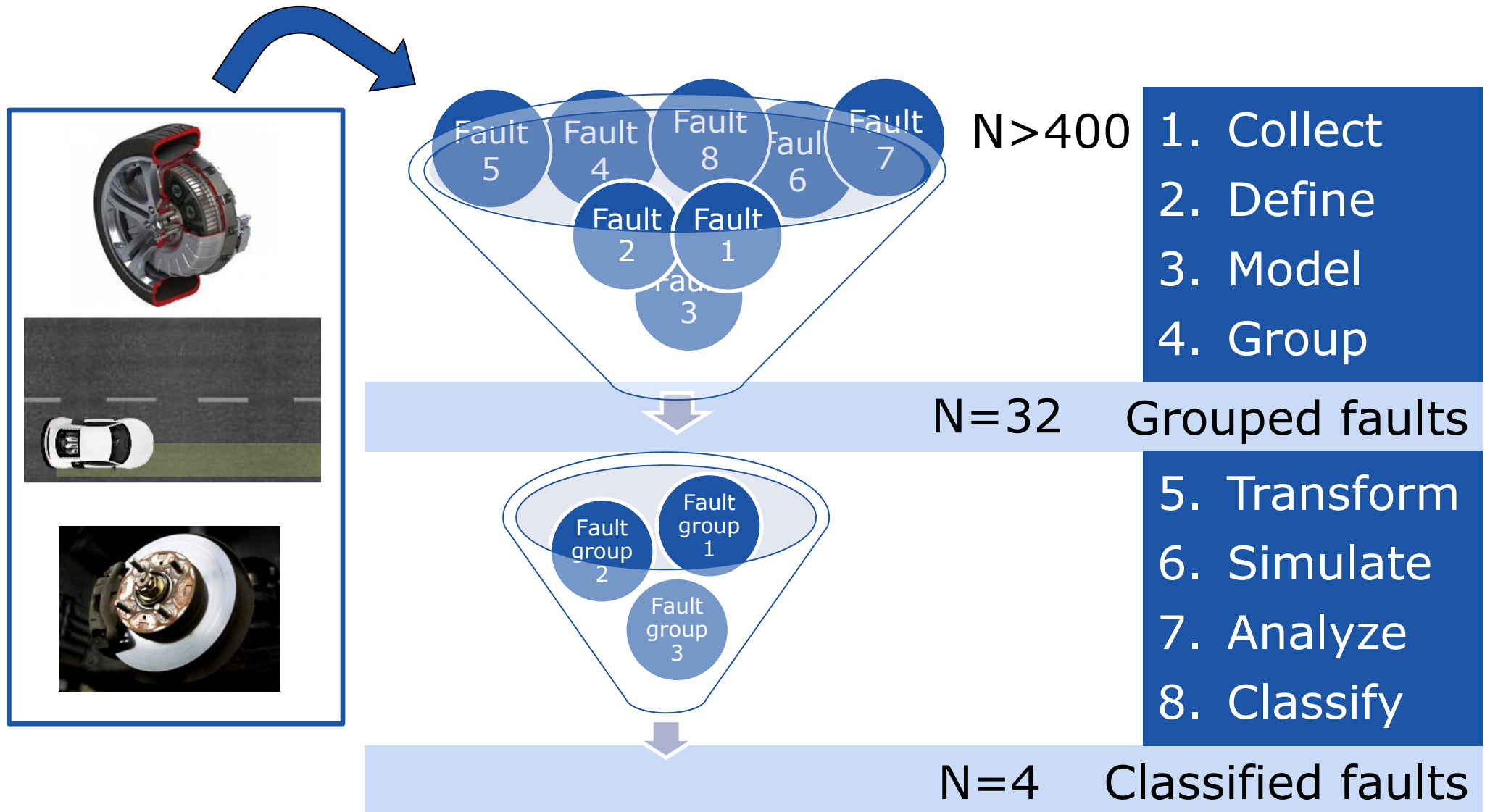


Vehicle with fault-tolerant control



Challenges

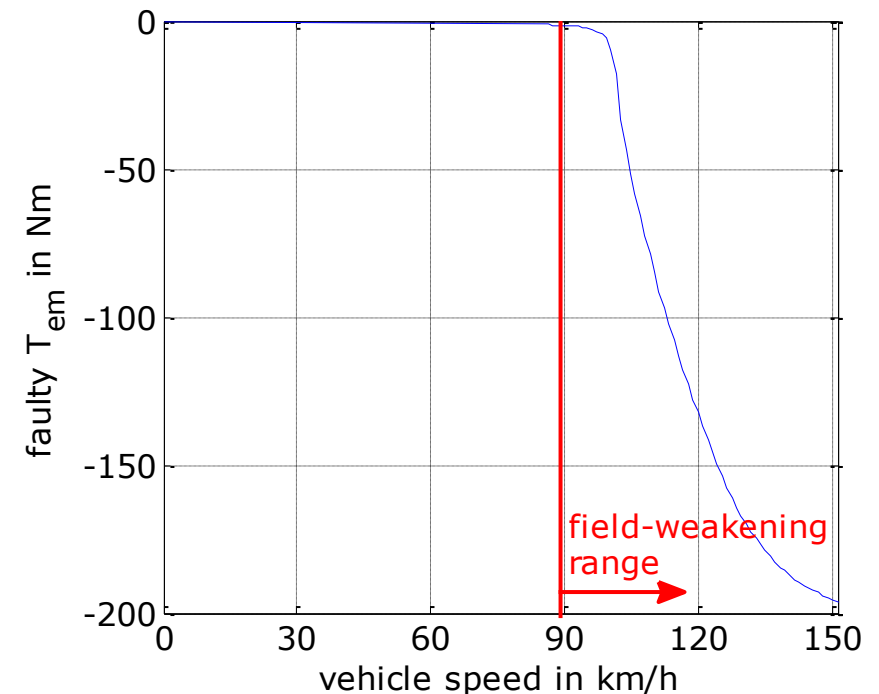
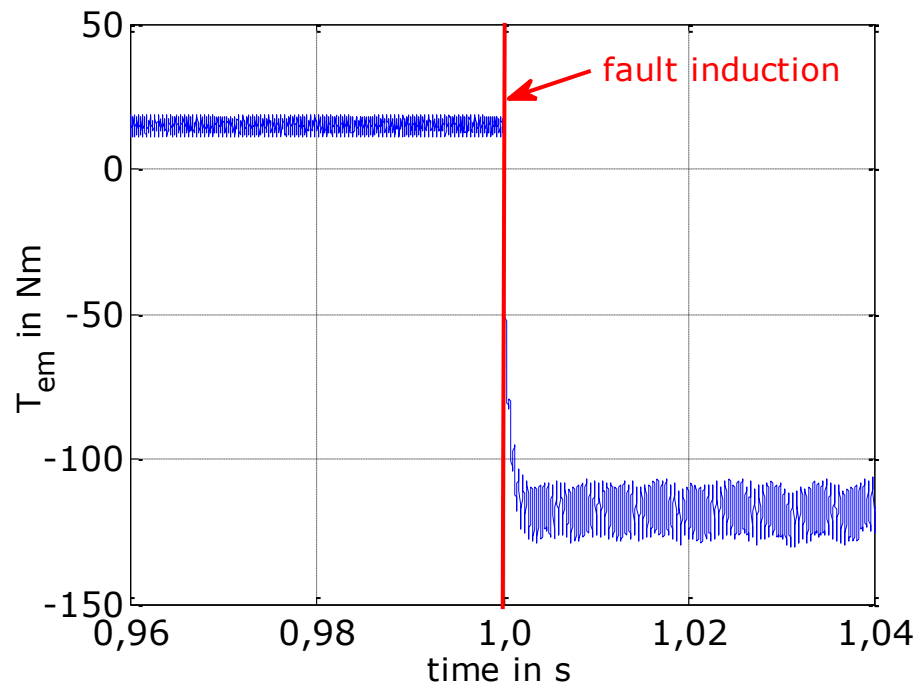
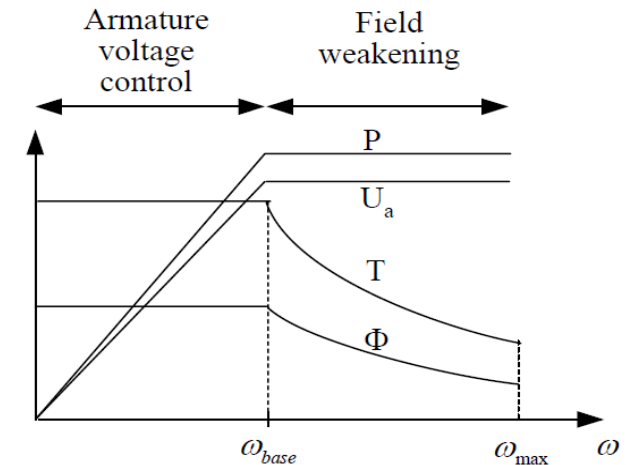
What kind of faults can occur?



Challenges

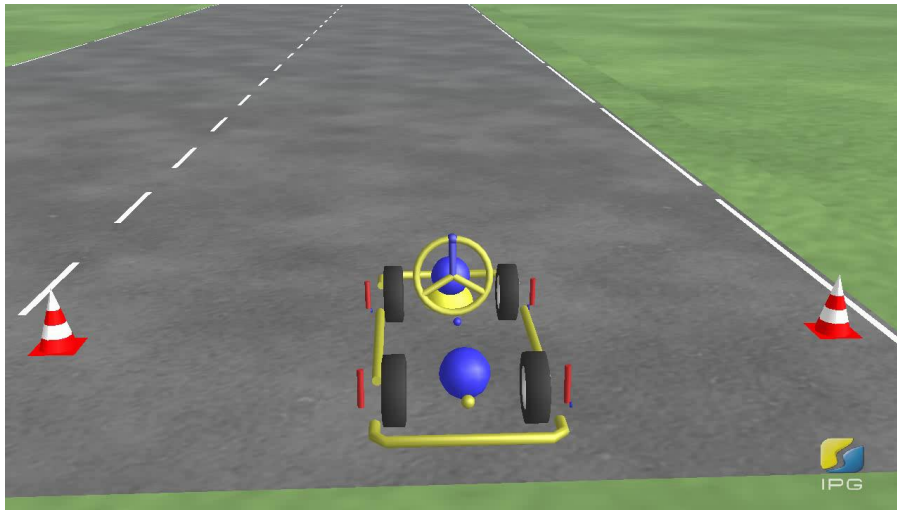
Fault analysis – modeling of selected fault

- Characteristics of electrical machine
- Typical and severe PMSM fault.
 - Inverter shutdown fault.
 - Beyond nominal working point, thus field-weakening range.

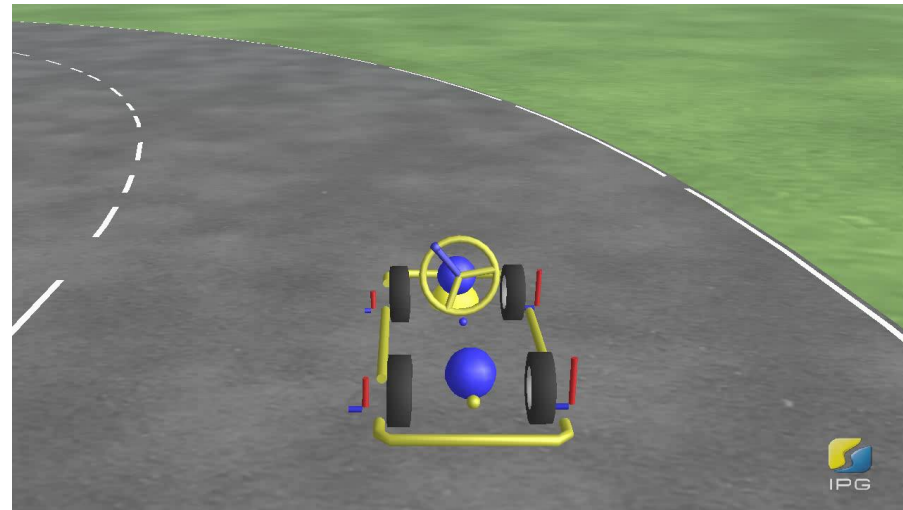


Challenges

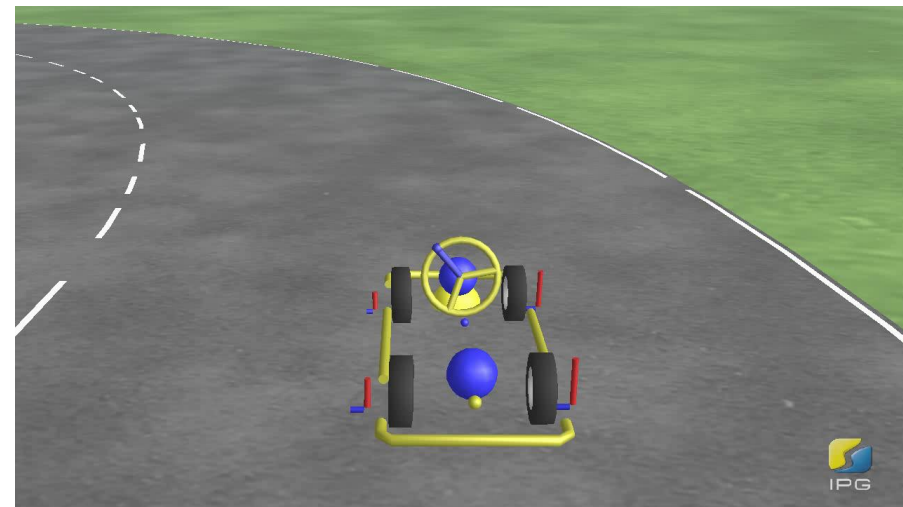
Results – electric fault @ 50km/h



Straight Wheel 3



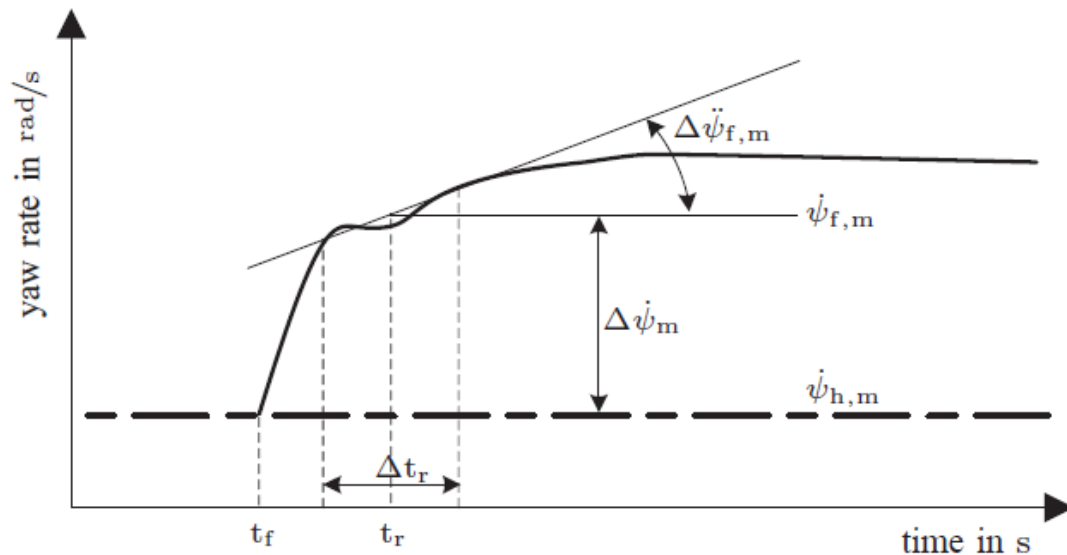
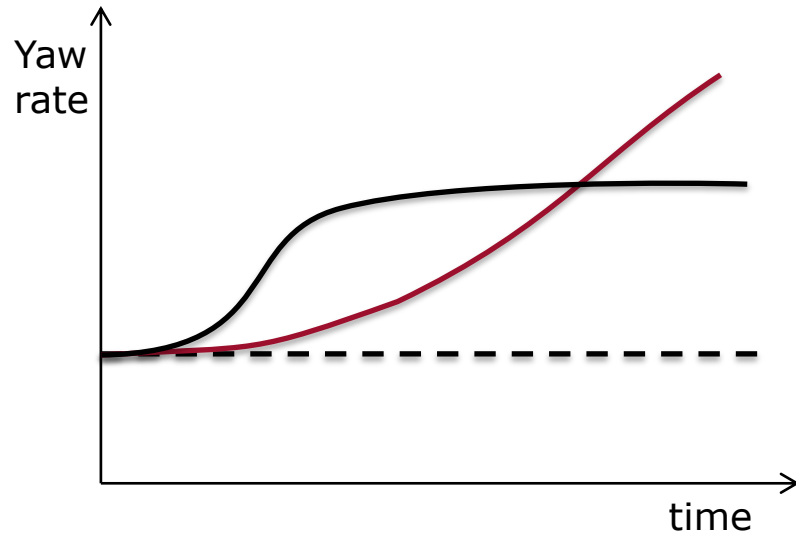
LH curve
Wheel 3



LH curve
Wheel 4

Challenges

Fault classification method

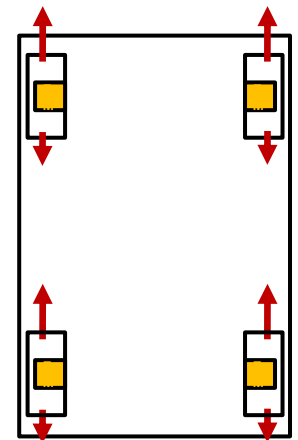
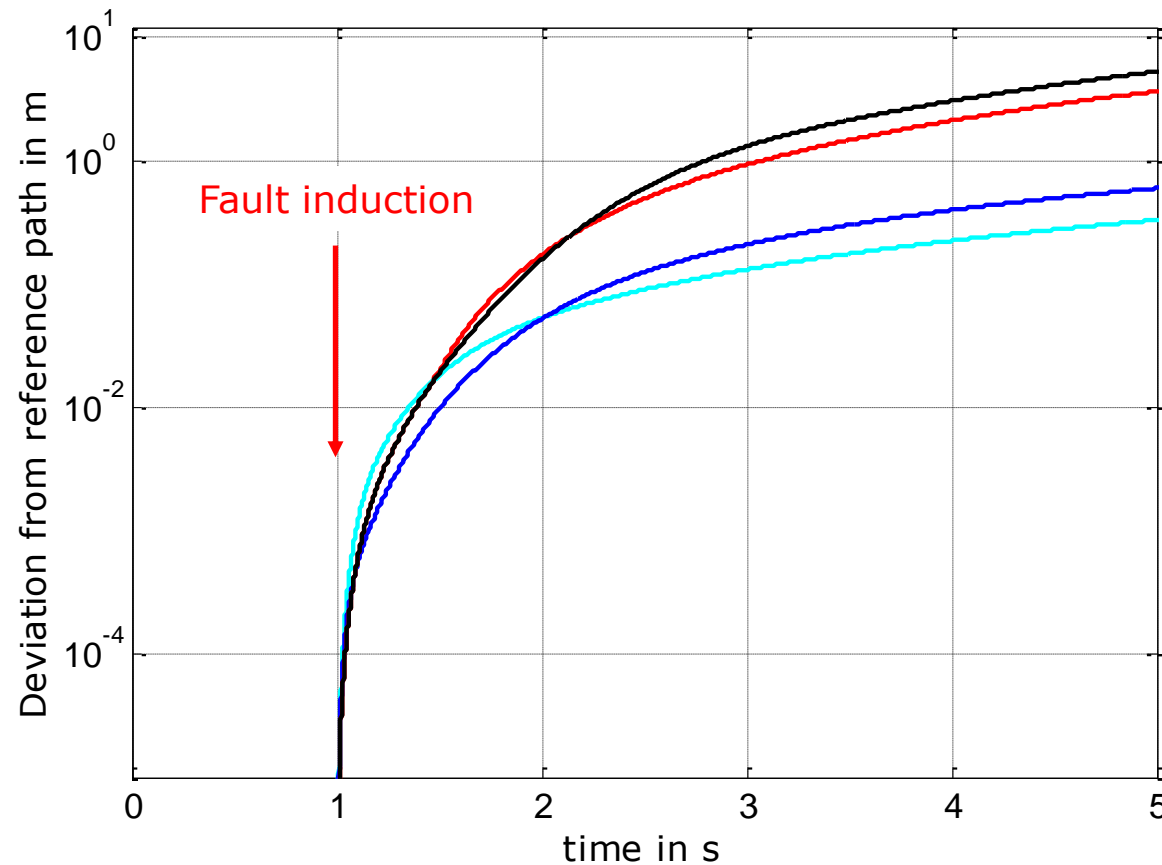


Severity Rating for	Range	Rating/Class	Description
$\Delta(a_x)$ in m/s^2 S_A	0 to 0.5	1	LOW
	0.5 to 1.5	2	MEDIUM
	1.5 to 3	3	HIGH
	3 +	4	VERY HIGH
$\Delta(a_y)$ in m/s^2 S_B	0 to 0.5	1	LOW
	0.5 to 1.25	2	MEDIUM
	1.25 to 2.5	3	HIGH
	2.5 +	4	VERY HIGH
$\Delta(\psi)$ in % $\Delta(\psi)$ S_C	0 to 10	1	LOW
	10 to 25	2	MEDIUM
	25 to 50	3	HIGH
	50 +	4	VERY HIGH
Final Severity Rating S_D	0 to 3	S1	LOW
	3 to 15	S2	MEDIUM
	15 to 40	S3	HIGH
	40 +	S4	VERY HIGH

Challenges

How to assist the driver?

Results with force allocation strategy



Controller type: — Simple FA — Optimized FA — ESC — uncontrolled

Input: Inverter-shutdown - Fault at wheel 3 - $T_{\text{fault}} = 1\text{ s}$ - $v_x = 120\text{ km/h}$ - $R = 225\text{ m}$

Thank you for your attention!



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Johannes Edrén

PhD Candidate

KTH Vehicle Dynamics

Phone: +46 8 790 7714

Mail: edren@kth.se

Daniel Wanner

PhD Candidate

KTH Vehicle Dynamics

Phone: +46 8 790 7805

Mail: dwanner@kth.se

Project leader and academic supervision

KTH Vehicle Dynamics

Annika Stensson Trigell

Lars Drugge

Jenny Jerrelind

Mats Jonasson (VCC)