BIOMOTION SOLUTIONS

VEHICLE DYNAMICS EXPO 2012

Active Human Body Models for Vehicle Dynamics Simulation

Dr. Valentin Keppler
R&D Biomotion Solutions
Tübingen (Germany)
www.biomotionsolutions.com

Company Profile

BIOMOTION SOLUTIONS

"Take virtual engineering to the next level – let virtual humans use your products"

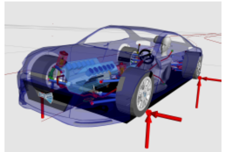
- Long term experience with biomechanical models
- Interdisciplinary research
- Biomotion Solutions:
  - University spin-off
  - Implementation of models in industry standard mbs-platform (SIMPACK)

Partner:

SIMPACK
Leading MBS Technology for Technology Leaders

Institut für Sportwissenschaft

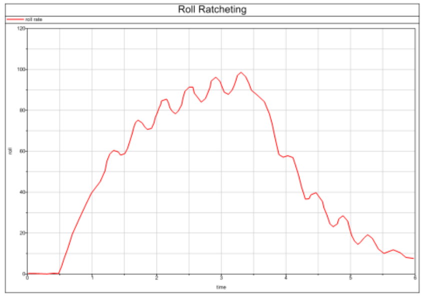
Biomechanical Influences on Vehicle Dynamics?

	Mass Machine [kg]	Ratio Human/ Machine (Mass Human 80 Kg)	influence to be expected?
	10	8	definitely
	210	0.38	possibly
	1 500	0.053	no specific assumption
	17 000	0.0047	none

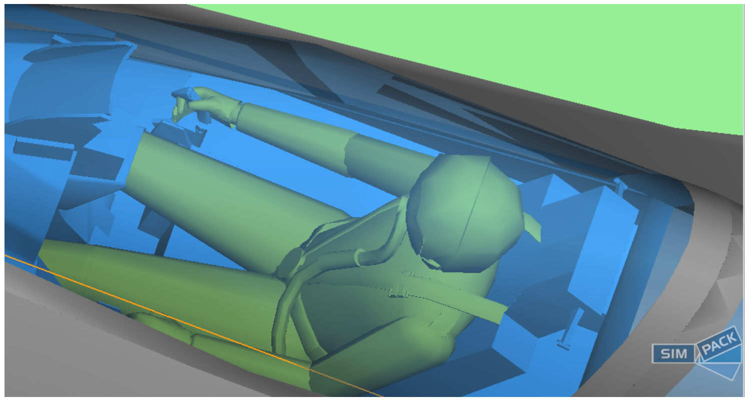
Human-Machine-Interaction

Roll-Ratcheting

Neuro-muscular vibration amplified by the fly by wire (side stick) system causes the system to show unwanted roll-oscillation.



- Smith J and Montgomery T July 1996 Biomechanically induced and controller coupled oscillations experienced on the f-16xl aircraft during rolling maneuvers. NASA Technical Memorandum 4752.
- Dr. Ing. Martin Hanel, Dipl. Ing. Robert Osterhuber EADS Military Air Systems, Manching"The Role of Pilot Modelling in Handling Qualities Evaluation", November 2008)



Biomechanical dynamics can affect vehicle dynamics

Detailed investigation of rider motorcycle system

The Active Human Body Model

Biomechanical Model with Motion Controller

- The mechanical interface between the driver and the vehicle has to be modeled with an appropriate level of detail to take into account the driver's influence on vehicle dynamics.
- Therefore a motion-control model for the upper limbs had to be developed.
- The model is capable of steering the motorcycle by hand-arm-movement.

Biomechanical Body Model

Elements and Parameters

- 17 rigid bodies
- Inertial parameters from literature (NASA)
- Torque generators at the joints represent net muscle moments
- Reaction forces (e.g. hand-handlebars or saddle-pelvis)

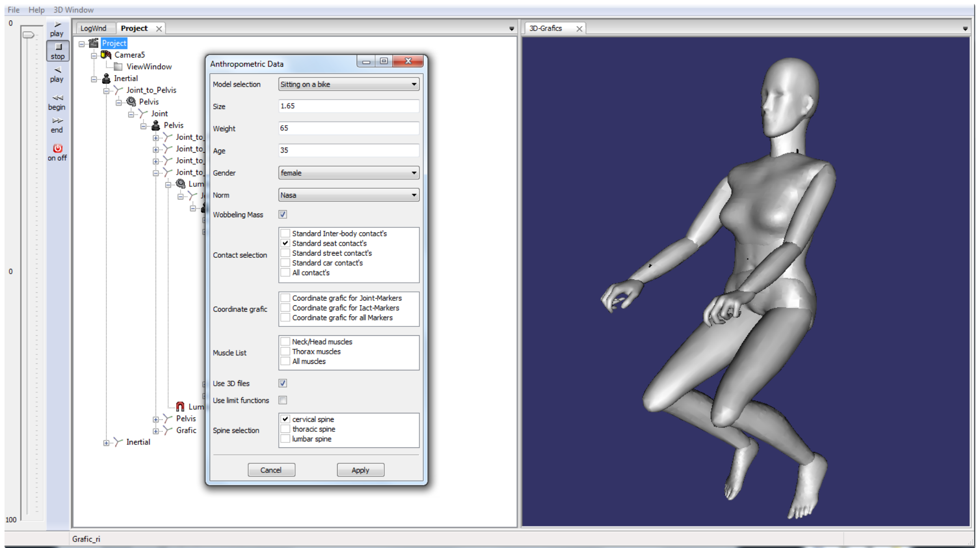
- Chandler R, Clauser R and MCConville C 1975 Investigation of inertial properties of the human body. AMRL Technical Report, NASA Wright-Patterson Air Force Base.
- Clauser C, MCConville J and Young J 1969Weight, volume and center of mass of segments of the human body. AMRL Technical Report, NASA Wright-Patterson Air Force Base.
- NASA 1978 NASA Reference Publication 1024: The internal properties of the body and its segments. (NASA).

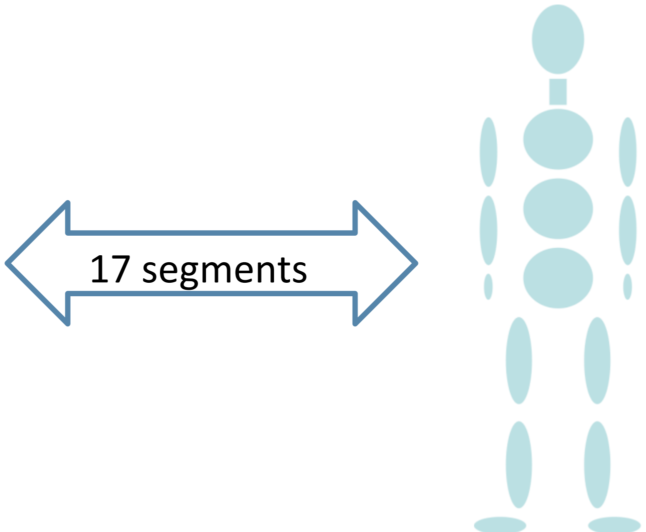
Biomechanical Body Model

Model Generation by means of Varibody

- Input parameters for model:
  - Stature
  - Weight
  - Gender

All necessary elements like joint actuators, wobbling mass elements or contact force elements are also generated by the model generator.

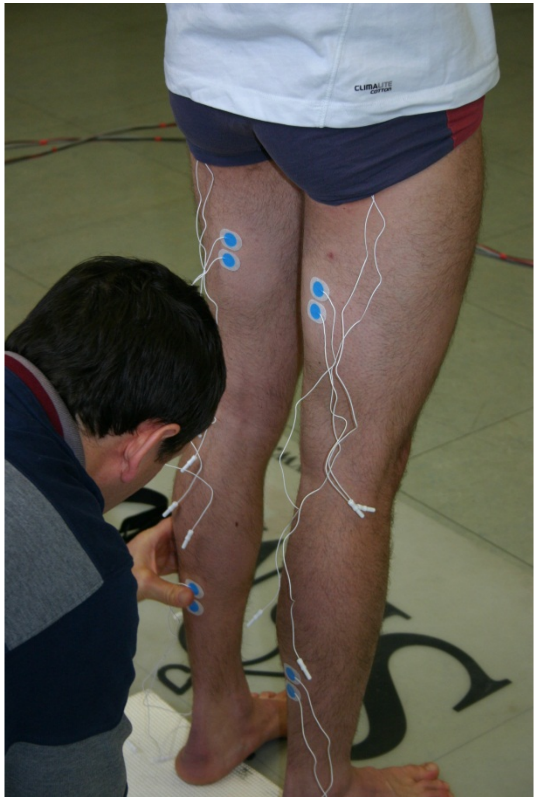


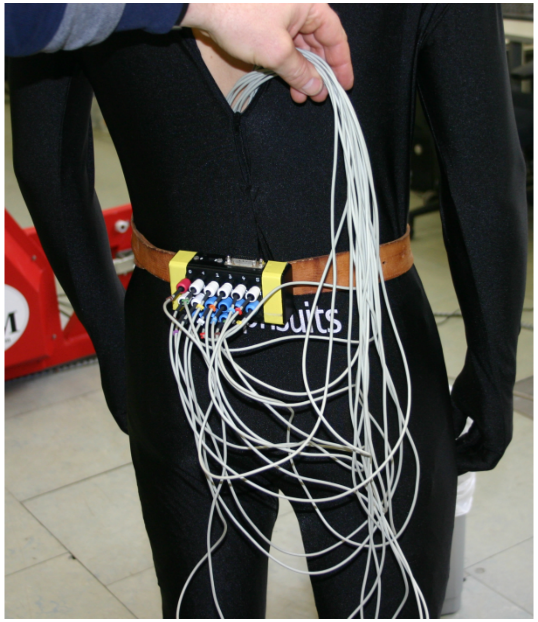


Biomechanical Body Model

Interdisciplinary Approach

BIOMOTION SOLUTIONS





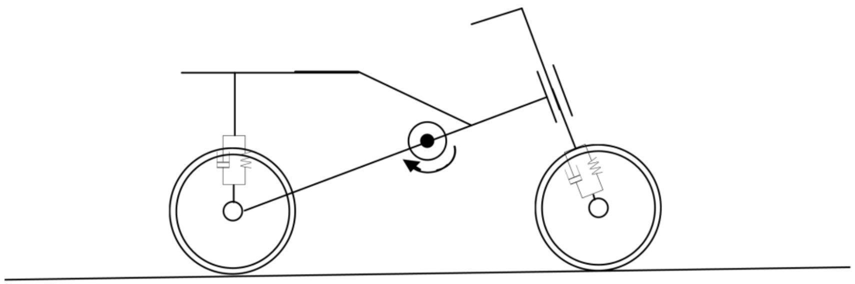
High Speed Video Analysis
EMG (muscular stimulation)
Reaction Forces

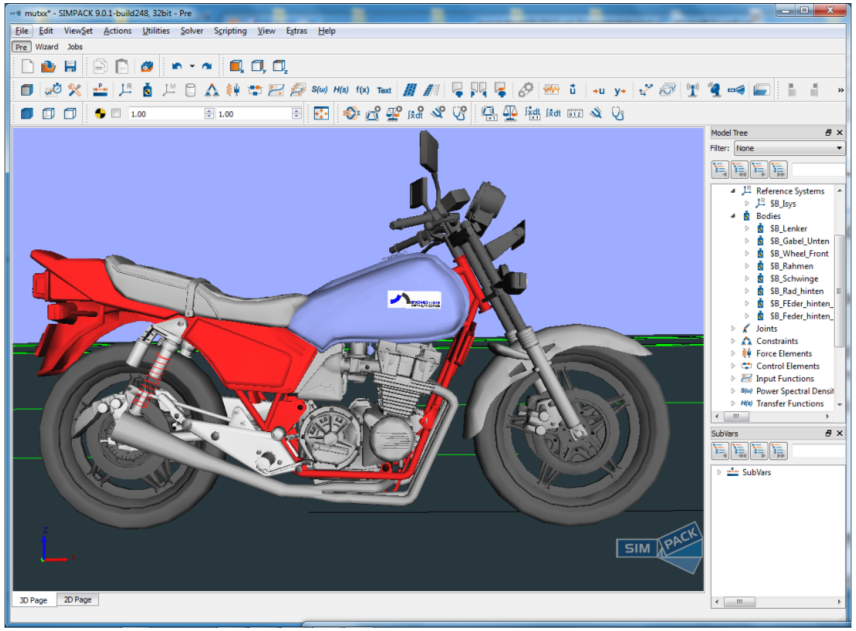
Cooperation:
Institute for Sports science University Tübingen
(Prof. Veit Wank)

Motorcycle Model

8 Bodies 11 Degrees of Freedom

BIOMOTION SOLUTIONS



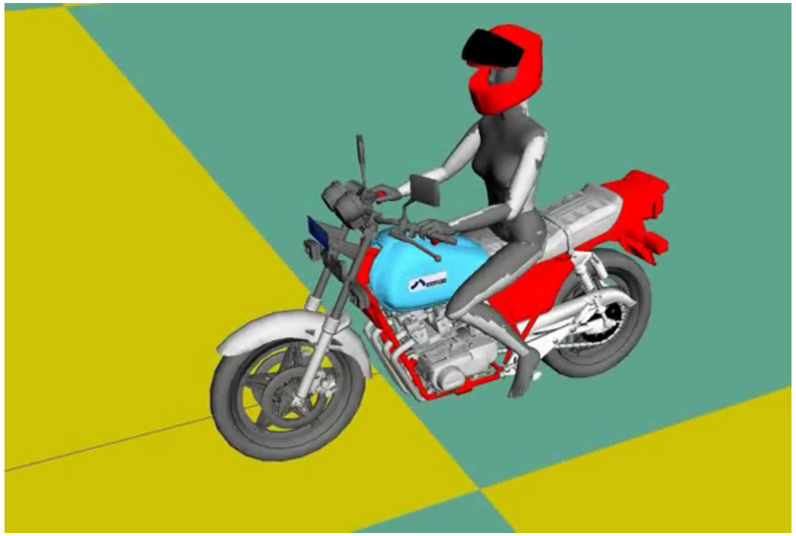


- MBS Model (SIMPACK)
- 8 rigid bodies (tot. 210 Kg)
- Linear suspension (damping and stiffness)
- Realistic tyre model ("magic formula")
- 13 Joint States, 2 Constraints
- 11 Degrees Of Freedom (DOF)

Frequency Response Function:

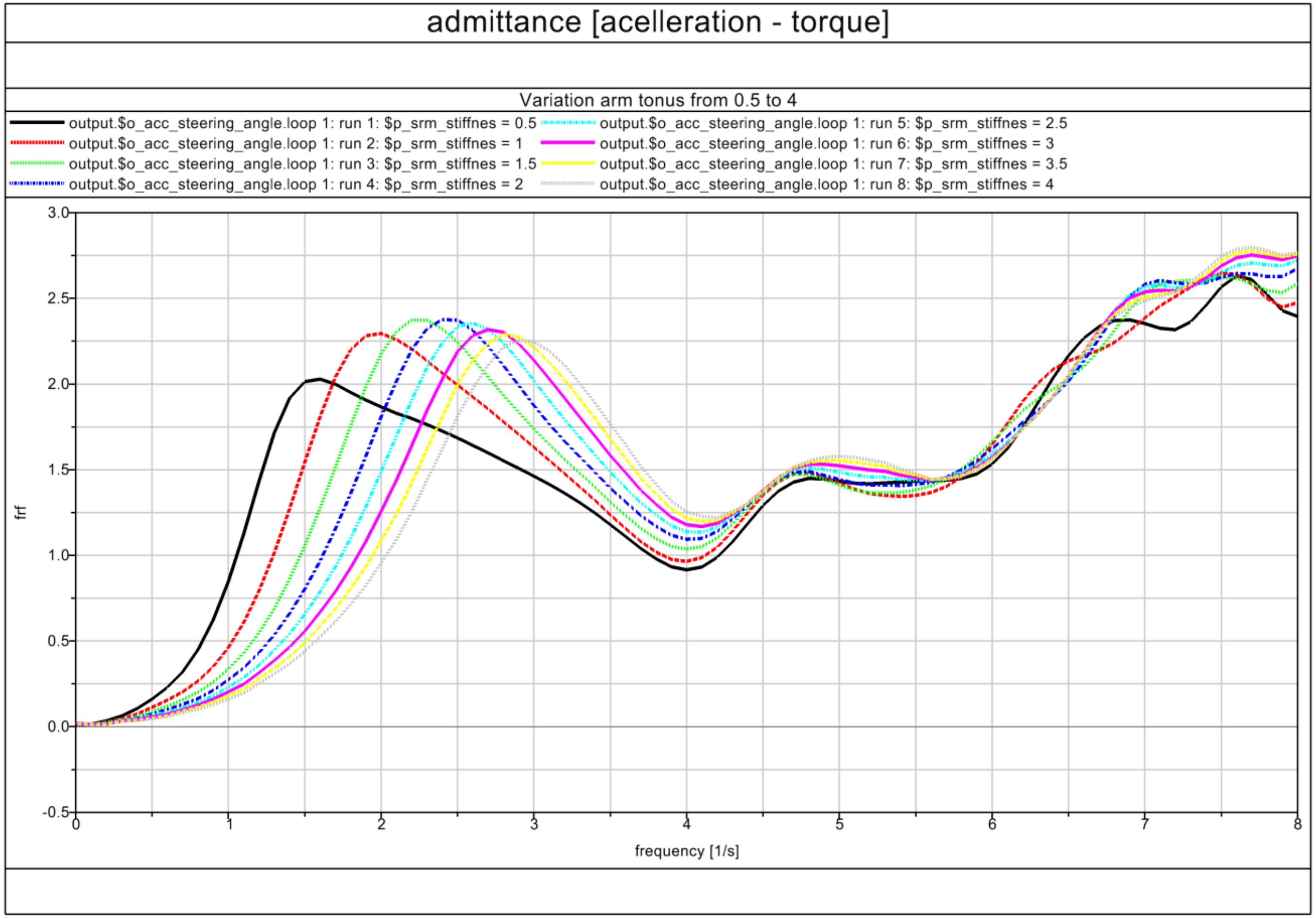
Identification of Joint Parameters of the Rider

- Compared with measurement data from V. Cossalter
- Cross spectrum: steering axis acceleration / excitation torque
- Frequency sweep



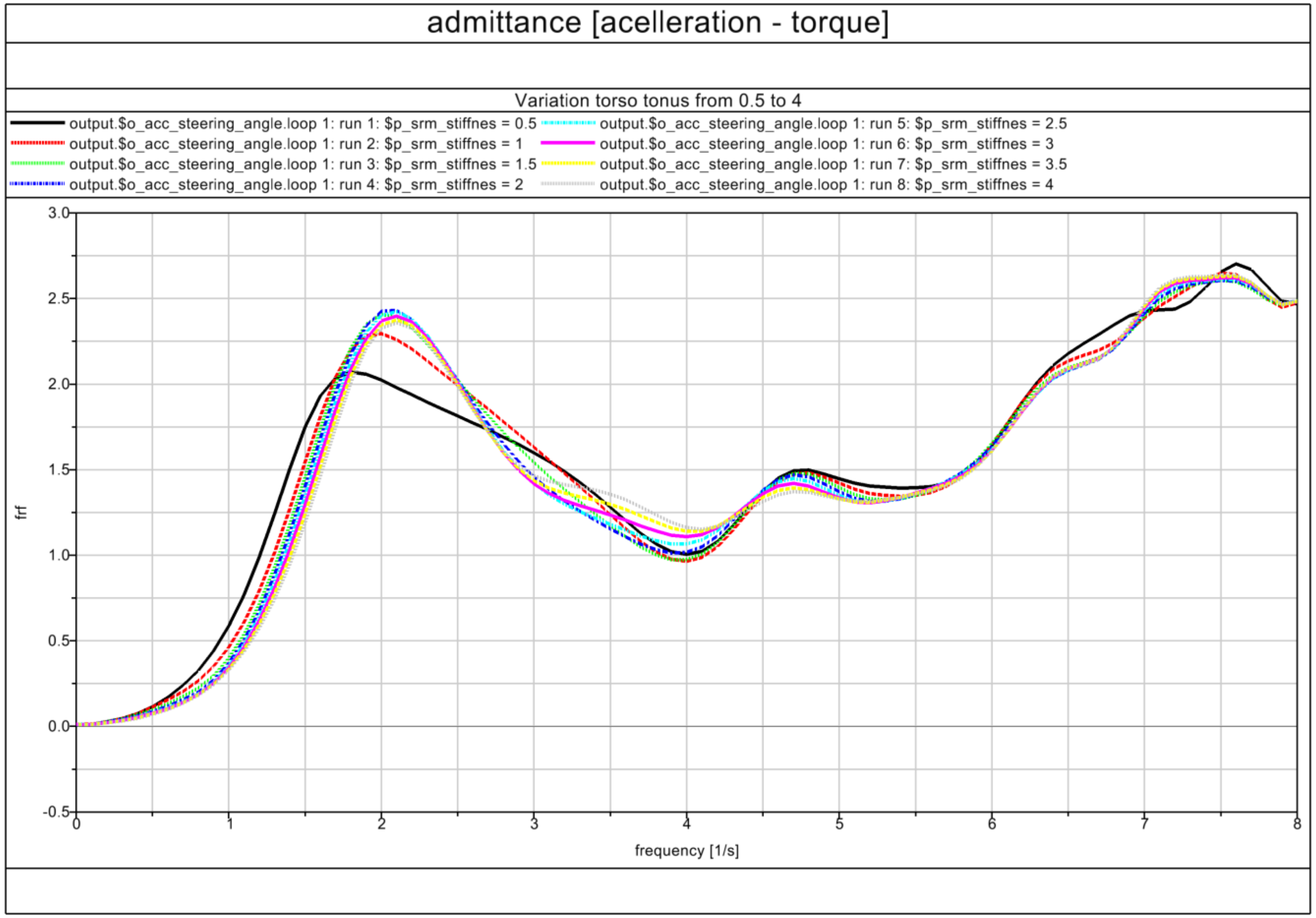
Variation of Arm Stiffness

Shifting the Resonance Frequency



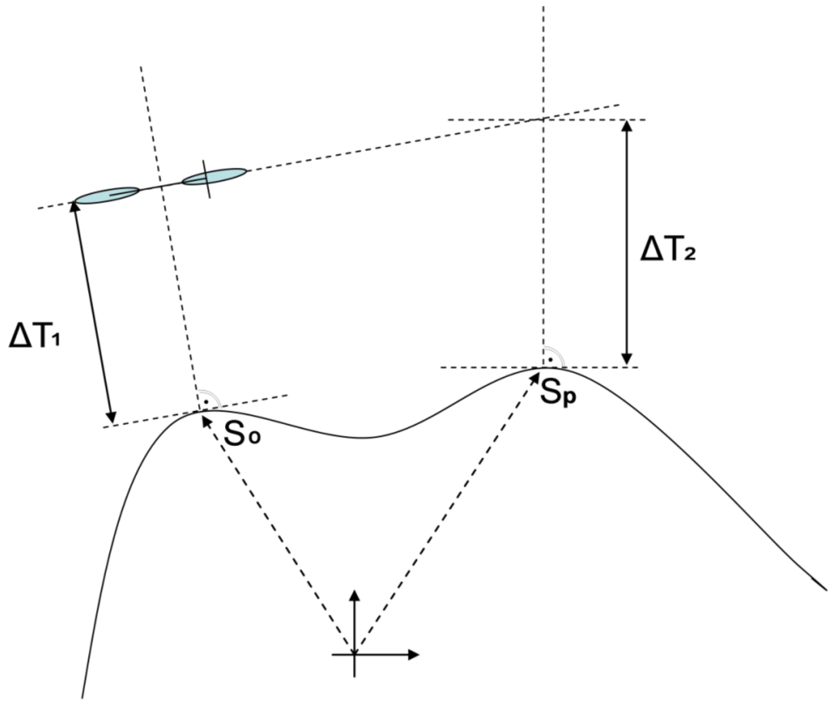
Variation of Trunk Stiffness

Lesser Influence on Resonance



Road Preview Sensor

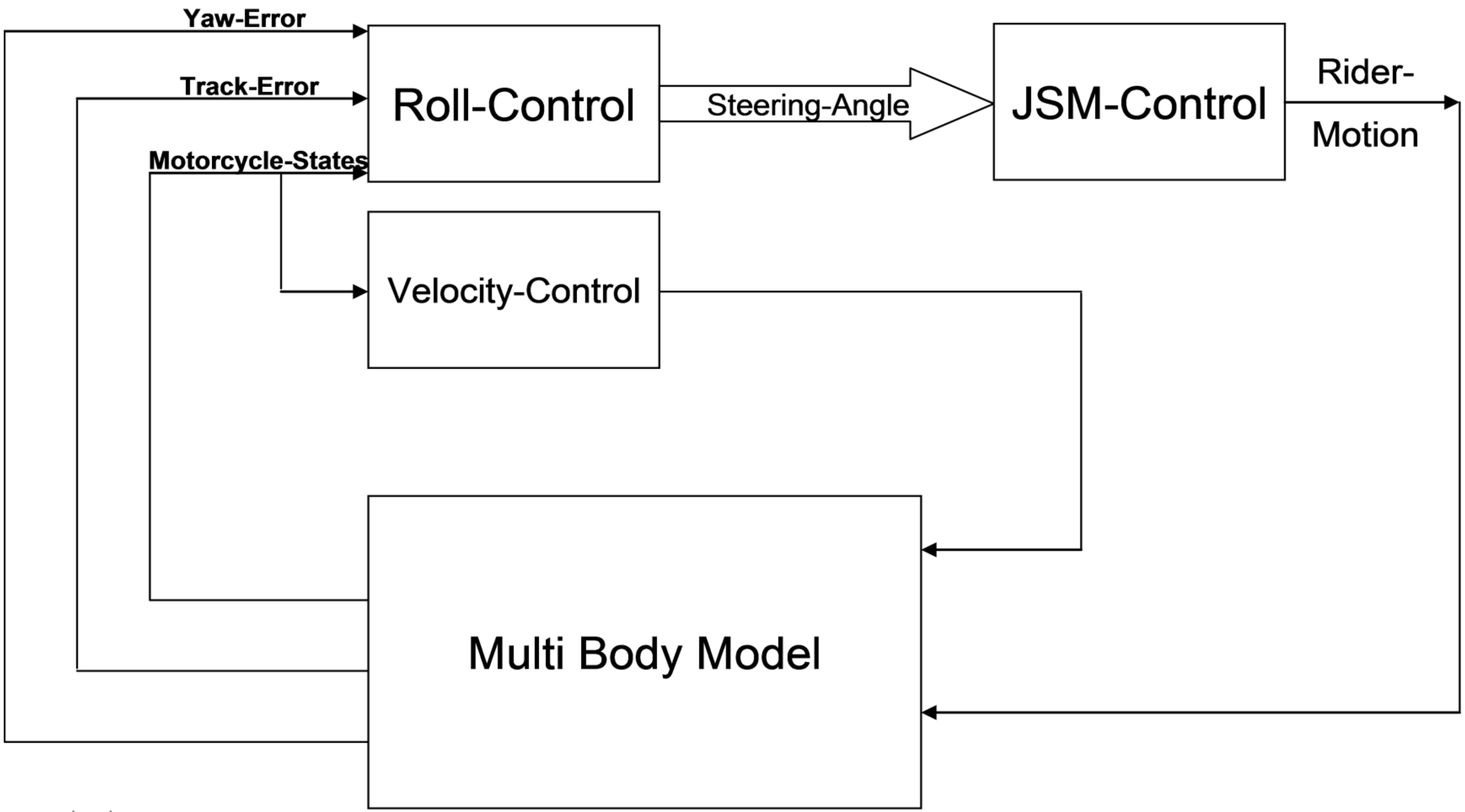
Velocity Dependent Preview Distance



- Simple control approach: Road Preview
- Not expected to be near optimal control
- Counter steering → ”steer into the fall“
- To control roll angle the steering angle has to be controlled
- The desired steering angle is input to Joint Space Model (JSM) controller

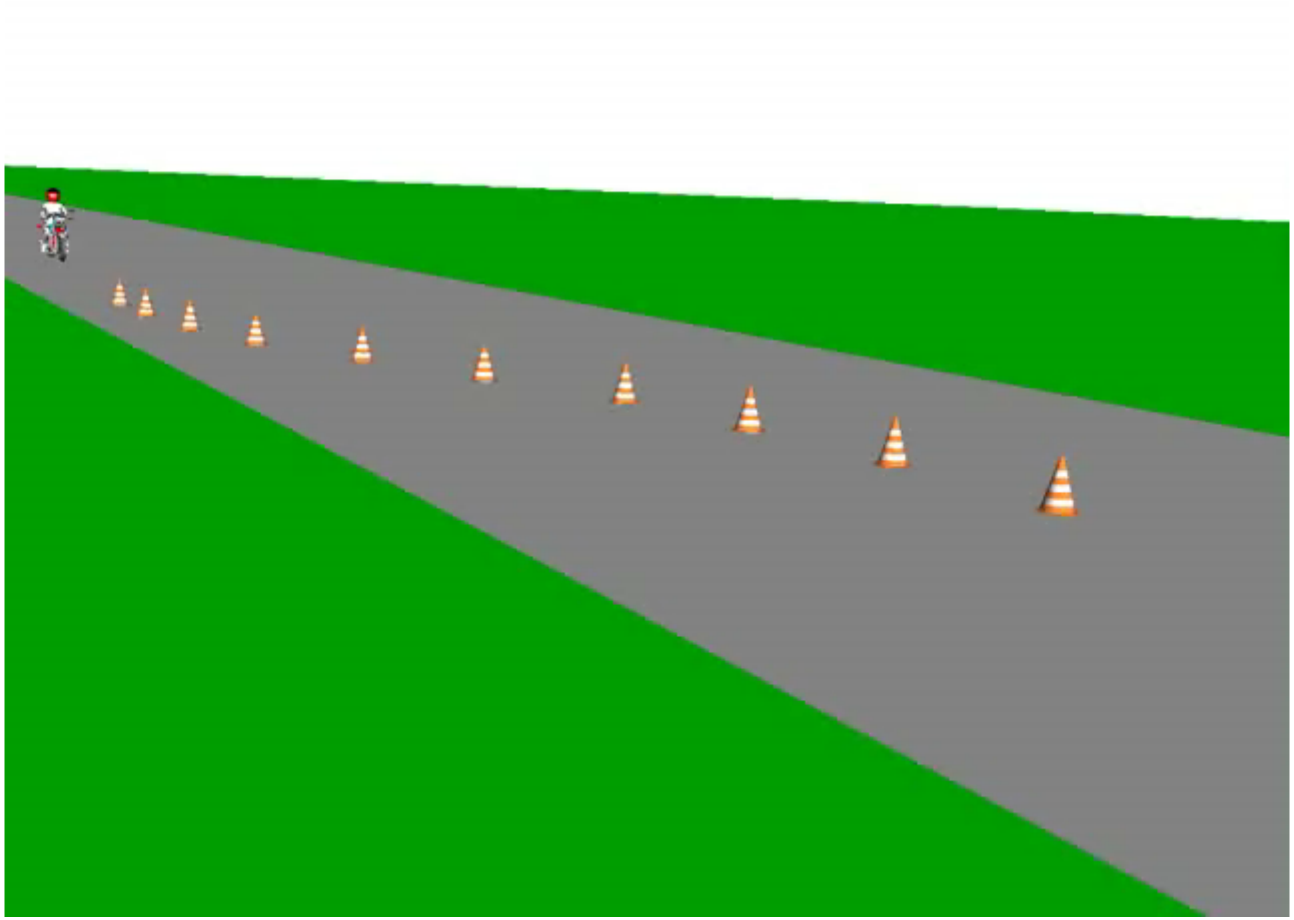
Rider Controller

Signal Processing Scheme



Crossover Maneuver

Stable Track Following

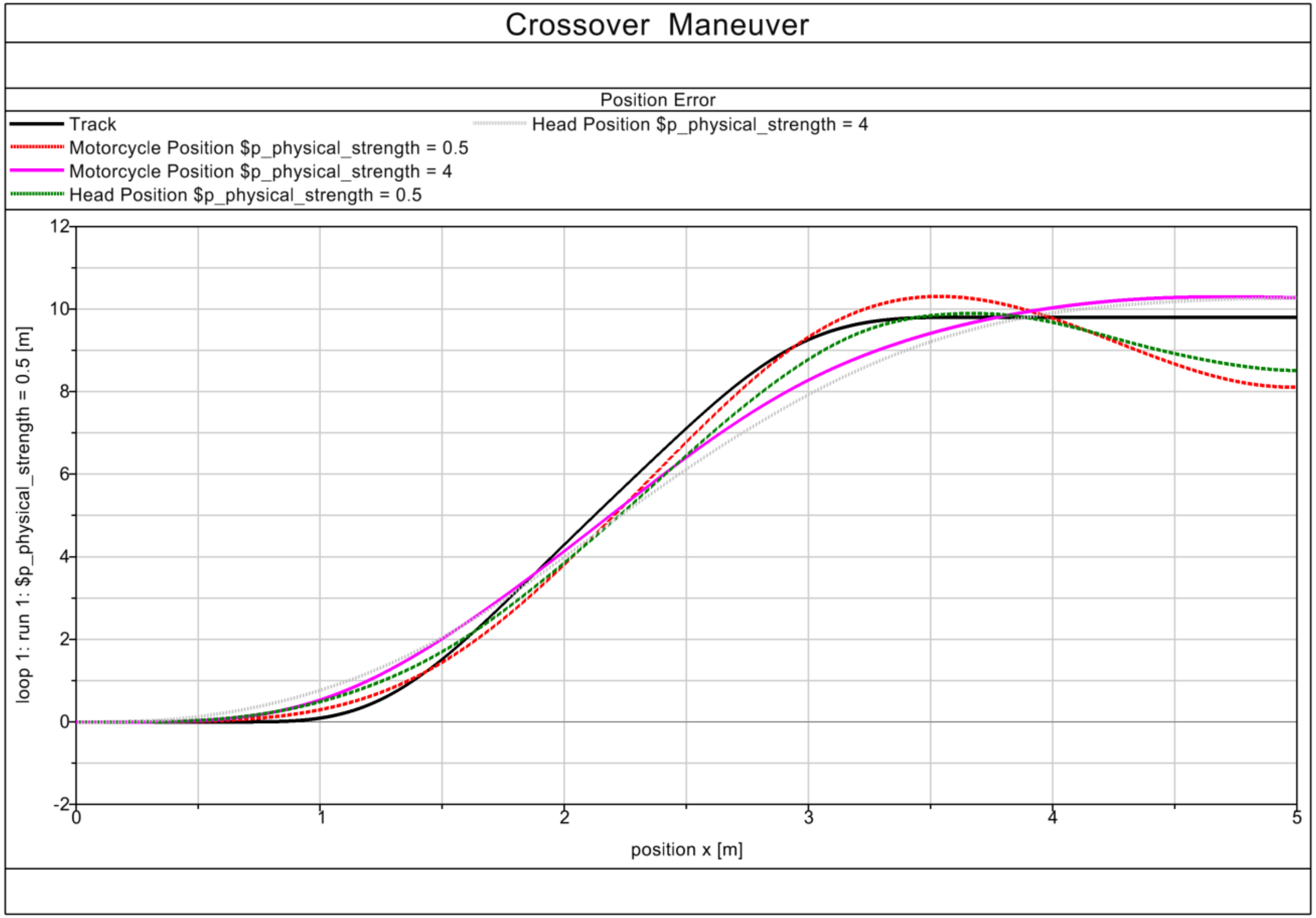


Results

1. It is possible to realize a steer by hand-arm motion control for standard maneuvers.

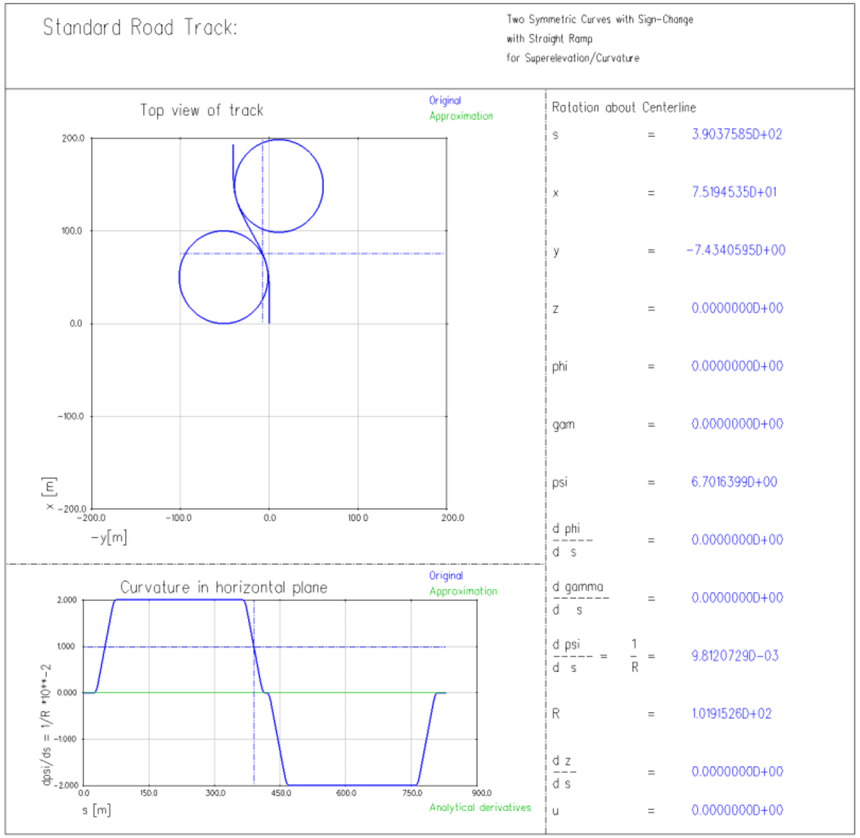
Crossover Maneuver:

Influence of Muscular Tension

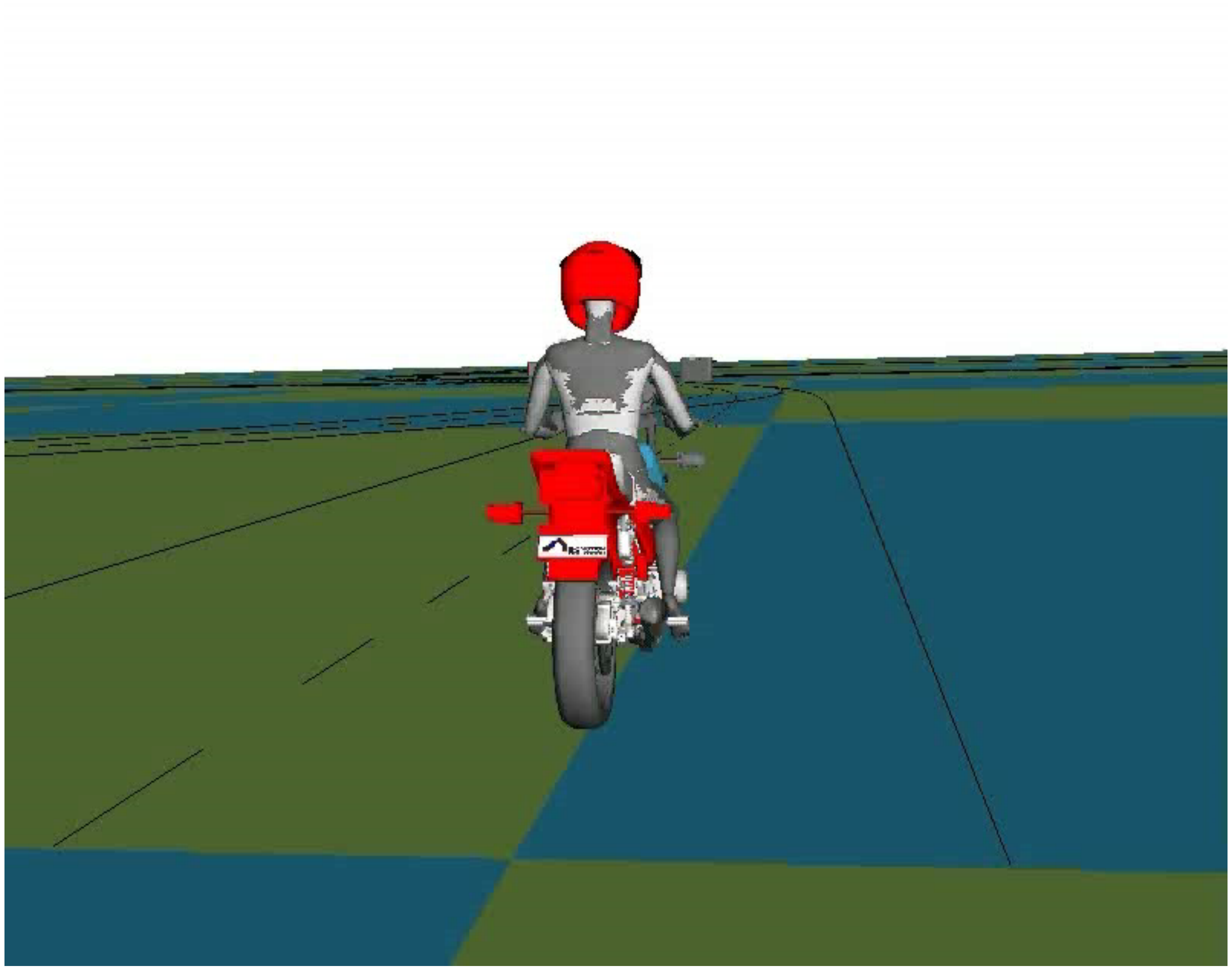


Circle Track Profile

Transition to Steady States

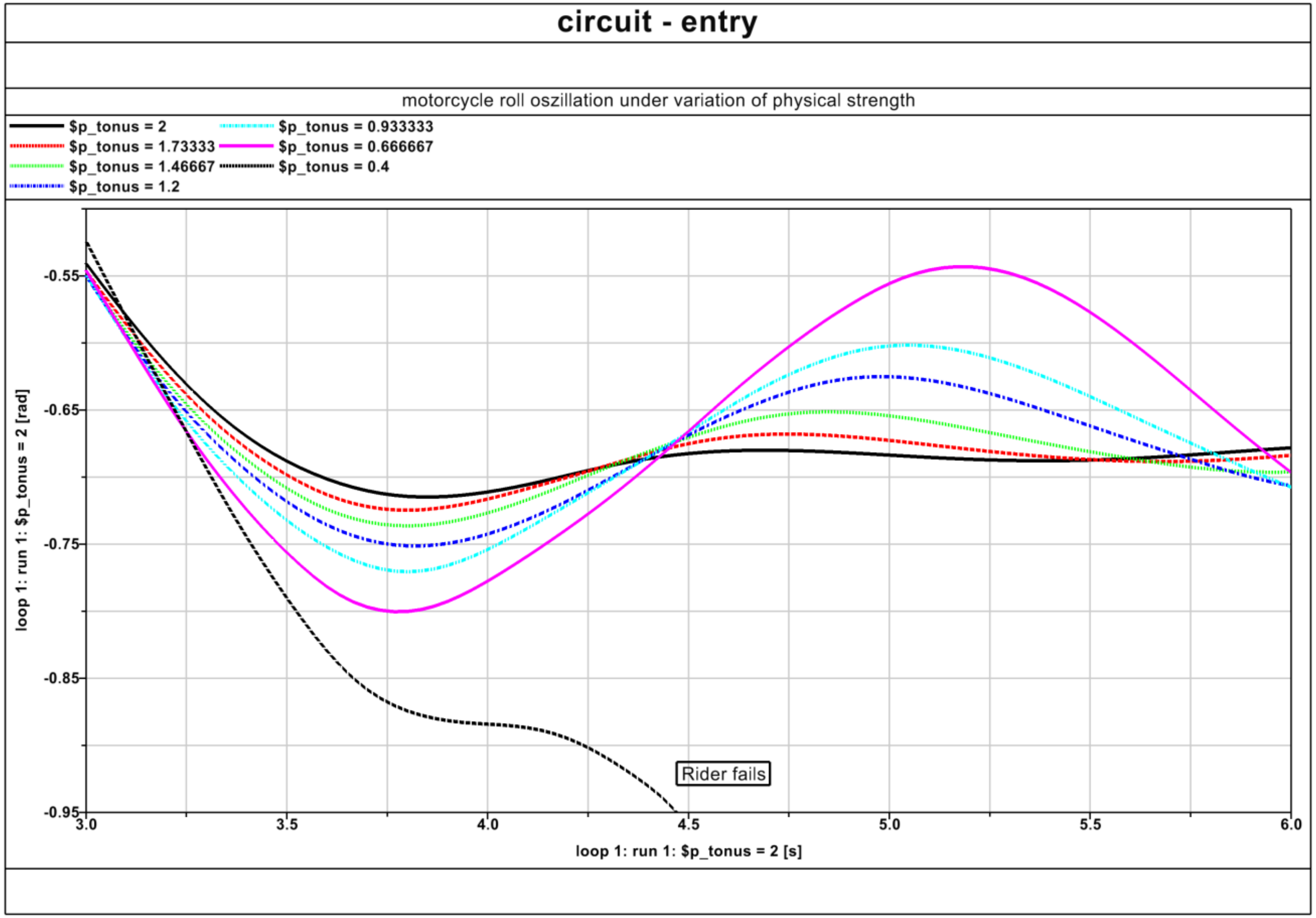


Circle Track:
Riding with 20 m/s



Cycles Maneuver:

Influence of Muscular Tension on Roll Oscillation

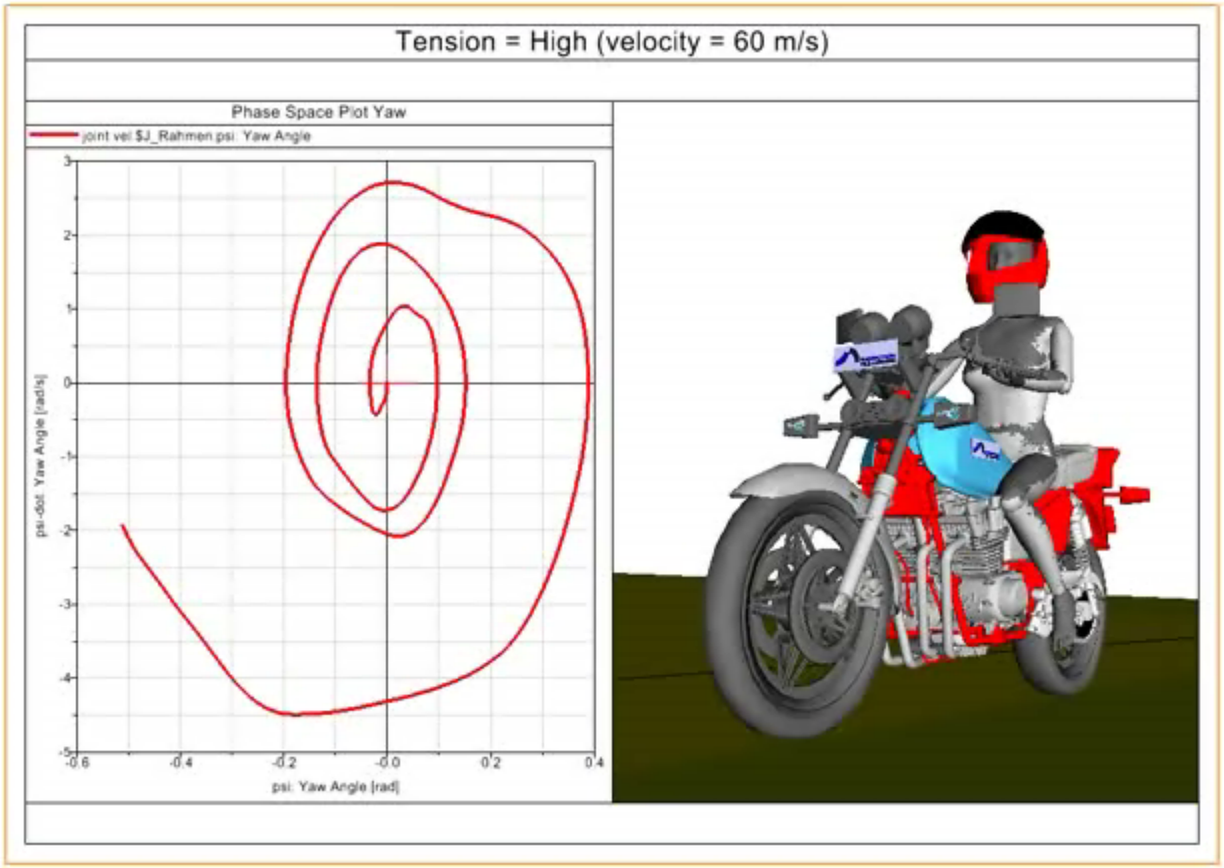


Results

1. It is possible to realize a steer by hand-arm motion control for standard maneuvers.
2. Anthropometrical parameters influence vehicle handling.

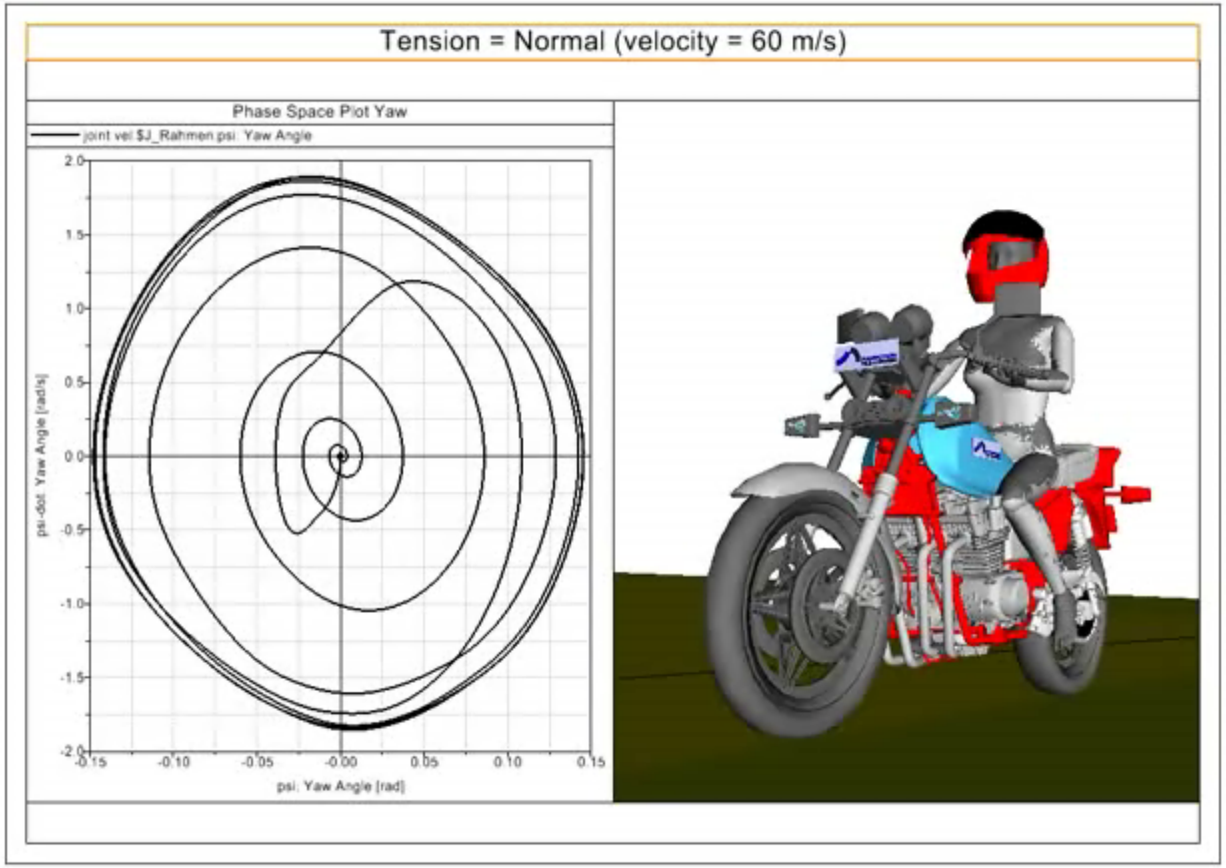
Weave Mode:

Dependency on Muscular Tension



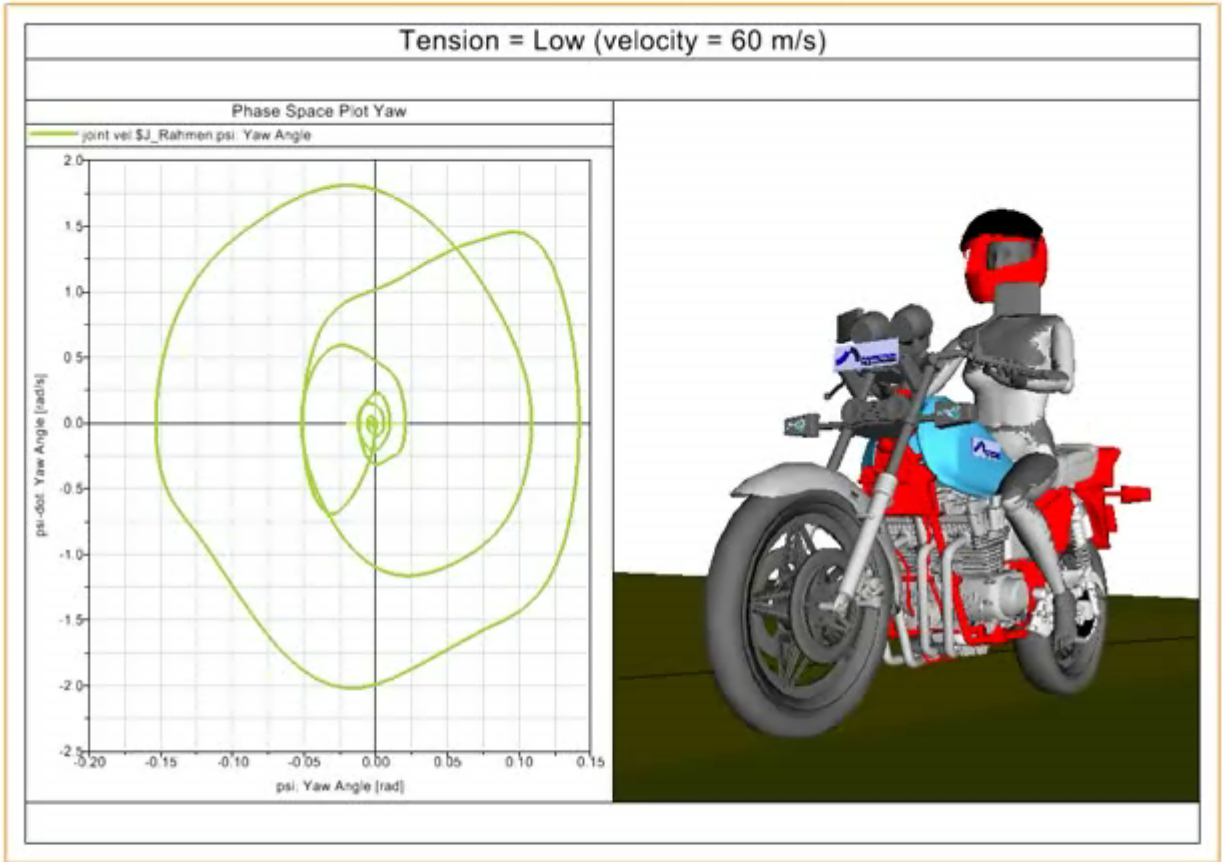
Weave Mode:

Dependency on Muscular Tension



Weave Mode:

Dependency on Muscular Tension



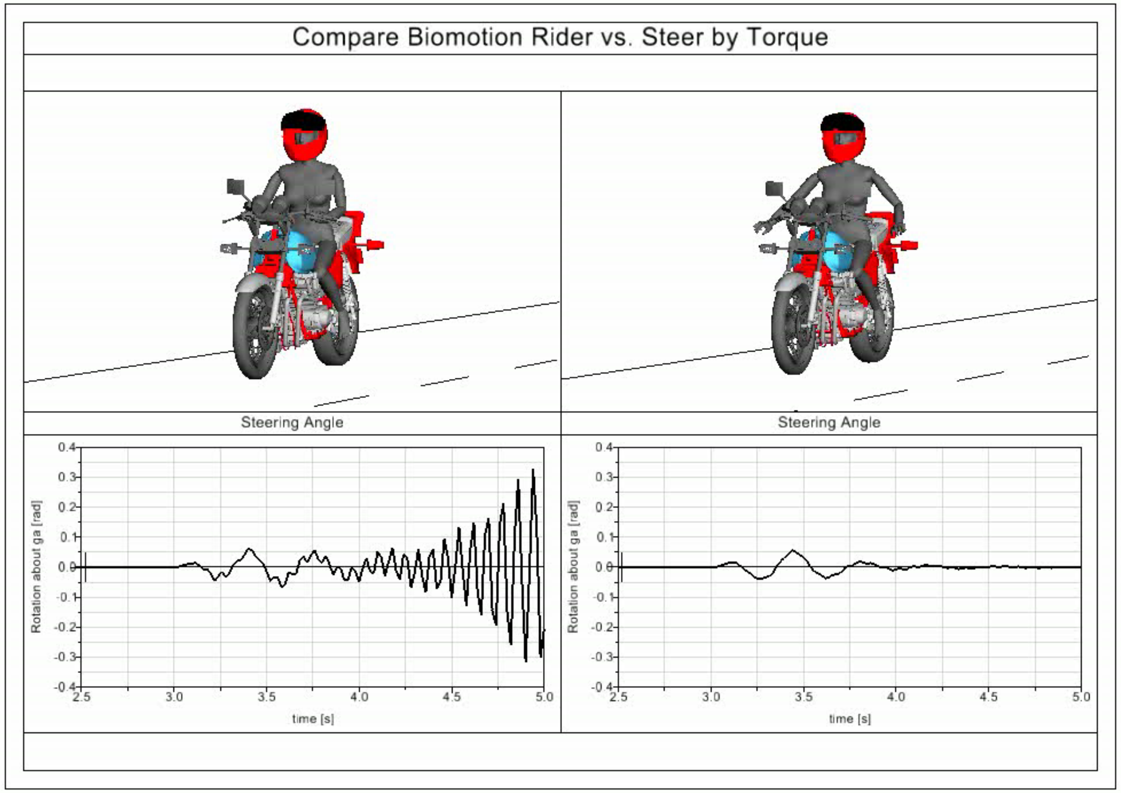
Results

1. It is possible to realize a steer by hand-arm motion control for standard maneuvers.
2. Anthropometrical parameters influence vehicle handling.
3. Rider' s muscular tension influences motorcycle ride stability.

Hip Swing Induces Wobble

Compare Active Rider with Direct Torque Steering

Biomotion Rider Model

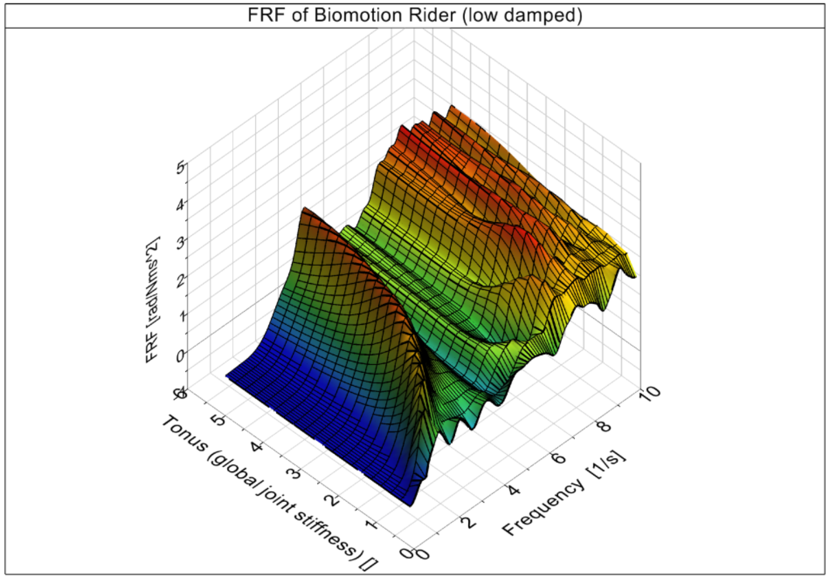


Direct Torque Steering

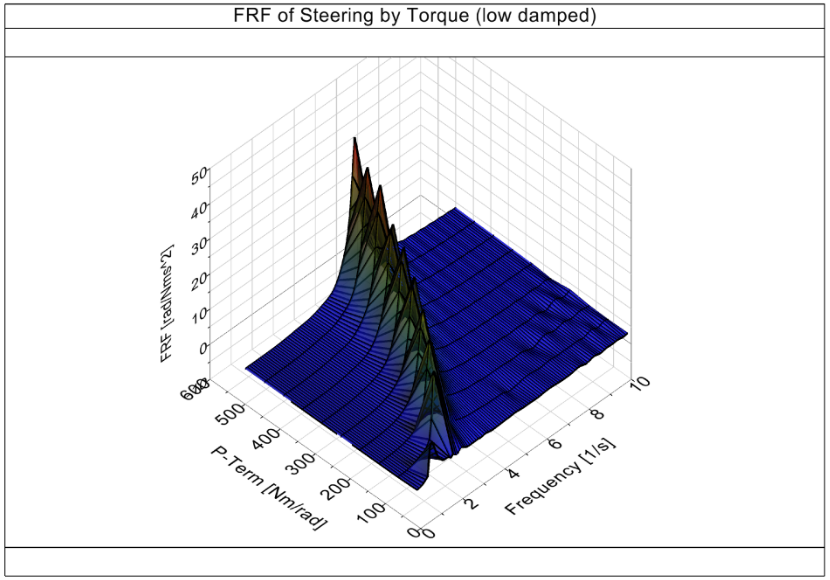
Steering Admittance (FRF)

Low Damping

Biomotion Rider



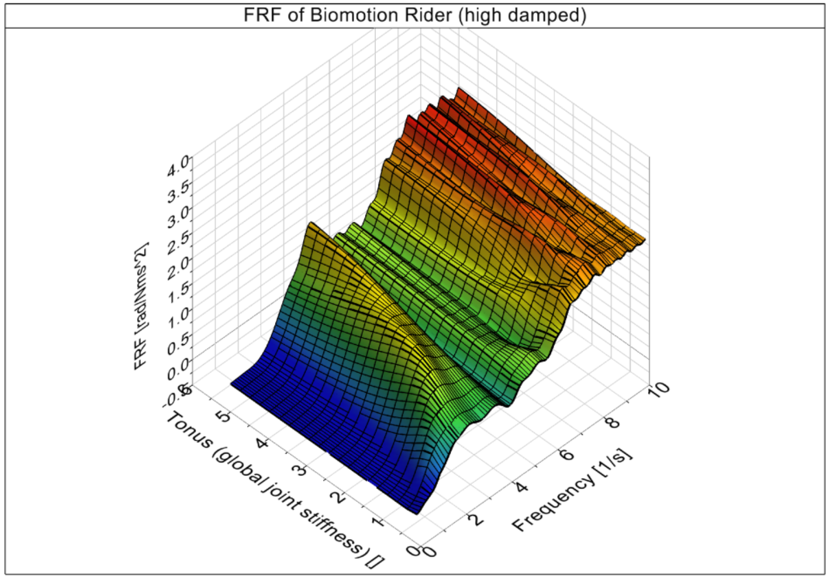
Steer by Torque



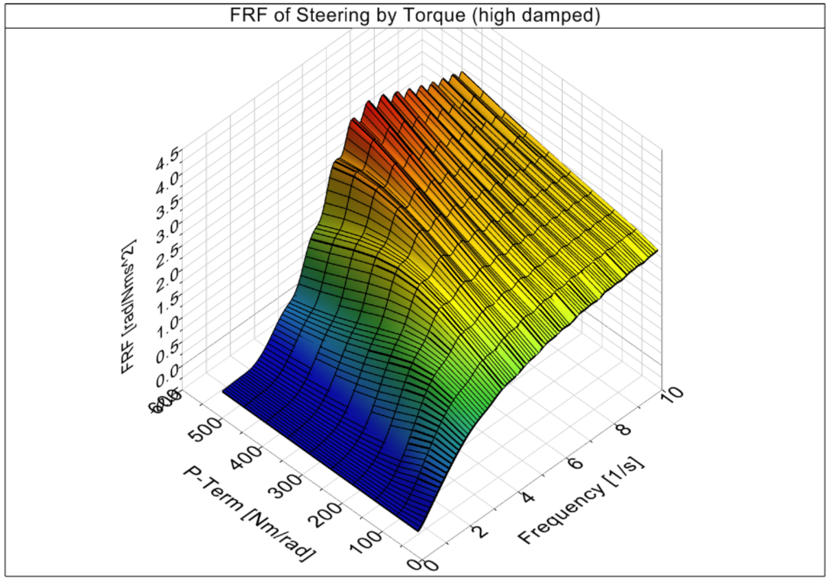
Steering Admittance (FRF)

High Damping

Biomotion Rider



Steer by Torque



Results

1. It is possible to realize a steer by hand-arm motion control for standard maneuvers.
2. Anthropometrical parameters influence vehicle handling.
3. Rider's muscular tension influences motorcycle ride stability.
4. The biomechanical rider FRF (admittance) results implicitly from physical parameters.

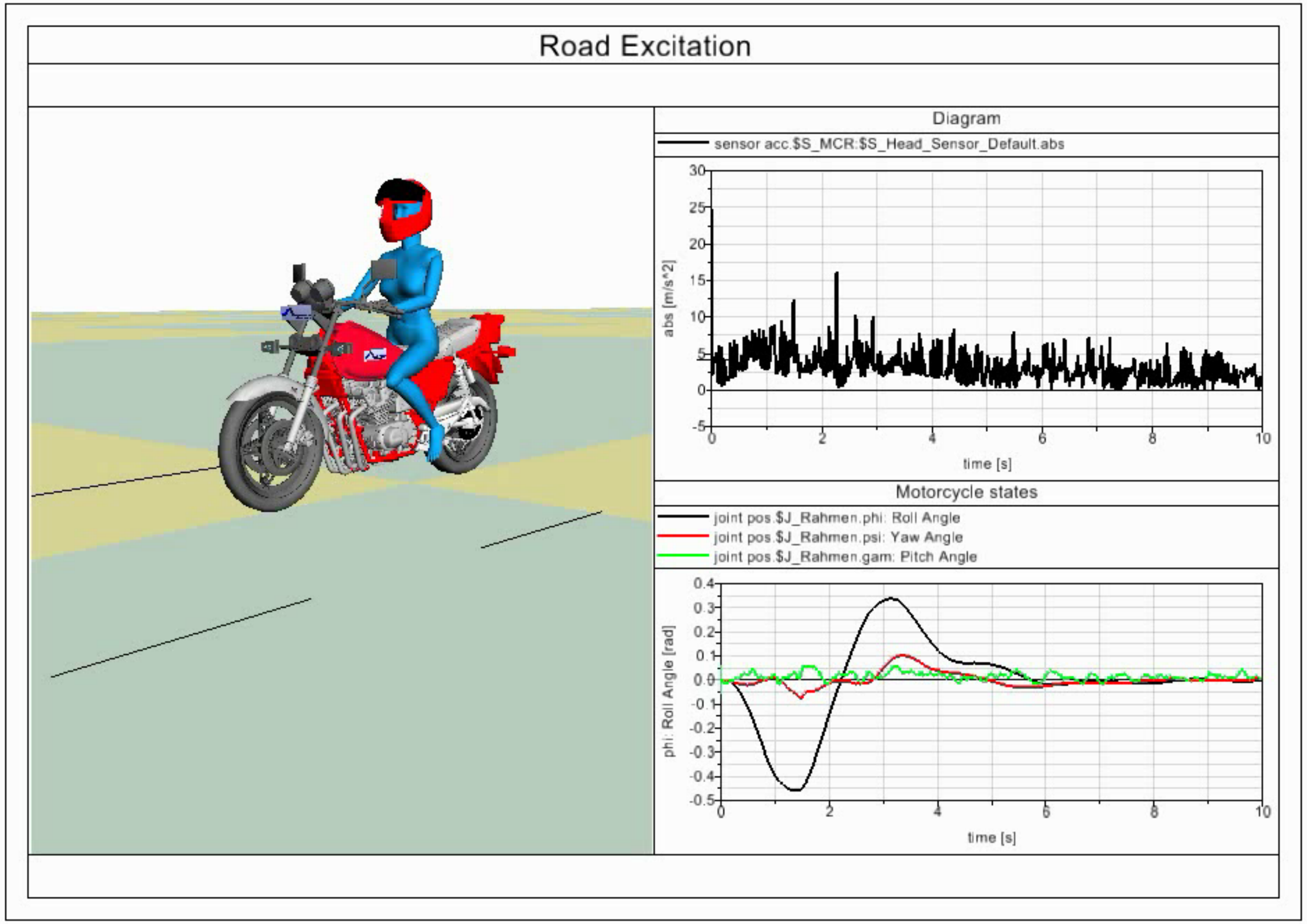
Perspectives

Active human body models have benefits in vehicle dynamics simulation

- The control scheme will be extended to cover lap-time optimization too (including rider's motion).
- Active driver and occupant models can be applied in general vehicle dynamic simulation, e.g. for cars and busses (driver assistance systems, steer and brake by wire, ride comfort, shift comfort etc.).
- Biomotion models are applicable in vehicle concept innovation, e.g. narrow track vehicles, e-bikes, three-wheelers.

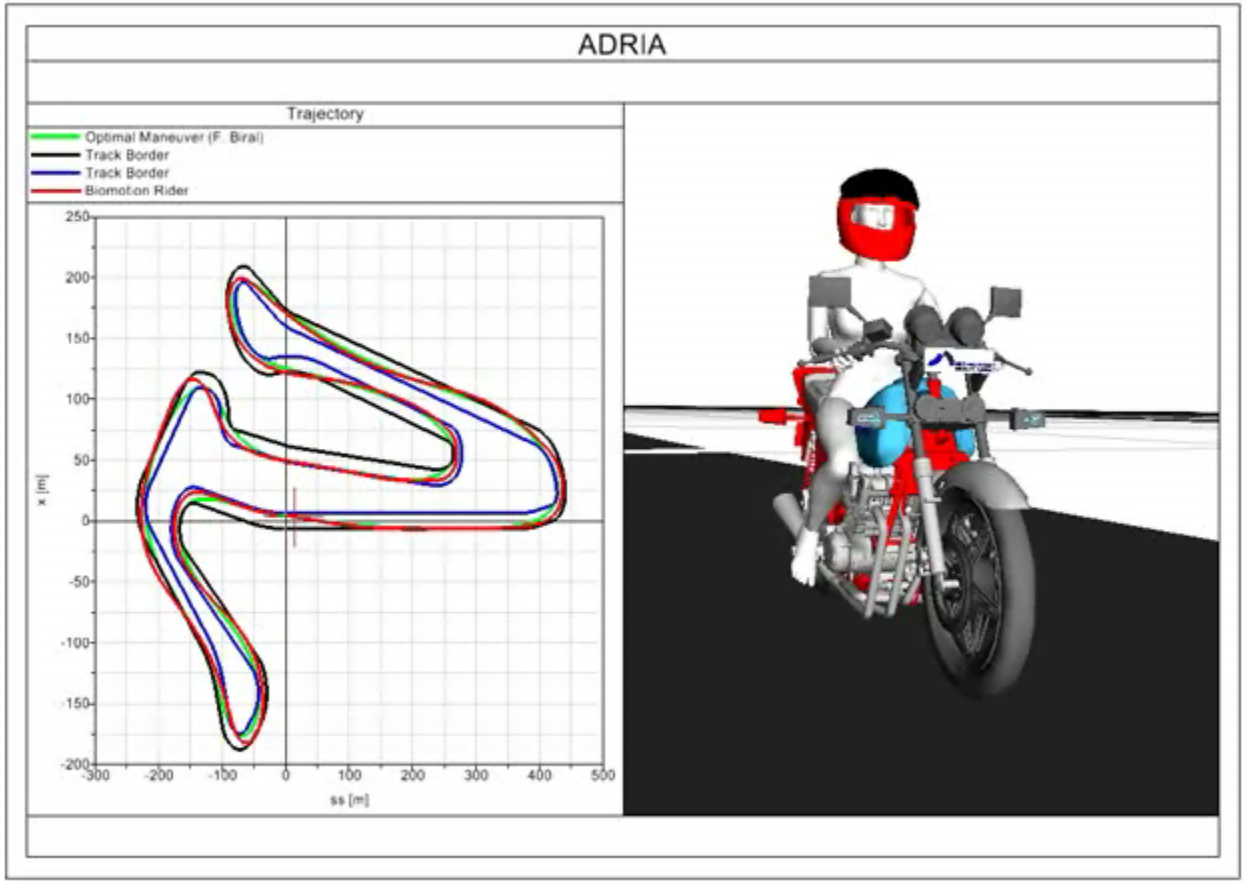
Road Excitation

Evaluation of Ride Comfort



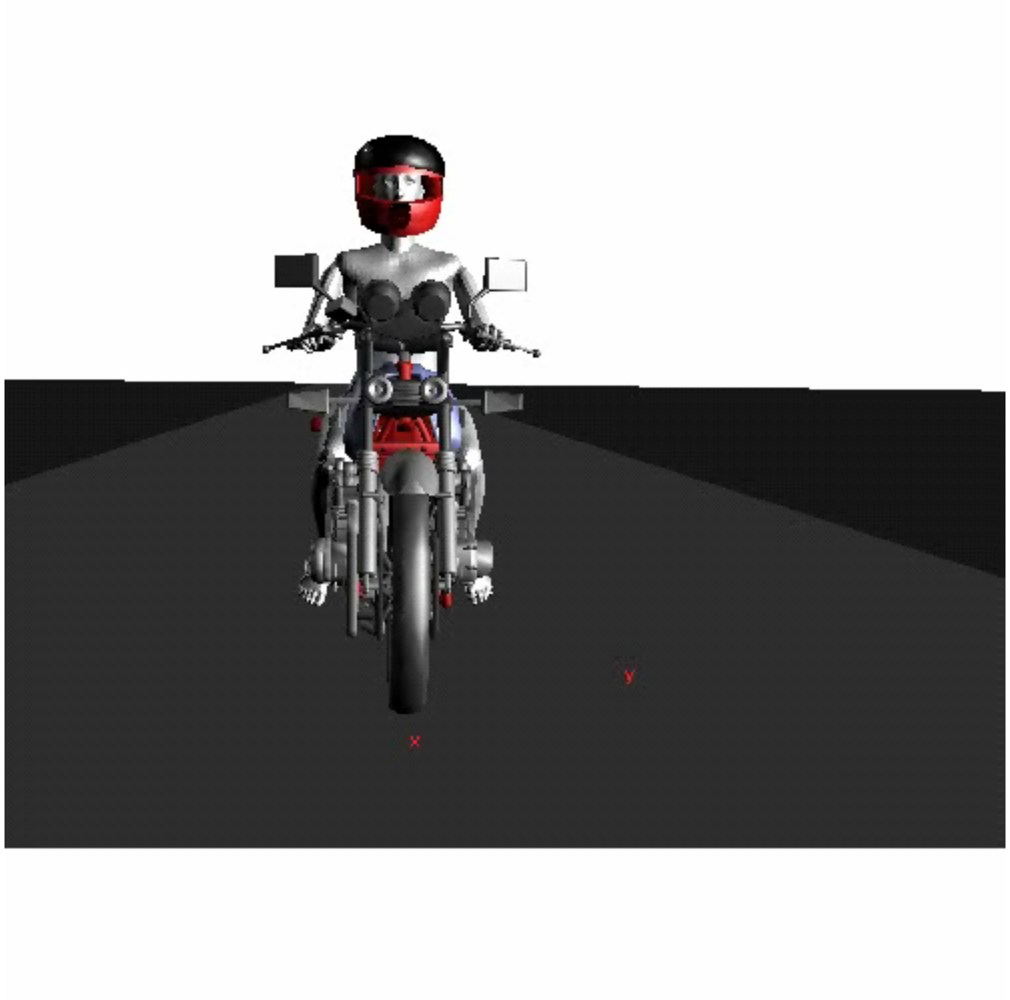
Course of Adria

Comparison with Optimal Maneuver Method



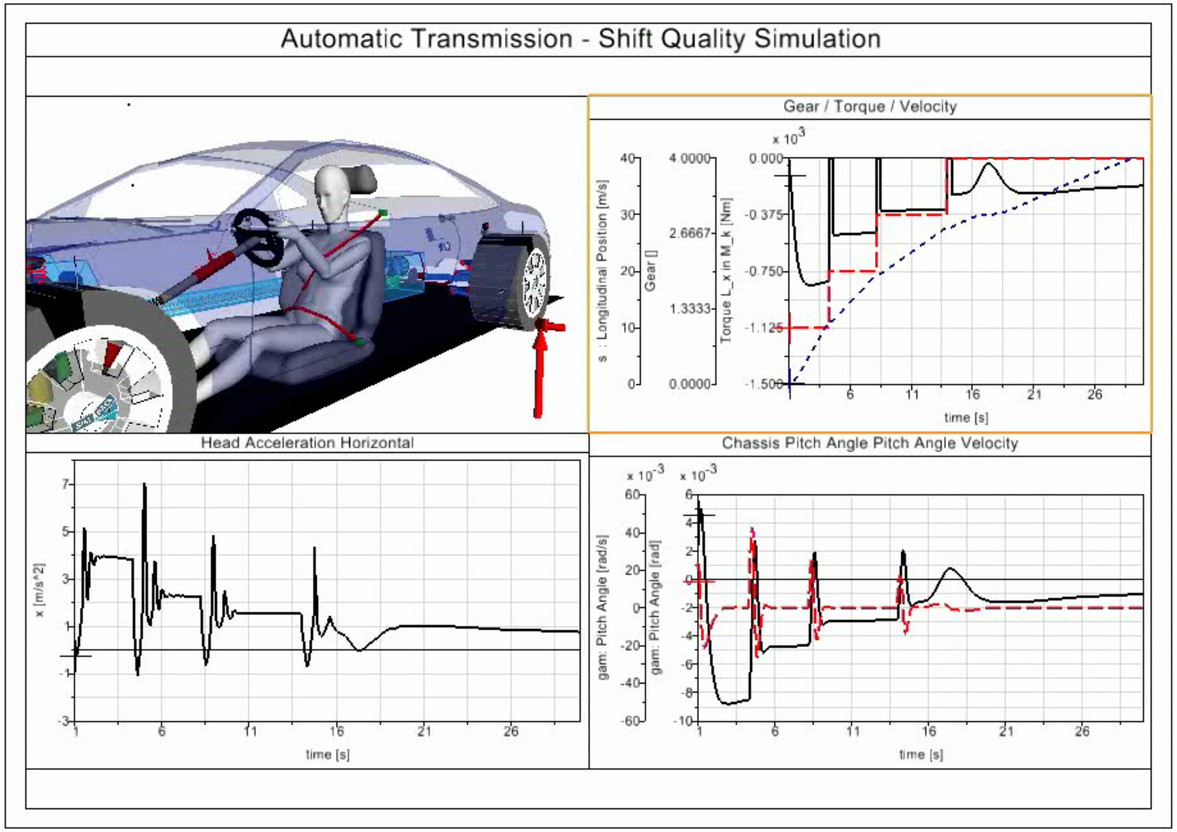
Jumping Over an Obstacle

Forces Acting on Human Body



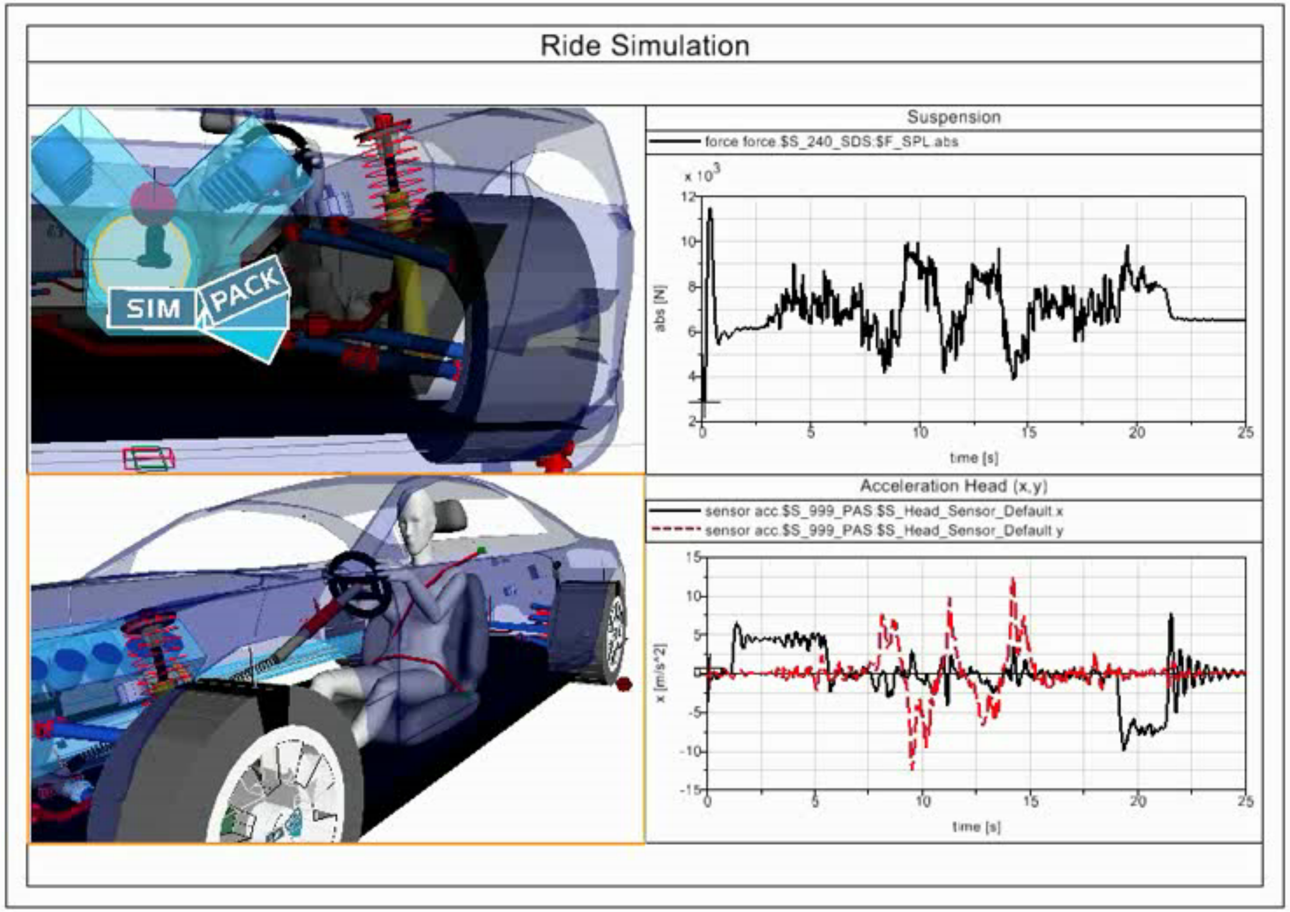
Application in Car Simulation

Shift Comfort Analysis



Application in Car Simulation

Ride Comfort Analysis



Thank you very much for your attention!