Object-Oriented Decomposition of Tire Characteristics Based on Semi-Empirical Models

Markus Andres, Dirk Zimmer and François E. Cellier

FHV University of Applied Sciences

ETH Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

September 21, 2009

Content

A Simplified Cross-Section of a Tire

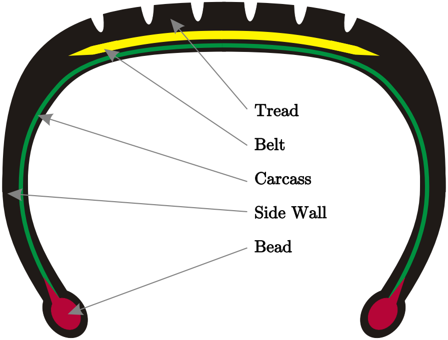
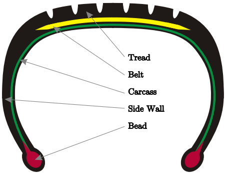
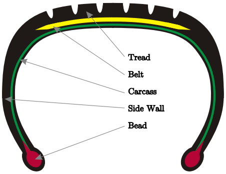


Figure: Basic structure of a steel-belt tire.



- The tire's duties:
  - Generate driving forces
  - Long lifetime
  - Small rolling resistance
  - Damping and acoustic properties
  - Reliable operation under differing environmental conditions
  - . . .



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Result

The tire is composed of a number of rubber composites, combined with steel elements making it very difficult to be described precisely.

State of the Art

There are numerous types of tire models suiting strongly differing needs.

- Simple models of ideal (non-slipping) tires.
- Semi-empirical single contact point models[1,2].
- Discretized multibody models (e.g. FTire).
- Models based on finite element analysis (FEA).

[1] Pacejka (2006): *Tyre and Vehicle Dynamics*.
[2] Rill (2007): *Simulation von Kraftfahrzeugen*.

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Vehicle Simulation

Semi-empirical single contact point models provide a very good trade-off between computational effort and accuracy.

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[2] Rill (2007): *Simulation von Kraftfahrzeugen*.

Semi-Emprical Models

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Single Contact Point Models

. . . apply forces and torques at a single point rather than an area (the tread area).

Motivation for Building a new Framework for Modeling Tires

- Existing models are often implemented in a flat and unstructured fashion.
- This results in models that are difficult to understand, maintain and customize.
- Implementations in Modelica have been made[3,4,5,6].

[3] Andreasson (2003): *VehicleDynamics Library*.
[4] Andreasson/Jarlmark (2002): *Modularised Tyre Modelling in Modelica*.
[5] Beckmann/Andreasson (2003): *Wheel model library for use in vehicle dynamic studies*.
[6] Zimmer/Otter (2009): *Real-Time Models for Wheels and Tires in an Object-Oriented Modeling Framework*.

It is NOT a Tire Model

- Utilize the capabilities of Modelica regarding object-orientation in tire modeling.
- Create a structure that can cover different tire models overcomes the formerly mentioned problems.

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Note!

This work concerns itself less with modeling new tire properties, but more with an improved organization of existing knowledge.

Wheel Properties Decomposition

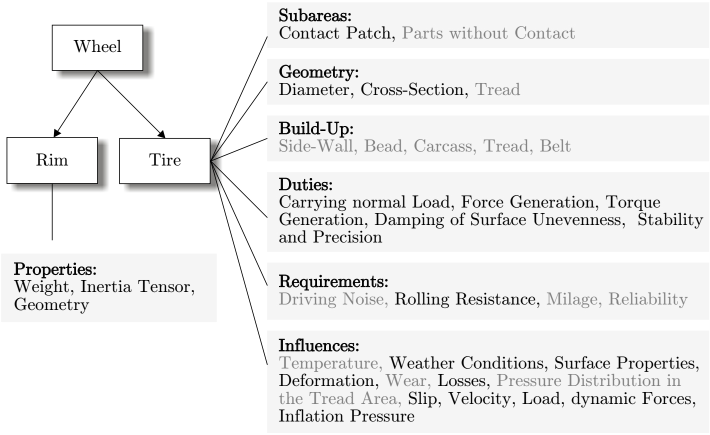


Figure: Composition of wheels and properties of tires.

Tire Properties Decomposition

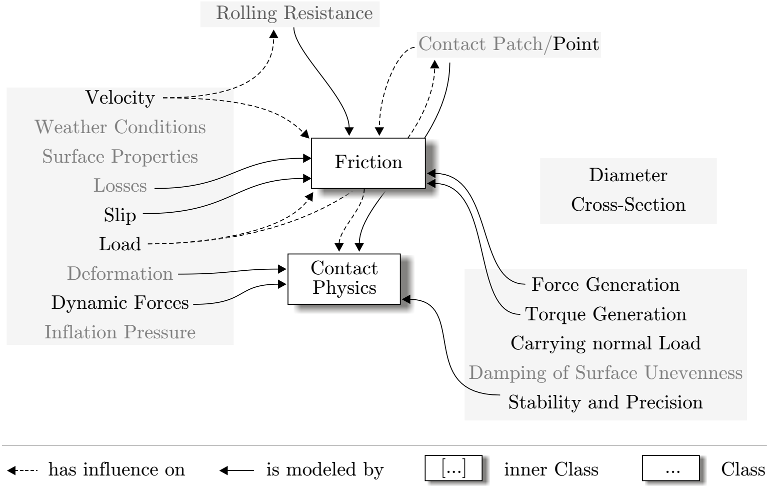


Figure: Properties shown in relation to closely related classes of the semi-empirical contact point model.

Tire Properties Decomposition

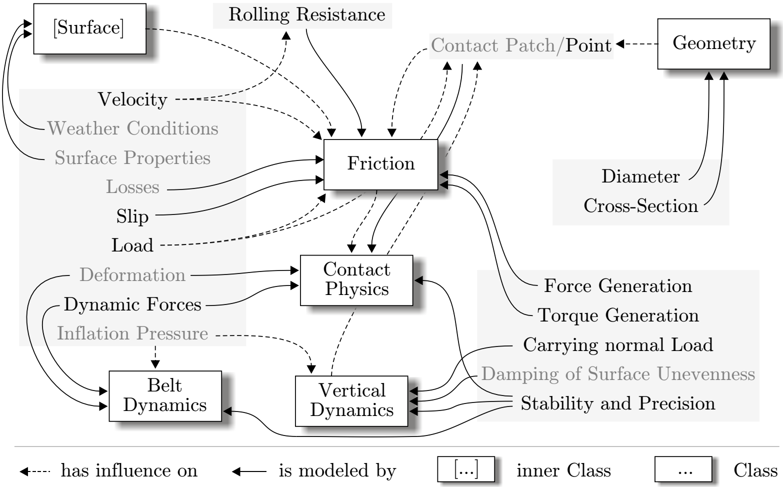


Figure: Final decomposition of the tire properties.

The Implemented Model

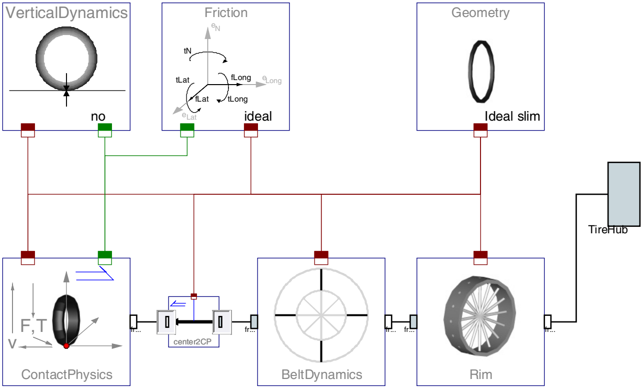


Figure: Structure of a tire model in Dymola 6.1 based on the *MultiBondLib*[7].

[7] Zimmer (2006): *A Modelica Library for MultiBond Graphs and its Application in 3D-Mechanics*.

The Communication Structure

Top Level Icon	Second Level Icon	Contained Variables
	Unit Vector Signals (UV)	
		RealSignal eLong[3]; RealSignal eLat[3]; RealSignal eN[3]; RealSignal ePlane[3]; RealSignal eAxis[3];
	Contact Property Signals (CP)	
		RealSignal xCP[3]; RealSignal rCP[3]; RealSignal lCR; RealSignal bCR; RealSignal penetrationDepth; BooleanSignal Contact[3];
	Sensor Value Signals (SV)	
		RealSignal eAxis[3]; RealSignal RBelt[3,3]; RealSignal wBelt[3]; RealSignal xBelt[3];

Figure: The elements contained in the *Tire Bus*.

Top Level Icon	Contained Variables
	RealSignal vLong; RealSignal vLat; RealSignal vN; RealSignal fLong; RealSignal fLat; RealSignal fN; RealSignal tLong; RealSignal tLat; RealSignal tN;

Figure: The elements contained in the *Contact Point Connector*.

The Vertical Dynamics Class

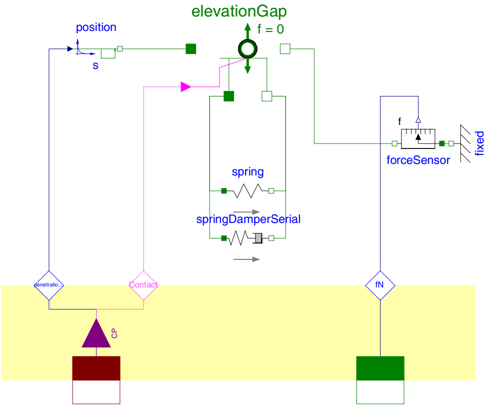


Figure: An exemplary class describing vertical dynamics, partly using the *BondLib*[8].

[8]Cellier/Netbot (2005): *The Modelica Bond-Graph Library*.

The Friction Class

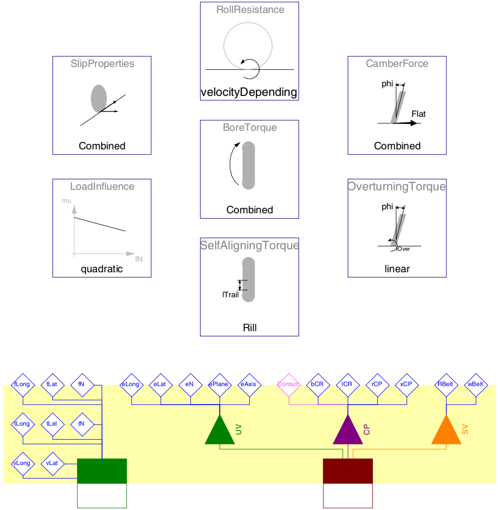
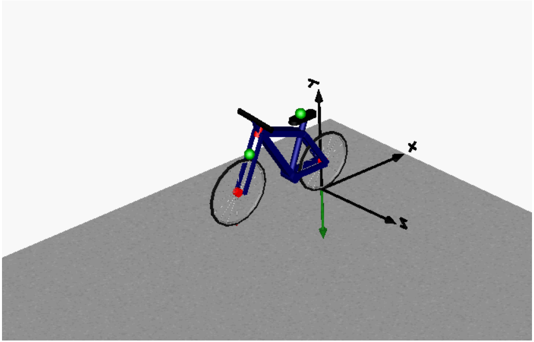


Figure: Classes that determine the frictional behavior of the tire.

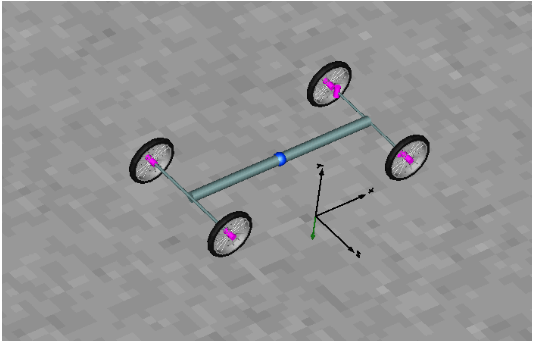
Animation: Bicycles Differing in Tire's Frictional Properties



Speed at 50%.

- The bicycle models are ideally rigid.
- The initialization is identical for both.
- Slim tires with differing frictional classes are mounted.
- This can be realized by a few clicks in the tire model.

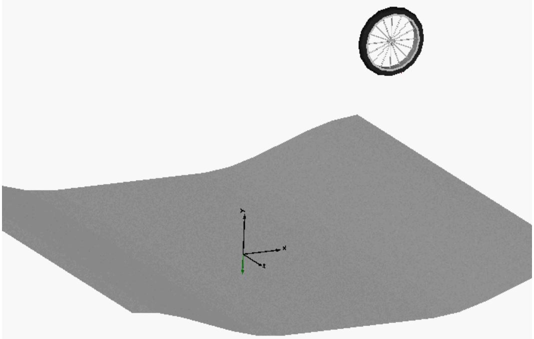
Animation: Four-Wheeled Vehicle



Speed at 100%.

- A very basic unsprung vehicle model.
- It is accelerated by a torque acting on the rear tires.
- Vehicle understeers at higher velocities.
- A torque impulse makes the vehicle drift.

Animation: Dropping Tire



Speed at 20%.

- Uneven surfaces are included in the library.
- Vertical dynamics allow the tire to lift from the ground.

Roundup

The freely available Library *Wheels and Tires* provides:

- A framework for the implementation of tire models or parts of these.
- A well-defined and expandable structure that allows a convenient customization.
- A number of predefined ready-to-use tire models.
- *Test Bench* models for testing of basic tire properties.
- Examples showing the application of the tire models.

[9] Andres (2009): *Object-Oriented Modeling of Wheels and Tires in Dymola/Modelica*.

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Further Work:

- Implement further tire models in the existing structure.
- Use as many "real world" parameters as possible.
- Add effects due to temperature changes.
- A detailed list of possible enhancements can be found in the corresponding master's thesis[9].

[9] Andres (2009): *Object-Oriented Modeling of Wheels and Tires in Dymola/Modelica*.

The End

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