

## Virtual Physics Introduction

TUM, October 07, 2014

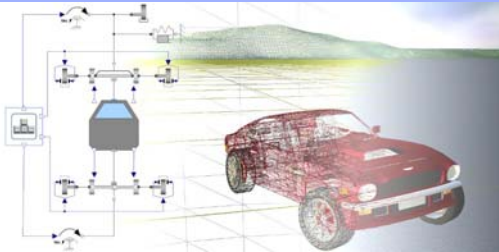
Using Modern Modeling Methodologies for Computer Simulation

equation

```

sx0 = cos(frame_a.phi)*sx_norm + ...
sy0 = -sin(frame_a.phi)*sx_norm + ...
vy = der(frame_a.y);
w_roll = der(flange_a.phi);
v_long = vx*sx0 + vy*sy0;
v_lat = -vx*sy0 + vy*sx0;
v_slip_lat = v_lat - 0;
v_slip_long = v_long - R*w_roll;

v_slip = sqrt(v_slip_long^2 + ...
-f_long*R = flange_a.tau;
frame_a.t = 0;
f = N * S_Func(vAdhesion,vSlide,...
f_long = f*v_slip_long/v_slip;
f_lat = f*v_slip_lat/v_slip;
f_long = frame_a.fx*sx0 + ...
f_lat = -frame_a.fy*sy0 + ...
    
```



Dr. Dirk Zimmer

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## The German Aerospace Center

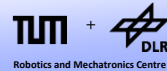


- The DLR (German Aero Space Center) has thirteen locations in Germany.
- The DLR Oberpfaffenhofen is located at the west side of Munich, between Gilching and Weßling.
- Number of Employees: > 6000 (all locations)
- The Robotics and Mechatronics Centre has more than 150 employees and is rapidly expanding.



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## M&S at DLR



Modeling at DLR concerns....

- Industrial Robots

Here the models are used to optimize the control of the robot.

The simulation of the robot-model is embedded in the controller and performed in real-time.

- Space Robots

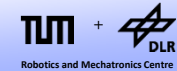
Special-purpose robots are developed for their use in space missions.

The robot can be remotely controlled from ground and features force-feedback.



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## M&S at DLR



Modeling at DLR concerns...

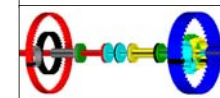
- Automobiles

The dynamics of a vehicle can be modeled in detail, including engine, gearbox, suspensions and wheels.

- Electrical Vehicles

A new electric vehicle has been designed, modeled, and built by the DLR.

Each of the four wheels contains an engine and can be steered individually.



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Modeling at DLR concerns...

- Real-Time Simulation

The car can be simulated in real-time. The controller of the steering balances the forces acting on each tire.

- Robocoaster

The forces acting on the driver can be computed.

These are the simulated using the robocoaster.

This is an industrial robot with a mounted cabin.



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Modeling at DLR concerns...

- Aircraft Systems:

Flight Simulation of Aircrafts.

- Environmental Control Systems:

Design of Climate Systems.

- Power Supply:

Design and Optimization of a reliable Power Supply .



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- **Simulation** is mostly the main purpose of a dynamic model, but there are different targets as well.
- Simulators can be used for training or just for fun.
- Models are used during the design stage of a product for the purpose of **optimization**. This drastically reduces the costs of product development.
- Good models are essential for the design of **controllers**. For instance, a model can be inverted in order to compute the forces that are required for a given movement.
- For driving simulations or for embedded controllers, **real-time interaction** of the model is desired. Often simulation is used in combination with hardware.

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- We see that the given demonstrations include the modeling of various physical domains:
  - Mechanic Systems
  - Electric Systems
  - Hydraulic Systems
  - Thermal Systems
  - Convective Mass-Flows
- But the modeling of all these different physical domains is performed by one common methodology.

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## Physical Domains

- We see that the given demonstrations include the modeling of various physical domains:
  - Mechanic Systems
  - Electric Systems
  - Hydraulic Systems
  - Thermal Systems
  - Convective Mass-Flows
- But the modeling of all these different physical domains is performed by one common methodology.

**Learning this methodology is the essential goal of this lecture!**

## Your Challenge

- Model your own car...



- ... and simulate it in real time!

## Your Challenge

- We will model the car, starting by first principles
- To this end, we build our own mechanical modeling library.
- You will learn, know, and understand every single underlying equation of the complete car model. It will be surprisingly simple.
- You will learn the basic techniques to create a computable code out of the physical model and to perform a simulation.
- You will learn to handle a real-time simulation with user-input and 3D-visualization.
- Finally, you can extend and modify the model and follow your own ideas.

## Lecture Outline

- Lecture 1 (15.10.2012):  
Introduction and Outline: Motivation and Purpose of Modeling and Simulation
- Lecture 2 (22.10.2012): History of object-orientation modeling of physical systems
- Lecture 3 (29.10.2012): The Modelica language
- Lecture 4 (05.11.2012): Compiling the Modelica language
- Lecture 5 (12.11.2012): Introduction to 1D and 2D mechanical systems
- Exercise Session (19.11.2012): Additional Training
- Lecture 6 (26.11.2012): Planar mechanical systems I+II.
- Lecture 7 (03.12.2012): 3D Mechanics

## Lecture Outline

- Lecture 8 (10.12.2012): Modeling the Car and Real-Time Simulation
- Lecture 9 (17.12.2012): Higher-Level Modeling Tasks: Parameterization and Stability Analysis
- Lecture 10 (07.01.2013): Analytical vs. Numerical Stability and Higher-Order ODE Solvers
- Lecture 11 (14.01.2013): Events and discontinuous systems
- Lecture 12 (21.01.2013): Control + Exam Preparation I
- Lecture 13 (28.01.2013): Bonus Lecture, Exam Preparation II

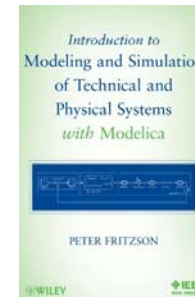
## WWW

- All slides and exercises can be downloaded from the course web site.
- Furthermore, there is a script from the FHV that explains the physical side of modeling using Bond-graphs.  
<http://www.robotic.de/279>
- Furthermore Prof. Martin Otter provides a Draft for a Modelica Book:  
<http://www.robotic.de/vorlesung>  
This course is related and the draft is for free!

## WWW

- Most important informations can be found at:  
[www.modelica.org](http://www.modelica.org)
- There you find:
  - A Modelica Tutorial (outdated)
  - The Modelica Language Specification

## Physical Reading Material



- Peter Fritzon (2011) :  
Introduction to Modelica and Simulation of Technical and Physical Systems *with Modelica*  
232 pages about 45 Euro  
Wiley IEEE

## Physical Reading Material



- Peter Fritzson (2003) :  
Principles of Object-Oriented Modeling and Simulation with Modelica 2.1  
Wiley IEEE



- Michael Tiller (2000):  
Introduction to Physical Modeling with Modelica  
Springer

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## Physical Reading Material



- François Cellier  
  
Continuous System Simulation (2006)

and



- Continuous System Modeling (1991 - outdated)

Springer

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## Required Software

- Further Required: MS Visual Studio C++ Compiler  
Free: Visual Studio 2008 Express Edition.

<http://visual-cplusplus-2008.soft-ware.net/downloads.asp>

- Further Software will be distributed during the course.

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## Required Software

- In order to obtain a student license:
  - Sign the license agreement and hand it in at the lecture or scan it and email me the pdf. Make sure the filename contains your name.
  - Send me an email: [dirk.zimmer@dlr.de](mailto:dirk.zimmer@dlr.de).
  - Heading. “[Dymola License]”.
  - Containing your name, student-id number, and department.
  - You will get the license file attached to my reply.
  - You will also receive the username and password that is required for the software download.
- Required Software for MS Windows:  
<http://www.dynasim.se/update/>  
Fill out the form and mention your license number.

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