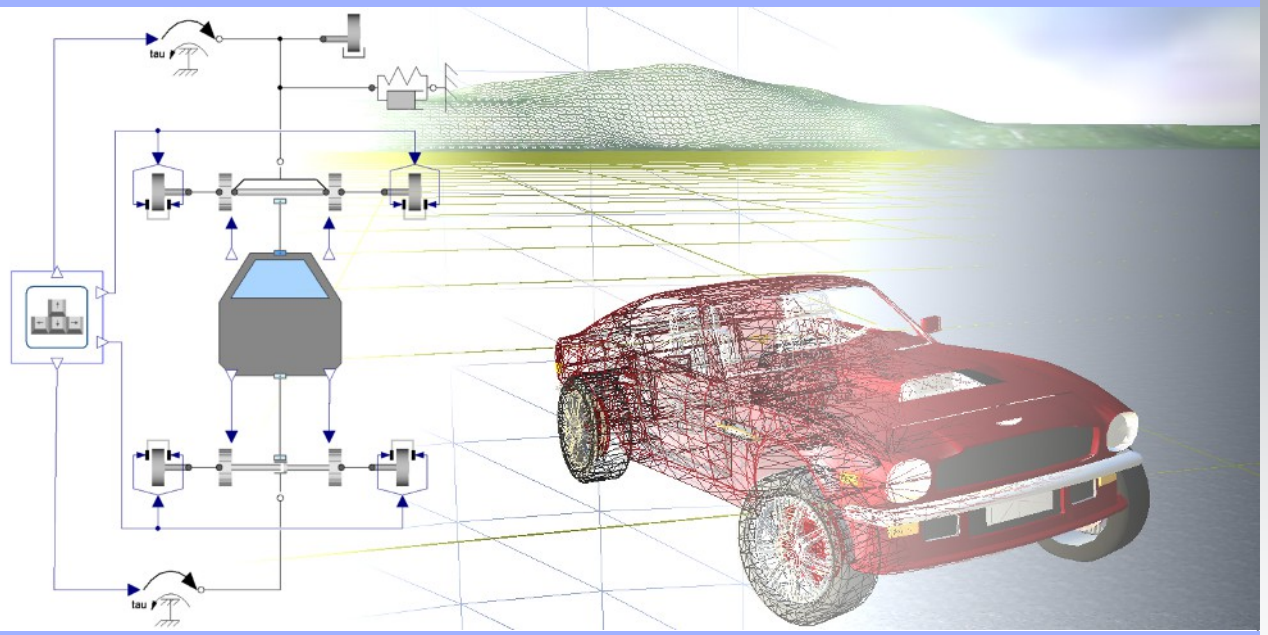
Virtual Physics Introduction

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.fx*sy0 + …
```



Dr. Dirk Zimmer

German Aerospace Center (DLR), Robotics and Mechatronics Centre

The German Aerospace Center

Robotics and Mechatronics Centre

- 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.

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.

M&S at DLR

Modeling at DLR concerns…

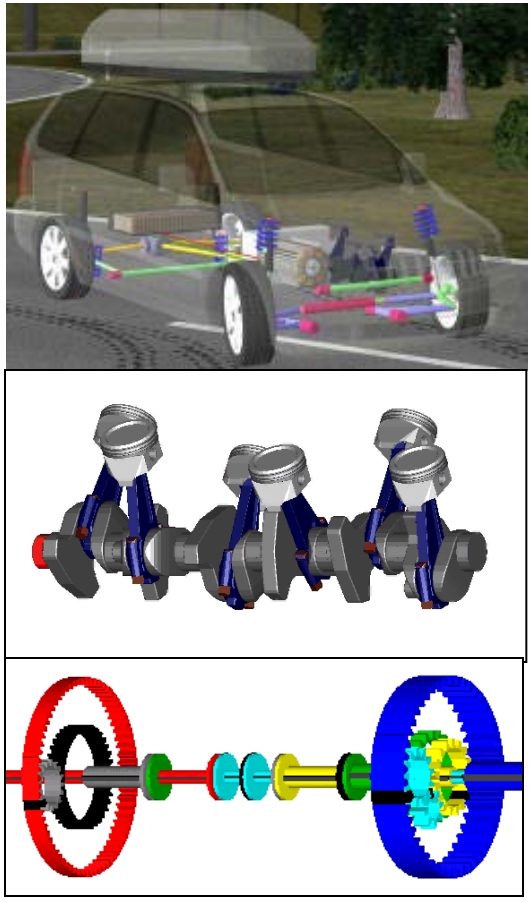
- Automobiles

  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.



M&S at DLR

Modeling at DLR concerns…

- Real-Time Simulation

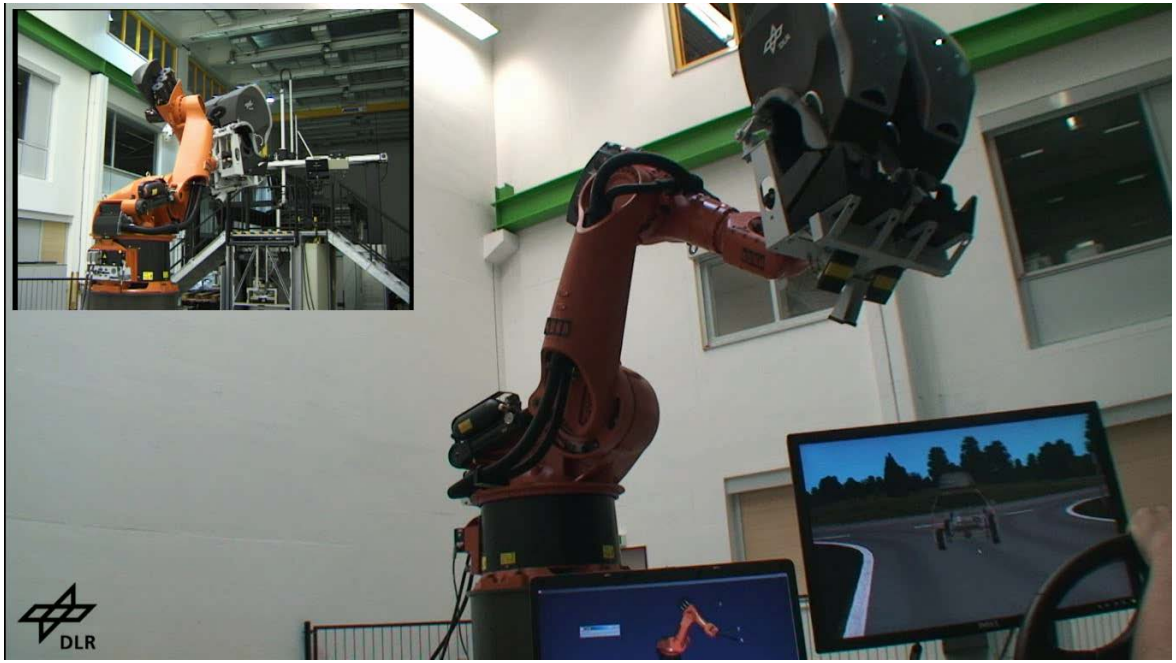
  The car can be simulated in real-time. The controller of the steering balances the forces acting on each tire.

- 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.



M&S at DLR

Modeling at DLR concerns…

- Aircraft Systems:

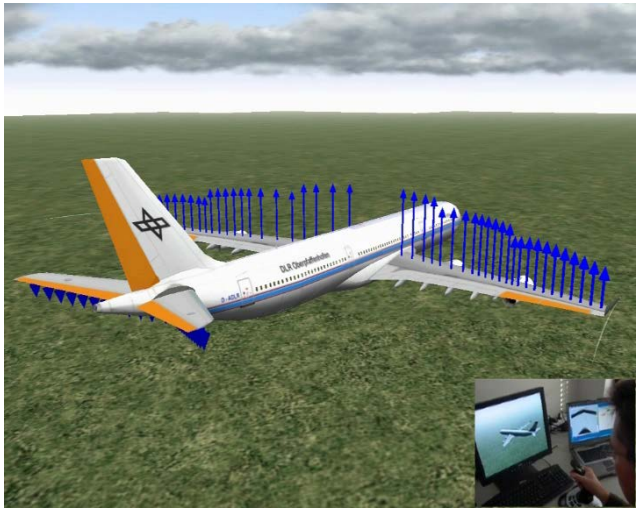
  Flight Simulation of Aircrafts.

- Environmental Control Systems:

  Design of Climate Systems.

- Power Supply:

  Design and Optimization of a reliable Power Supply .



Motivation behind Modeling

- **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.

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.

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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 or 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-visulization.
- 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

- 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!

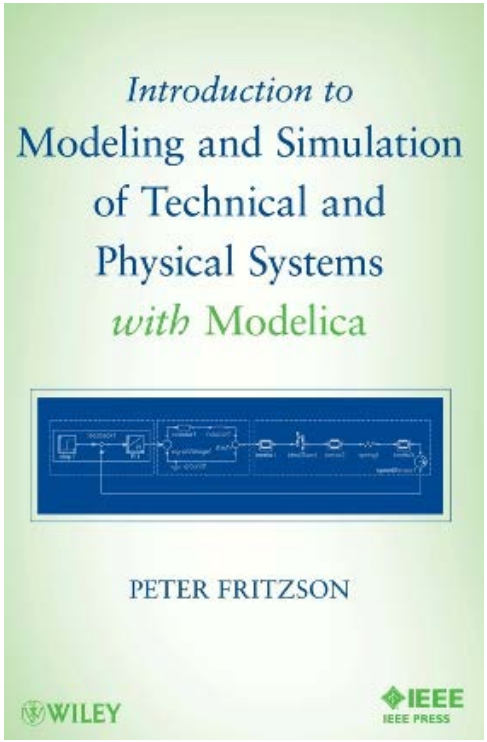
WWW

- Most important informations can be found at:

  www.modelica.org

- There you find:
  - A Modelica Tutorial (outdated)
  - The Modelica Language Specification

Physical Reading Material



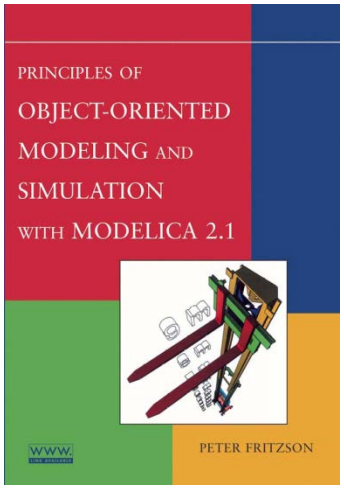
- Peter Fritzson (2011) :

  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

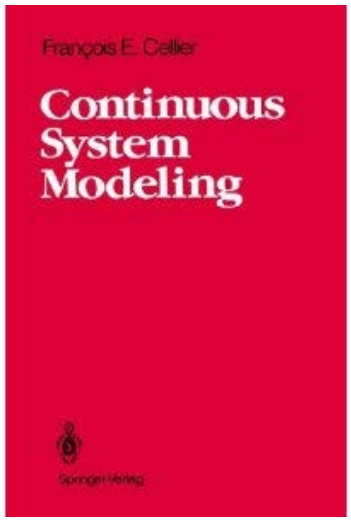
  Wiley IEEE

- Michael Tiller (2000):

  Introduction to Physical Modeling with Modelica

  Springer

Physical Reading Material



- François Cellier

  Continuous System Simulation (2006)

  and

  Continuous System Modeling (1991 - outdated)

  Springer

Required Software

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

  http://visual-cplus-2008.soft-ware.net/downloads.asp

- Further Software will be distributed during the course.

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.
  - 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.