

Seminar

Modeling and Simulation of Dynamical Systems

Presented by the
IEEE Control Systems Society
Santa Clara Valley

Sunnyvale, 5 February 2011



Program

Welcome	08:45 – 09:10am	Coffee and bagels, Seminar kickoff at 9:00am
Session 1	09:10 – 10:00am	Mathematical models of dynamical systems Dr. P.K. Menon, Optimal Synthesis
Session 2	10:10 – 11:00am	System Identification - Theory and Practice Dr. Mark B. Tischler, Ames Research Center
Session 3	11:10 – 12:00am	Visualization and Virtual Environments Dr. Hadi Aggoune, Cogswell Polytech. College
Lunch	12:00 – 12:40pm	Sandwiches, sodas, discussions and product demos
Session 4	12:40 – 01:30pm	Applications of Hardware-in-the-Loop Simulators Christoph Wimmer, National Instruments
Session 5	01:40 – 2:30pm	Simulation with Software Tools Elliot English, Dr. Martin Aalund, Dr. Karl Mathia

Session 5

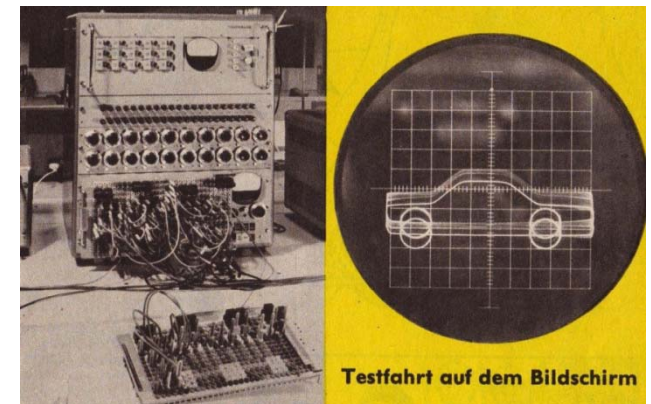
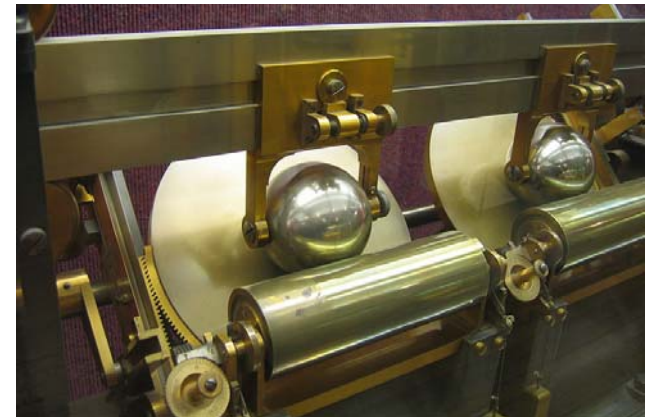
Simulation Software Tools

Martin Aalund

Historical Simulation Tools

Historically dynamical systems were often simulated with:

- Scaled Models
 - Such as the Antikythera mechanism used by the Greeks to calculate astronomical positions in 100 BC
- Mechanical Analogue Computers
 - French physicist Gaspard-Gustave Coriolis designed a mechanical device to integrate differential equations of the first order in 1839
 - Differential Analyzers such as the Thomson Disk and Sphere analyzer used to simulate tides
- Simplified Systems Lumped models
 - Spring as Capacitor
 - Damper as Resistor
 - Inertia as Inductors
- Analog Computers (Gained Popularity in 1940s)
 - Use Active circuits integrate, differentiate and scale signals.
 - Can model complex electro mechanical systems.
 - Real time operation and reprogrammable



Current State of the Art

- Analog Solutions were
 - Hard to setup,
 - problem size limited,
 - must carefully scale problems,
 - Have limited dynamic range
- Advent of Modern Computers and Advanced Software have replaced analog computers in most cases
 - Allow for unlimited size of model
 - Reusable models
 - Large choice of tools available
 - Domain Specific
 - Commercial
 - Free

Simulation SW (Open/Free)

- **Octave** <http://www.gnu.org/software/octave/>
 - Matlab like language
 - Numerical Computations
 - Linear and Non-linear solvers
- **SciLab** <http://www.scilab.org/products/scilab/features>
 - 2d and 3d Visualization
 - Numerical Computation
 - Data Analysis
 - Xcos: hybrid dynamic systems modeler and simulator
- **Maxima** <http://maxima.sourceforge.net/>
 - manipulation of symbolic and numerical expressions
- **Euler Math Toolbox** <http://eumat.sourceforge.net/>
 - Built on Maxima
 - Provides notebook style interface
 - Advanced Graphics, Numerical functions
- **Sage** <http://www.sagemath.org/>
 - Open source alternative to Magma, Maple, Mathematica and Matlab.
 - Web Based Interface

Simulation SW (commercial)

- Matchcad <http://www.ptc.com/products/mathcad/>
 - Visual Interface WYSIWYG
 - Symbolic and numerical simulations
- MapleSim <http://www.maplesoft.com/products/maplesim/#>
 - Based on Maple Symbolic Computation technology
 - Multi-Domain Systems
- Matlab/Simulink <http://www.mathworks.com/products/simulink/>
 - Powerful modeling and simulation capability
 - Can generate code based on models
- Anycode/Marilou <http://www.anycode.com/marilou.php>
 - Modeling and simulation tools for mobile robotics
- Microsoft Robotics Studio <http://www.microsoft.com/robotics/>
 - Simulations and development environment
 - Contains Physics models for Gravity
- PHYSX http://www.nvidia.com/object/physx_new.html
 - Free commercial Physics engine from NVIDIA



MathCad Demo

Can Solve Equations Symbolically

$x^2 - 3x + 2$ Can find the derivative by highlighting variable

Next we can solve for the value.

we can also define a function

$f(x) := (x^2 - 3x + 2)$ Press Ctr period to insert symbolic equal sign and factor $f(x) \rightarrow x^2 - 3 \cdot x + 2$

Can also differentiate by hitting ? or CTR Shift / $\frac{d}{dx} f(x) \rightarrow 2 \cdot x - 3$

Press Ctrl Shift period and type keyword

Symbolic					
→	▪→	Modifiers	float	rectangular	assume
solve	simplify	substitute	factor	expand	coeffs
collect	series	parfrac	fourier	laplace	ztrans
invfourier	invlaplace	invztrans	$m^T \rightarrow$	$m^{-1} \rightarrow$	$ m \rightarrow$
explicit	combine	confrac	rewrite		

$f(x) \rightarrow x^2 - 3 \cdot x + 2$ $f(x)$ factor $\rightarrow (x - 1) \cdot (x - 2)$ $\sin(x)$ series $\rightarrow x - \frac{x^3}{6} + \frac{x^5}{120}$

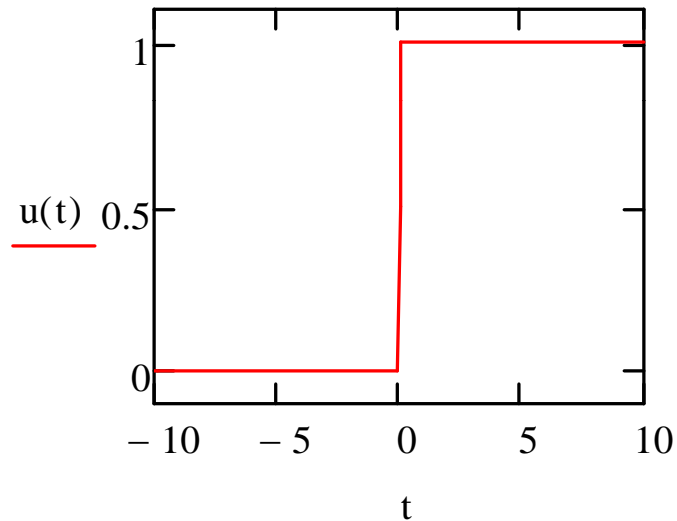
Can also calculate results by entering value for x

$x := 3$ $f(x) = 2$

Demo Continued

Can define functions and plot them

$$u(t) := \Phi(t)$$



we can use built in functions to find the laplace transform

$$U(s) := u(t) \text{ laplace} \rightarrow \frac{1}{s}$$

We can define a function in s domain and do an inverse transform

$$\omega := 3$$

$$\underline{H}(s) := \frac{\omega}{s^2 + \omega^2}$$

$$\underline{H}(t) := \underline{H}(s) \text{ invlaplace} \rightarrow \sin(3 \cdot t)$$

Other Open SW for simulation

- FreeMat <http://freemat.sourceforge.net/>
- JMathLib Java Clone <http://www.jmathlib.de/>
 - Octave, SciLab and Matlab functionality
- Mathnium <http://www.mathnium.com/>
 - Numerical Computing, Data Analysis, and Graphics
- TeLa <http://www.geo.fmi.fi/prog/tela.html>
- Algae <http://algae.sourceforge.net/>
 - Language For Large Systems
- Lush <http://lush.sourceforge.net/>
 - Lisp Based for Large scale numerical and graphical applications
- Yorick <http://yorick.sourceforge.net/>
- Rlab <http://rlab.sourceforge.net/>
- Python Extensions <http://www.python.org/>
 - NumPy <http://sourceforge.net/projects/numpy/>
 - SciPy <http://www.scipy.org/>
- The R Project <http://www.r-project.org/>
 - Statistical Computing

Other Open SW for simulation

- Delta3D <http://www.delta3d.org/>
 - 3D visualization and simulations
 - Dynamic Engine based on ODE
- ODE <http://ode.org/>
 - Open Dynamics Engine
 - Simulation of Ridged body dynamics
- Physics Abstraction Layer <http://www.adrianboeing.com/pal/index.html>
 - Fluids
 - Dynamics
 - Actuators, Sensor



Sponsors



<http://www.applimotion.com>



<http://www.willowgarage.com>



<http://www.cogswell.edu>



<http://www.asme.org>