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

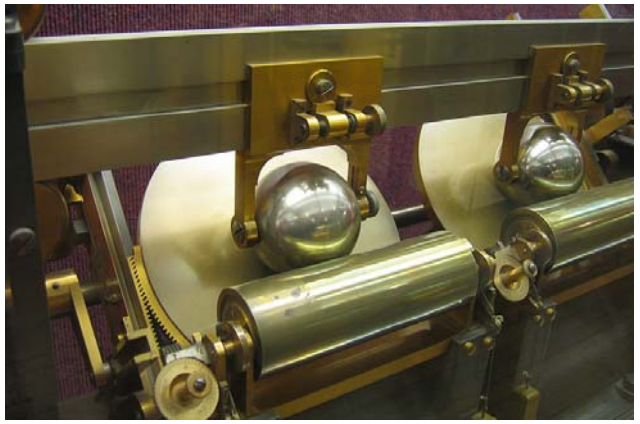
Simulation Software Tools

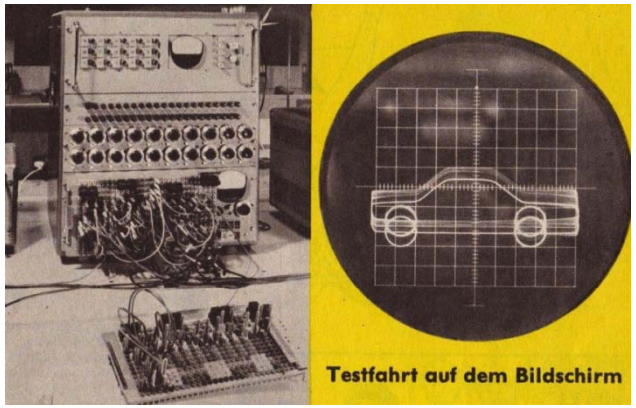
Martin Aalund

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





From Wikipedia

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
- Anykode/Marilou http://www.anykode.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

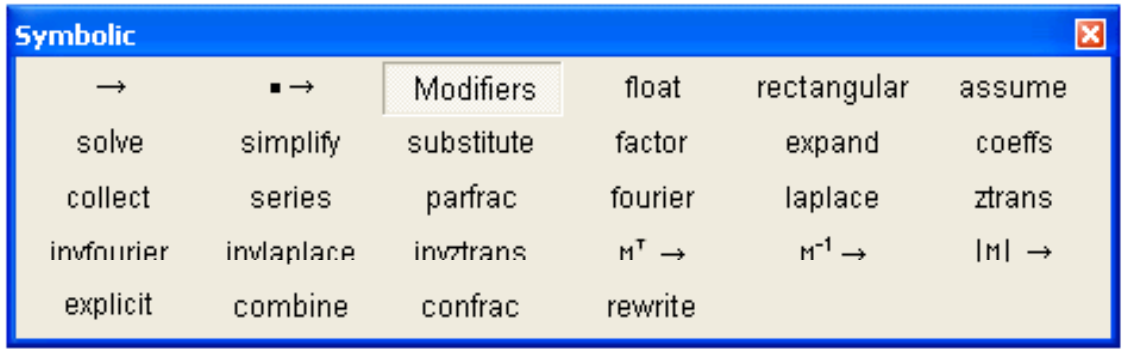
Next we can solve for the value.

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 Shit / $\frac{d}{dx} f(x) \rightarrow 2 \cdot x - 3$

Press Crtl Shift period and type keyword



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

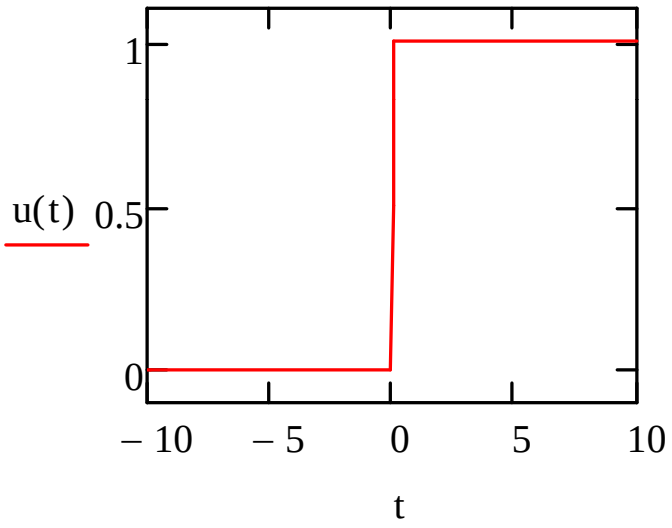
Can also calculate results by entering value for x

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

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

$$\omega := 3$$

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

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

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.adi.com

http://www.applimotion.com

http://www.ni.com

http://www.willowgarage.com

http://www.cogswell.edu

http://www.asme.org