EL2620 Nonlinear Control

Lecture 2

- Wrap-up of Lecture 1: Nonlinear systems and phenomena
- Modeling and simulation in Simulink
- Phase-plane analysis

Today's Goal

You should be able to

- Model and simulate in Simulink
- Linearize using Simulink
- Do phase-plane analysis using pplane (or other tool)

Analysis Through Simulation

Simulation tools:

ODE's $\dot{x} = f(t, x, u)$

- ACSL, Simnon, Simulink

DAE's $F(t, \dot{x}, x, u) = 0$

- Omsim, Dymola, Modelica

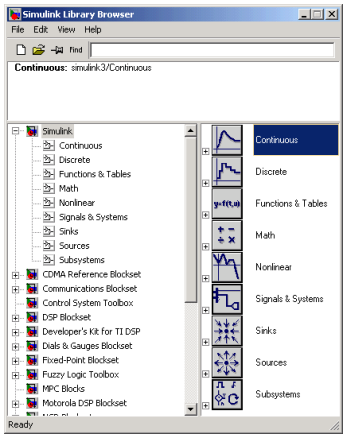
  `http://www.modelica.org`

Special purpose simulation tools

- Spice, EMTP, ADAMS, gPROMS

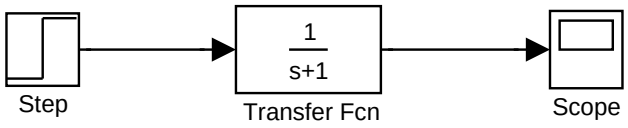
Simulink

```
> matlab
>> simulink
```

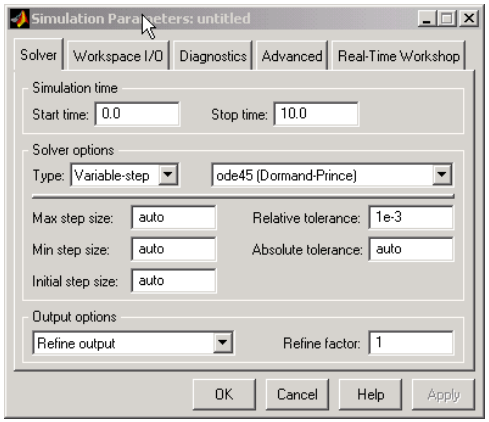


An Example in Simulink

```
File -> New -> Model
Double click on Continous
Transfer Fcn
Step (in Sources)
Scope (in Sinks)
Connect (mouse-left)
Simulation -> Parameters
```



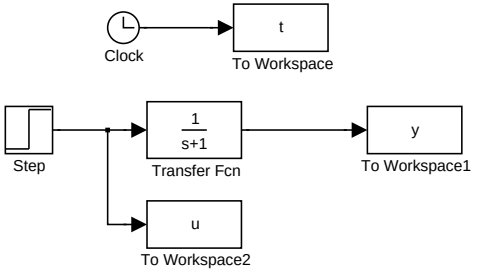
Choose Simulation Parameters



Don't forget "Apply"

Save Results to Workspace

stepmodel.mdl



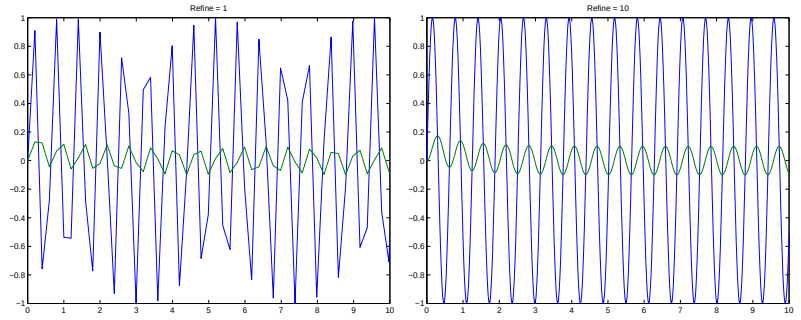
Check "Save format" of output blocks ("Array" instead of "Structure")

```
>> plot(t,y)
```


How To Get Better Accuracy

Modify Refine, Absolute and Relative Tolerances, Integration method

Refine adds interpolation points:



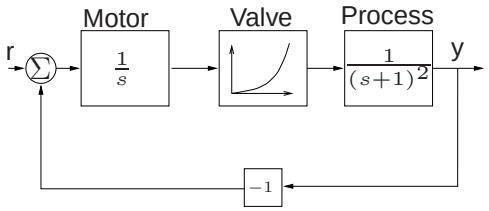
Use Scripts to Document Simulations

If the block-diagram is saved to `stepmodel.mdl`,
the following Script-file `simstepmodel.m` simulates the system:

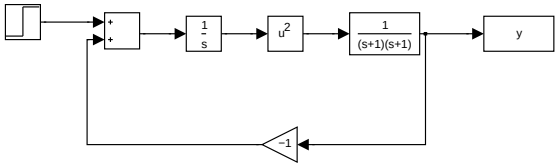
```
open_system('stepmodel')
set_param('stepmodel','RelTol','1e-3')
set_param('stepmodel','AbsTol','1e-6')
set_param('stepmodel','Refine','1')
tic
sim('stepmodel',6)
toc
subplot(2,1,1),plot(t,y),title('y')
subplot(2,1,2),plot(t,u),title('u')
```


Nonlinear Control System

Example: Control system with valve characteristic $f(u) = u^2$



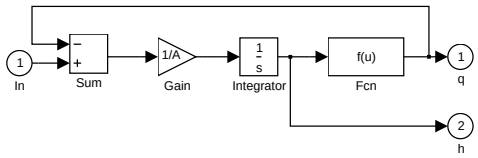
Simulink block diagram:

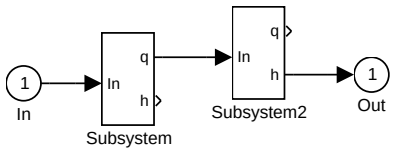


Example: Two-Tank System

The system consists of two identical tank models:

$$\dot{h} = (u - q)/A$$
$$q = a\sqrt{2g}\sqrt{h}$$





Linearization in Simulink

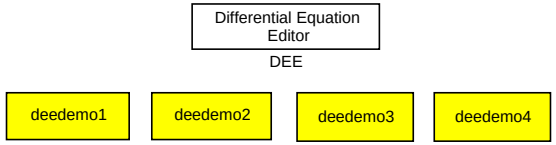
Linearize about equilibrium (x_0, u_0, y_0):

```
>> A=2.7e-3;a=7e-6,g=9.8;
>> [x0,u0,y0]=trim('twotank',[0.1 0.1]',[],0.1)
x0 =
    0.1000
    0.1000
u0 =
   9.7995e-006
y0 =
    0.1000
>> [aa,bb,cc,dd]=linmod('twotank',x0,u0);
>> sys=ss(aa,bb,cc,dd);
>> bode(sys)
```

Differential Equation Editor

`dee` is a Simulink-based differential equation editor

```
>> dee
```



Run the demonstrations

Phase-Plane Analysis

- Download ICTools from
  `http://www.control.lth.se/~ictools`
- Down load DFIELD and PPLANE from
  `http://math.rice.edu/~dfield`
  This was the preferred tool last year!

Homework 1

- Use your favorite phase-plane analysis tool
- Follow instructions in Exercise Compendium on how to write the report.
- See the course homepage for a report example
- The report should be short and include only necessary plots. Write in English.