MATLAB Introduction Course: Lecture 5

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Symbolic Math Toolbox

- MATLAB can do symbolic math!
- Don't do nasty calculations by hand!

	Advantages	**Disadvantages**
Symbolic	→ Analytical solutions → Intuitive	→ May lack solution → Can be overly complicated
Numeric	→ Always a solution → Accurate → Easy to code	→ Harder to extract understanding → Num. methods can fail → Computational time

Symbolic Variables

- Symbolic variables are a type, like double or char
- To make symbolic variables, use `sym`
  - `>> a=sym('1/3')`
  - `>> b=sym('4/5')`
  - `>> mat=sym([1 2;3 4])`
    - ★ fractions remain as fractions
  - `>> c=sym('c','positive')`
    - ★ can add tags to narrow down scope
    - ★ see `help sym` for a list of tags
- Or use `syms`
  - `>> syms x y real`
    - ★ shorthand for `x=sym('x','real'); y=sym('y','real');`

Symbolic Expressions

- Multiply, add, divide as you would normally
  - `>> d=a*b`
    - ★ gives `>> d = 4/15`
- Expand expressions
  - `>> expand((a-c)^2)`
    - ★ gives `>> ans = 1/9-2/3*c+c^2`
- Factor expressions
  - `>> factor(1/9-2/3*c+c^2)`
    - ★ gives `>> ans = 1/9*(3*c-1)^2`

Cleaning up Symbolic Statements

- `pretty(...)`
  - makes it look nicer
- `collect(...)`
  - collects terms
- `simplify(...)`
  - simplifies expressions
- `subs('c^2',c,5)`
  - Replaces variables with numbers or expressions. To do multiple substitutions pass a cell of variable names followed by a cell of values
- `subs('c^2',c,x/7)`
  - gives `>> ans = 1/49*x^2`

More Symbolic Operations

- Matrix symbolics
  - `>> mat = sym('[a b;c d]')`
  - `>> mat2 = mat*[1 2;4 -2]`
    - ★ computes the matrix product
  - `>> D = det(mat)`
    - ★ computes the determinant
  - `>> mat_i = inv(mat)`
    - ★ computes the inverse
- You can access symbolic matrix elements normally
  - `>> mat_i(1,2)=-b/(a*d-b*c)`

Exercises

Exercise a

The equation of a circle of radius r centered at (a,b) is given by:

$$(x-a)^2 + (y-b)^2 = r^2$$

- Use `solve` to solve this equation for x and then for y

Exercise b

Use `int` to do the following integral symbolically:

$$\int_a^b xe^x dx$$

and then compute the value by `subs`tituting 0 for a and 2 for b

Solution

Exercise a

```
>> syms a b r x y
>> solve('(x-a)^2+(y-b)^2=r^2','x')
>> solve('(x-a)^2+(y-b)^2=r^2','y')
```

Exercise b

```
>> syms a b x
>> Q=int(x*exp(x),a,b)
>> subs(Q,{a,b},{0,2})
```

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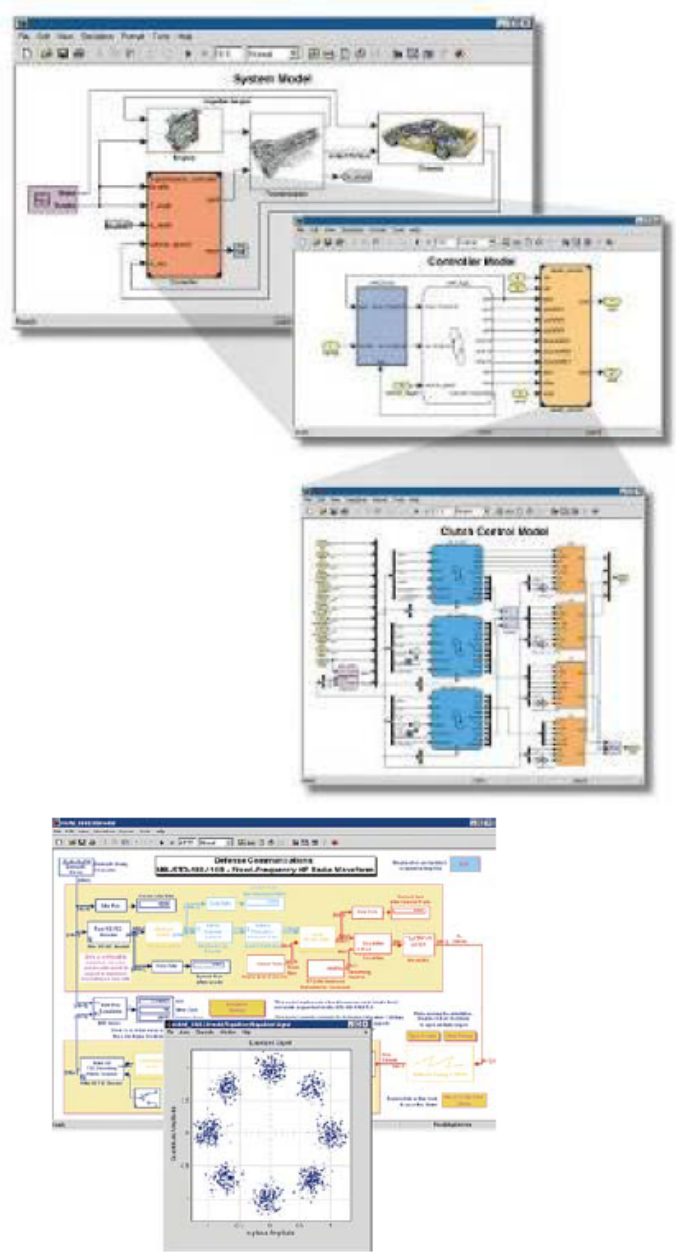
What is Simulink

Simulink is a software package for modeling, simulating, and analyzing dynamical systems



- Graphical programming
- Nonlinear simulation
- Hybrid (continuous and discrete) models
- Asynchronous (non-uniform sampling) simulation
- Fully integrated with MATLAB, MATLAB toolboxes and blocksets

What to use it for

Design, implement, and test:

- Dynamical systems
- Control systems
- Communications systems
- Signal Processing systems
- Embedded systems
- +++

Anything that is time-varying!

NTNU usage

Most of the control development at NTNU is done using MATLAB/Simulink

Bell Helicopter Develops the First Civilian Tiltrotor, Using Model-Based Design

The BA609, flying in airplane mode.

Challenge

To design and build the BA609, the first and fastest commercially available tiltrotor aircraft in the world

Solution

Use Model-Based Design with MATLAB, Simulink, and Real-Time Workshop software to model, simulate, test, and verify designs

Results

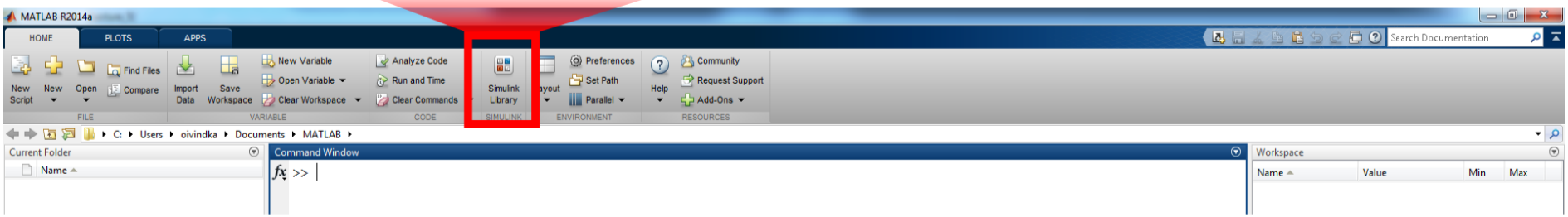
- Full collaboration with suppliers via Simulink models
- Flight control system code generated automatically from models
- 40% improvement in design and development time
- Flawless first flight, which went exactly like the simulation

"Simulations and a rapid, iterative approach enabled us to minimize the unknowns and ensure that we had established enough margin that when we ran into a surprise we could continue to have a safe flight test program—and run it with unprecedented efficiency."

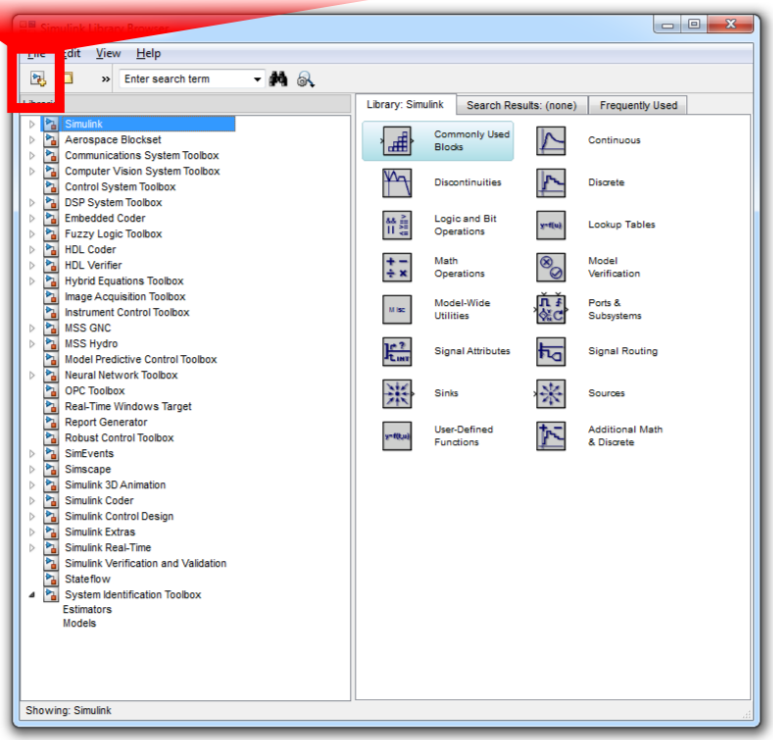
David King
Bell Helicopter

Getting started

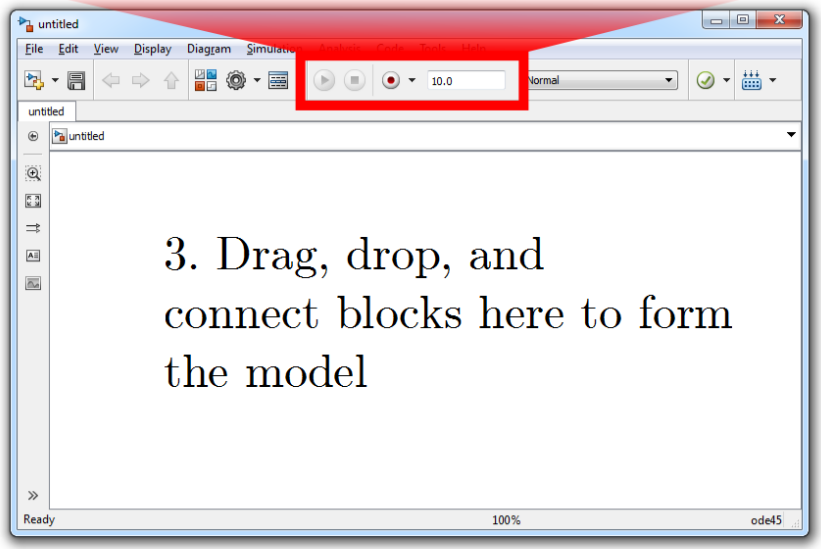
1. Start Simulink



2. Create a new model

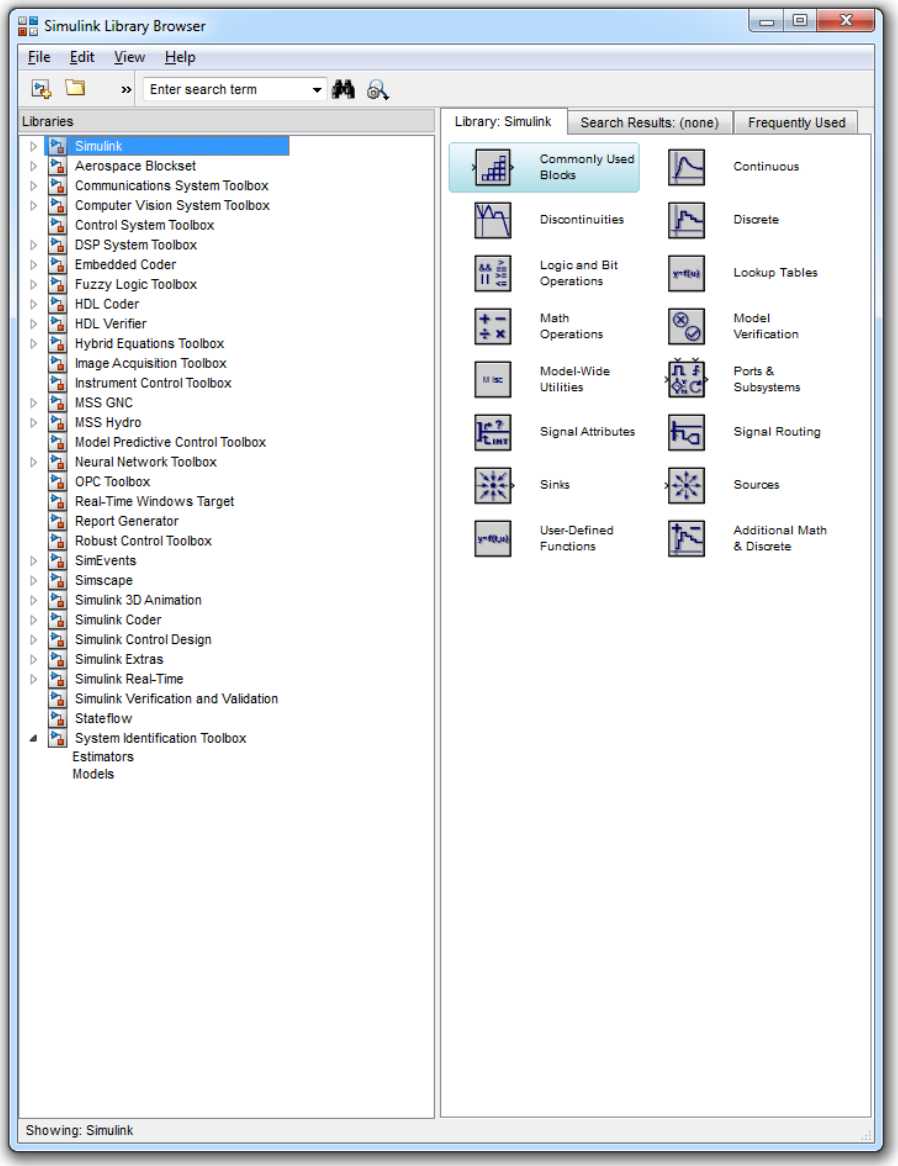


4. Run the model in a given interval



3. Drag, drop, and connect blocks here to form the model

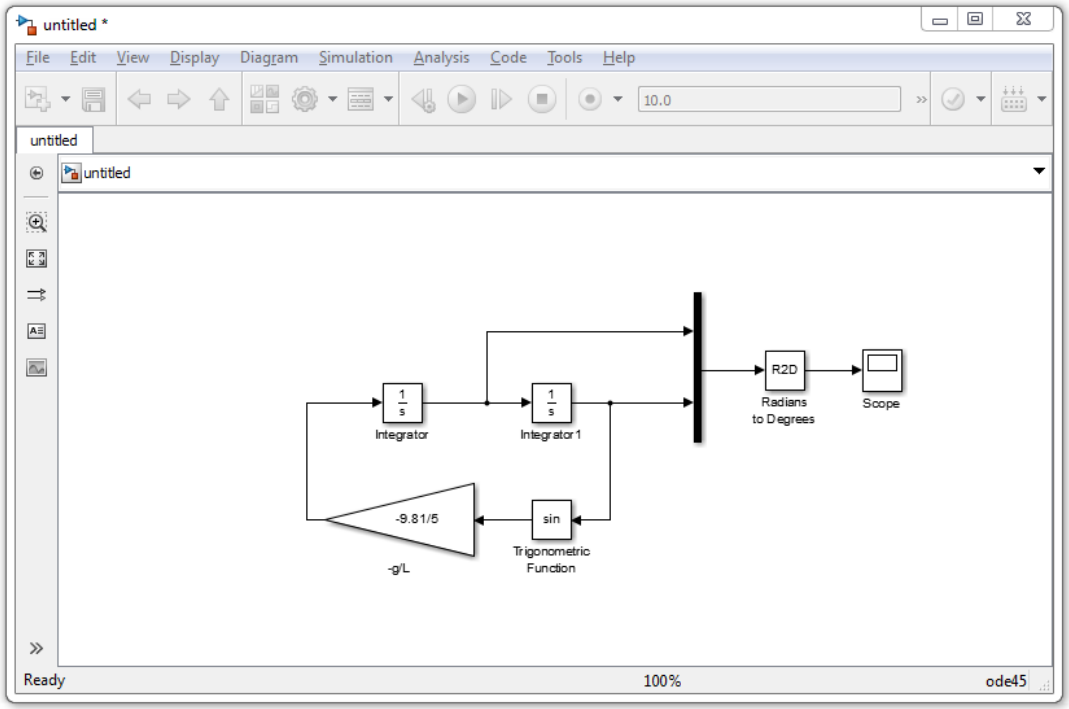
The Library Browser

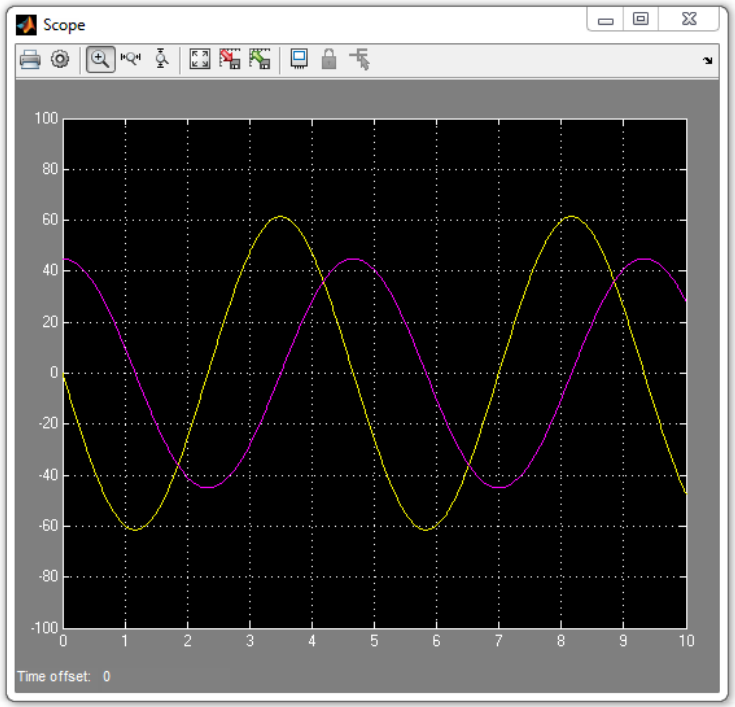


- The Library Browser contains various blocks that you can put into your model
- Find blocks by searching or browsing
- Not always intuitive

A simple example: the pendulum revisited

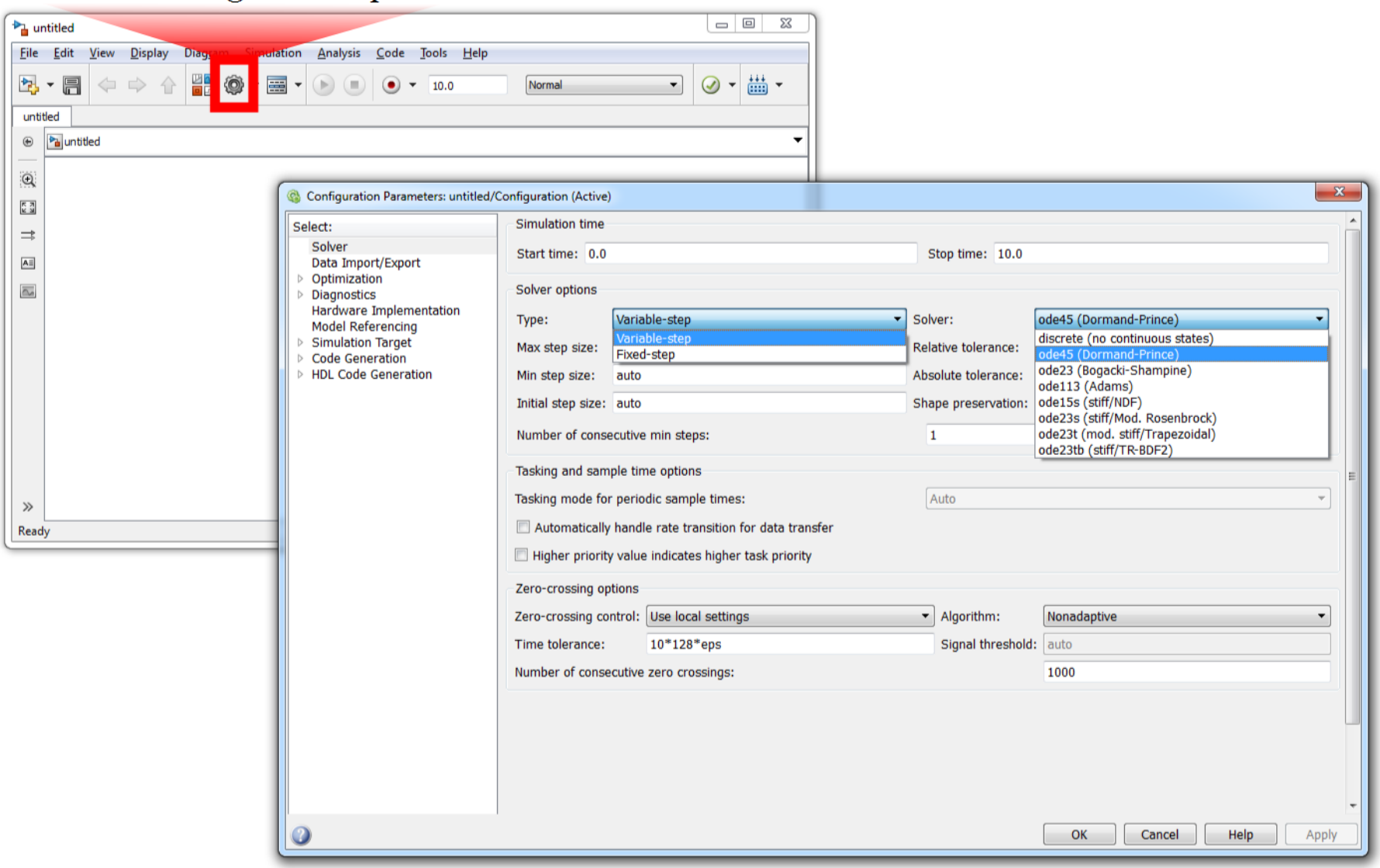
$$\ddot{\theta} + \frac{g}{L} sin(\theta) = 0$$





Behind the curtain: solvers

Model configuration pane



Useful tips and blocks

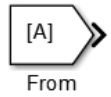
Large Simulink models may get really messy!

To avoid this use:

- Subsystems to modularize
- Goto and From blocks
- Color code
- Labels

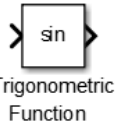
Most blocks are straight forward to use

However..

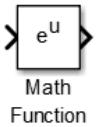


Send data wirelessly with a given tag

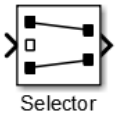
Receive wireless data with a given tag



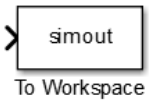
Trigonometric functions: sin, cos, tan, arcsin, arccos, arctan, hyperbolics



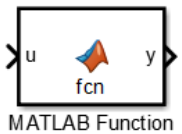
Common math functions



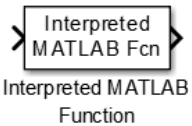
Select a set of signals within a multisignal wire



send data to MATLAB workspace



Code a function directly in Simulink

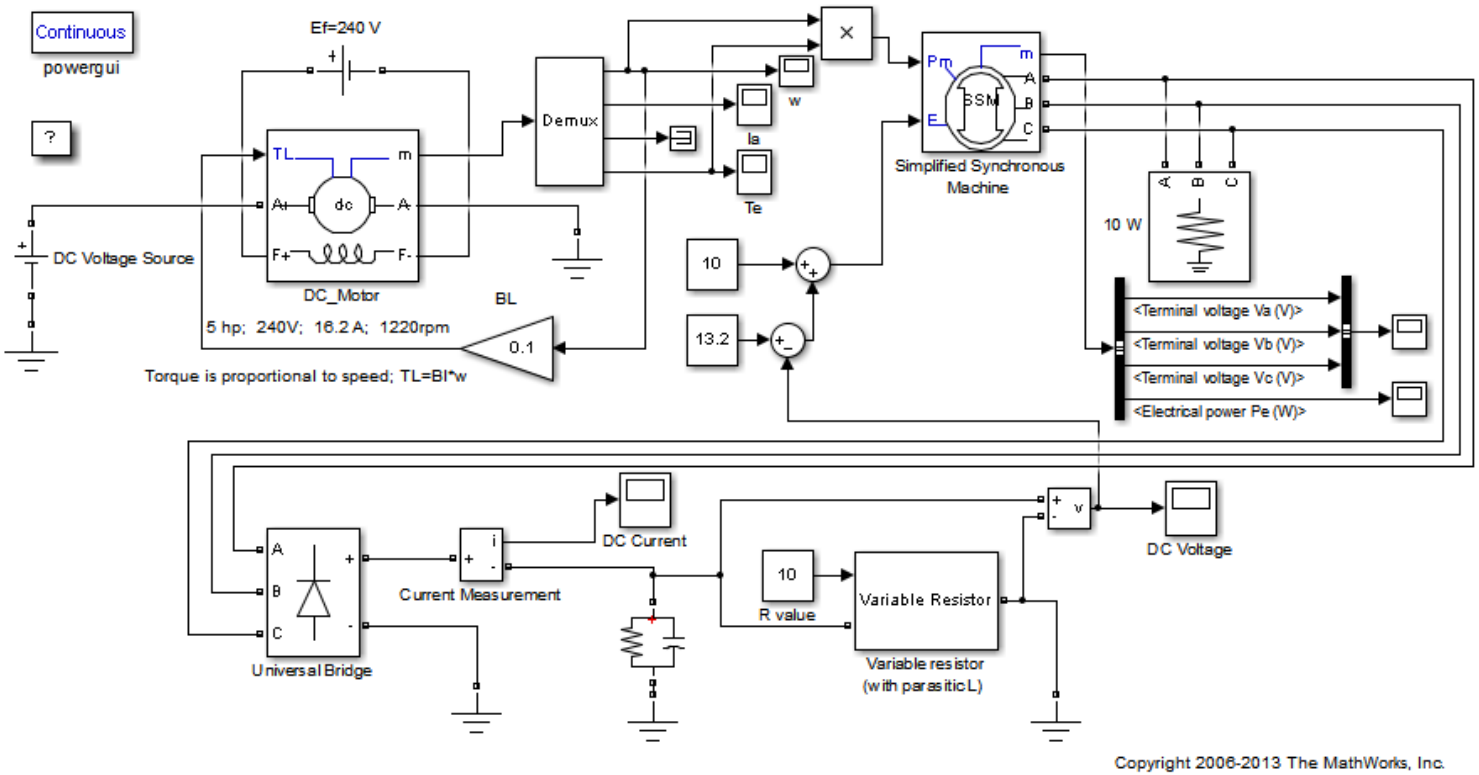


Use a MATLAB function

Mathworks Simulink demos

Mathworks have some nice demonstration examples of how to use Simulink. Check them out at:

http://www.mathworks.se/help/simulink/examples.html



Marine applications: The MSS toolbox

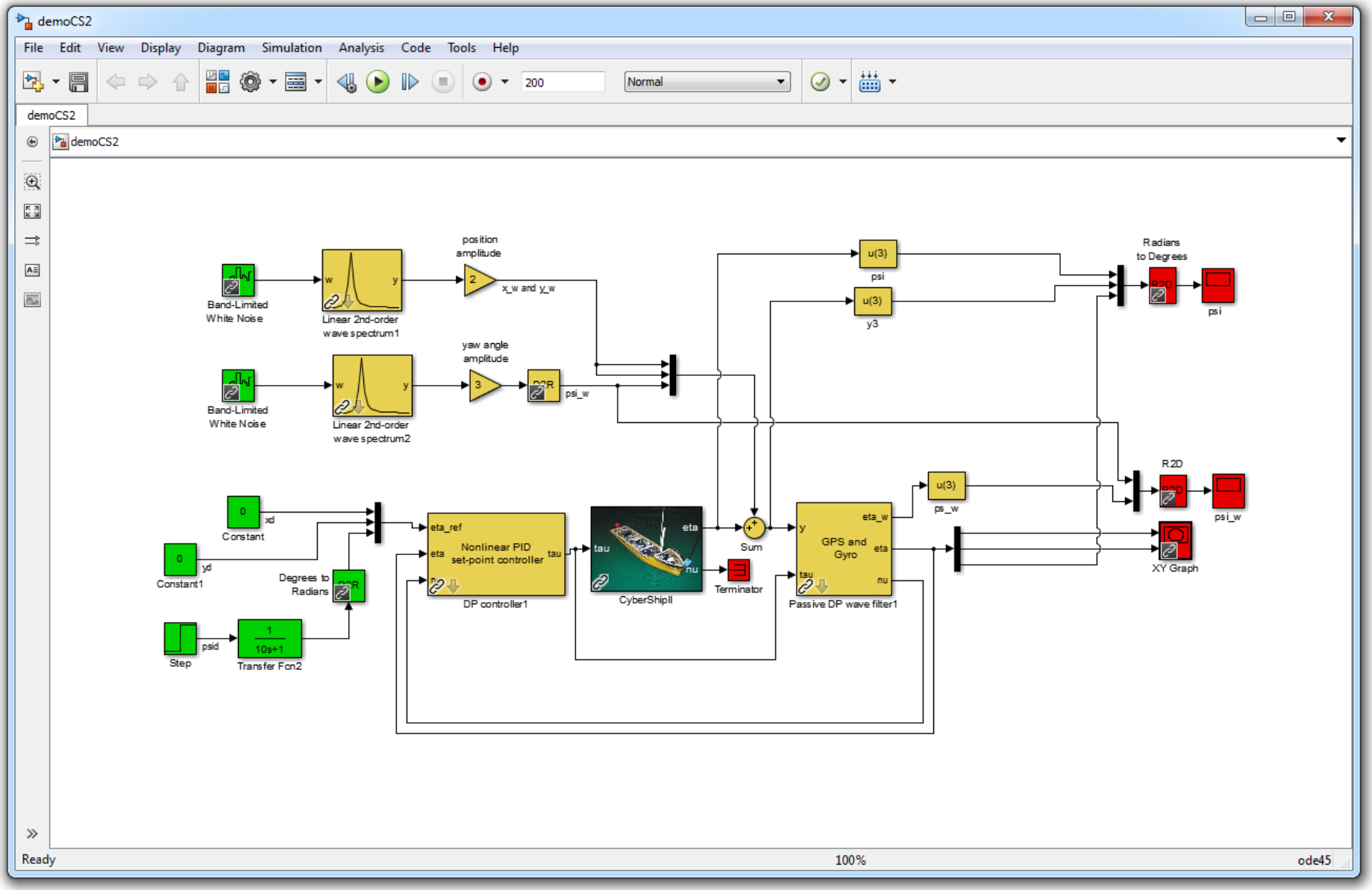
The Marine Systems Simulator

- MATLAB/Simulink library
- NTNU initiative
- Freeware
- Useful for
  - guidance, navigation and control
  - process hydrodynamic data
  - identification of radiation-force models and fluid memory effects

Get it at

http://www.marinecontrol.org

Example: Dynamic positioning



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