Embedded Systems
MATLAB Tutorial

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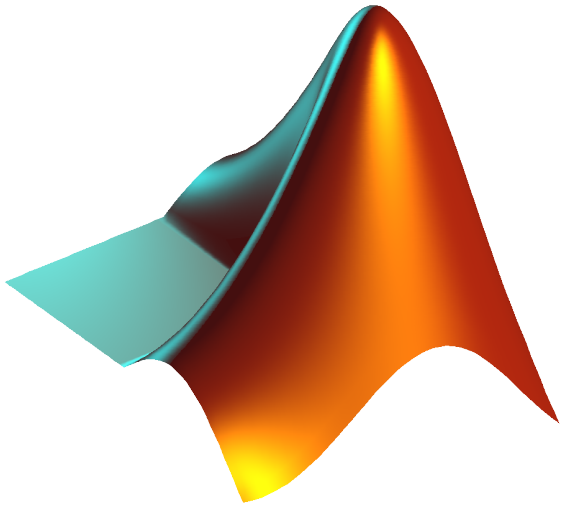
Assignments and Tutorials

- Assignments
  - Handout / return: Thursdays (before the lecture)
  - Teams are allowed (at most 3 students / team)
  - Box will be available
- First assignment
  - Handout: Today afternoon, online available
  - Return: By Monday, 8:00
- Tutorials
  - Monday, 16:00 - 18:00, SR 015 / E1.3
  - Wednesday, 14:00 - 16:00, SR 5 (215) / E2.4
  - Friday, 10:00 - 12:00, SR 015 / E1.3

MATLAB - Matrix Laboratory

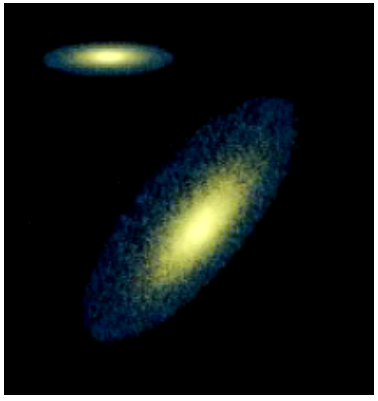
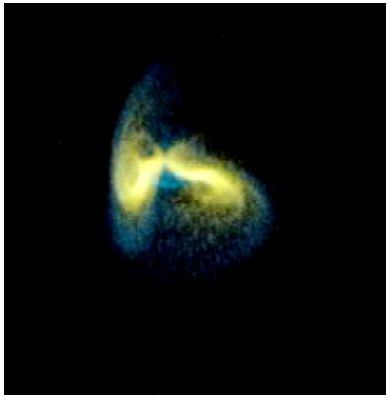
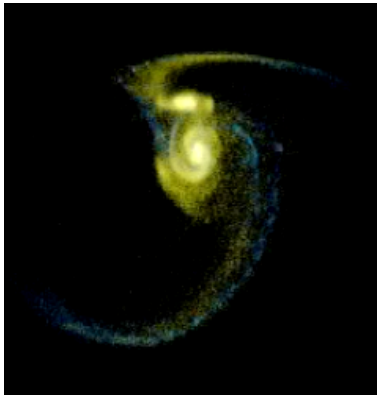


- Produced by The Mathworks
- Used for simulation and numerical computation
- No (Maple-like) symbolical solving
- Standard tool for developing embedded systems

MATLAB Structure

- MATLAB core: IDE for the MATLAB language
- Simulink: Graphical environment for continuous simulation
- Stateflow: Statecharts for Simulink
- Many other add-ons available...

Numerical Computing

- Some problems cannot be solved precisely
- Approximative numerical solutions
- Simulation of the physical world

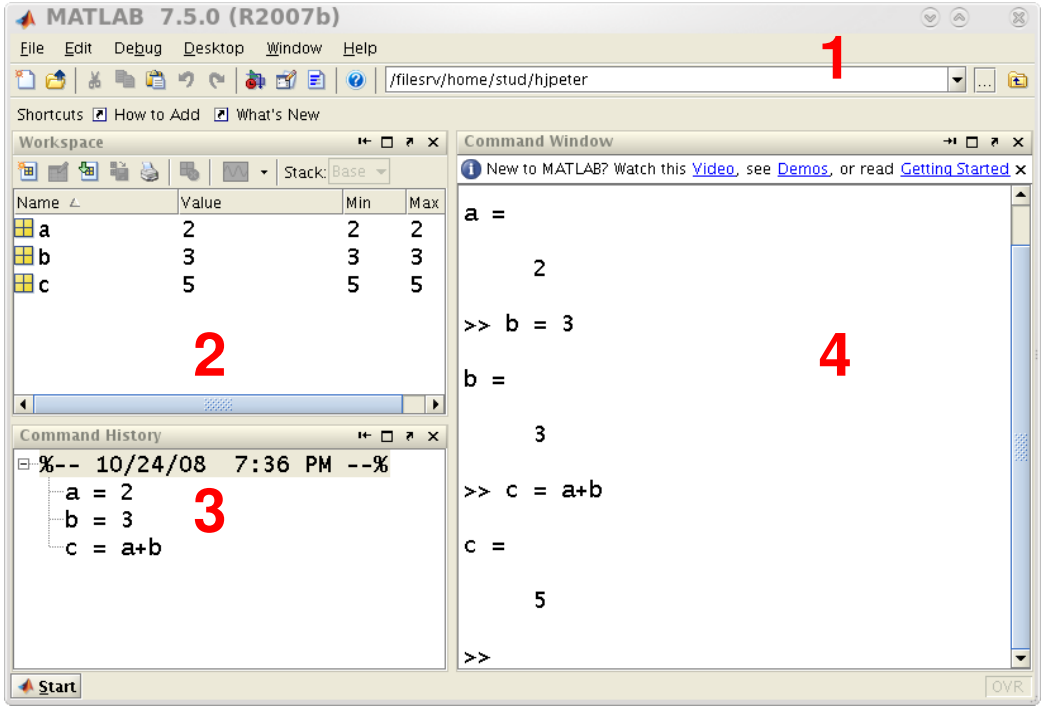
Starting MATLAB

1. `http://sunray1.studcs.uni-sb.de`
2. Log in
3. Click on `MatLab`

alternatively:

1. Log onto a `cip`, `bio`, or `sunray` workstation
2. `ssh -Y appsrv{1,2}.studcs.uni-sb.de`
3. Execute `/usr/local/matlab/bin/matlab`

MATLAB IDE



1. Current directory
2. Workspace
3. Command history
4. Command window

The MATLAB Language

- Simplified C-like syntax
- Case sensitive
- Interactive shell: command window
- User defined functions: m-files
- Many built-in commands:
  - `lookfor <keyword>`
  - `help <function>`
  - `sprintf (<format str>, v1, v2, ...)`
  - `disp (<object>)`
  - `plot (Y)`
  - `plot (X, Y)`
  - `...`

Variables

- Each numerical variable is a matrix
- Scalars = 1×1 matrices
- No explicit declarations / dynamic typing
- Polymorphism
- Removing variables:
  - `clear <variable>`
  - `clear`

Working with Matrices

- `a = 4`
- `b = [4 8 15 ; 16 23 42 ; 1 2 3]`
- `c = b'`
- `d = 0:10`
- `e = 0:0.01:2*pi`
- `f = ones(4)`
- `g = eye(3)`
- `h = b*b`
- `i = b.*b`

Script Files

- So called m-files
- Must be located in
  - the current directory or
  - the global search path
- Can be executed from the command window
- Can also define functions

Control Structures

- Conditional

```
if <cond>
  <statements>
[else
  <statements>]
end
```

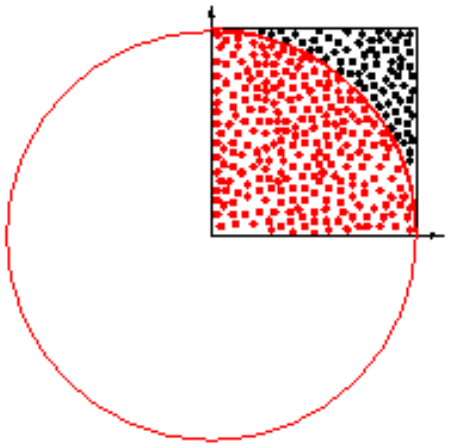
- While loop

```
while <cond>
  <statements>
end
```

- For loop

```
for v = <from>:[<step>:]<to>
  <statements>
end
```

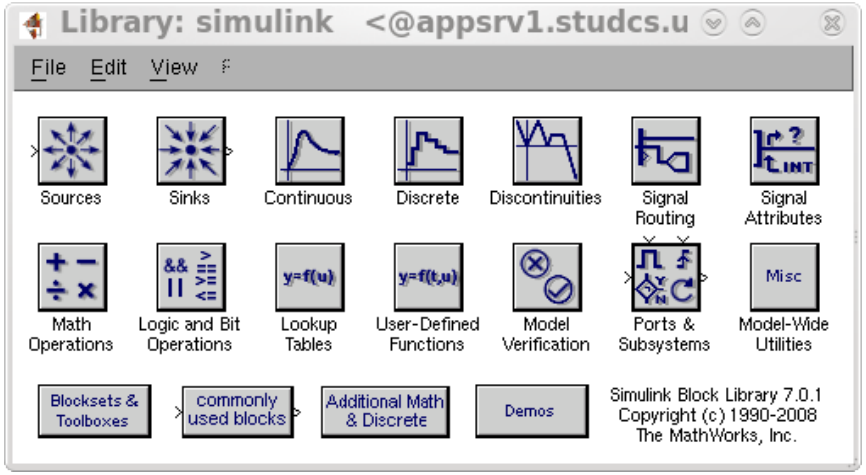
Example: Computing π



- Monte Carlo method for computing π

$$\frac{\text{points inside}}{\text{points total}} \approx \frac{\pi}{4}$$

Simulink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Sources
Sinks
Continuous
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Signal Routing
Signal Attributes
Math Operations
Logic and Bit Operations
Lookup Tables
User-Defined Functions
Model Verification
Ports & Subsystems
Model-Wide Utilities
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commonly used blocks
Additional Math & Discrete
Demos
Simulink Block Library 7.0.1
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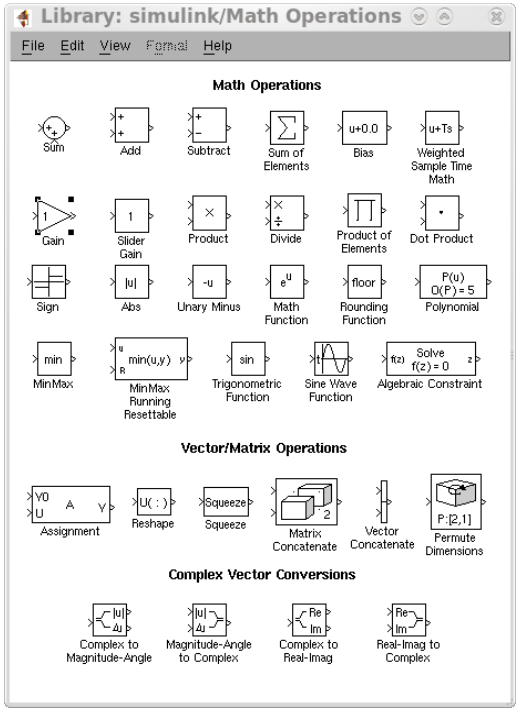
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Math Operations
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Polynomial
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Trigonometric Function
Sine Wave Function
Algebraic Constraint
Vector/Matrix Operations
Assignment
Reshape
Squeeze
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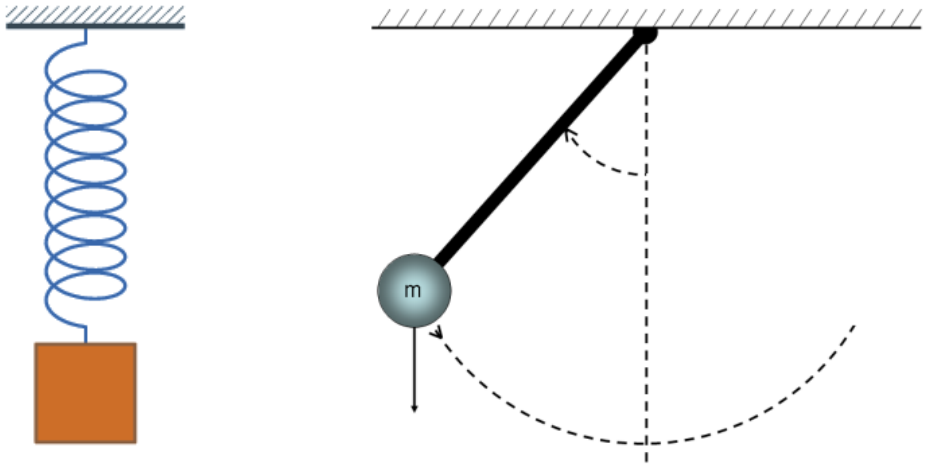
Complex to Magnitude-Angle
Magnitude-Angle to Complex
Complex to Real-Imag
Real-Imag to Complex

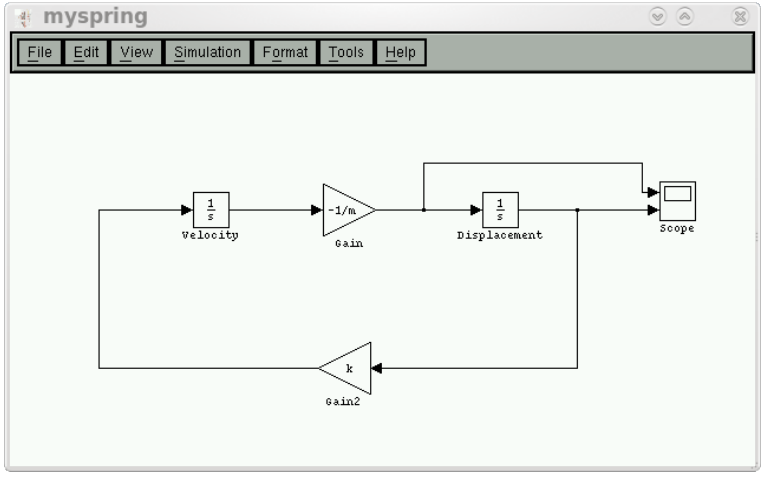
Harmonic Oscillator



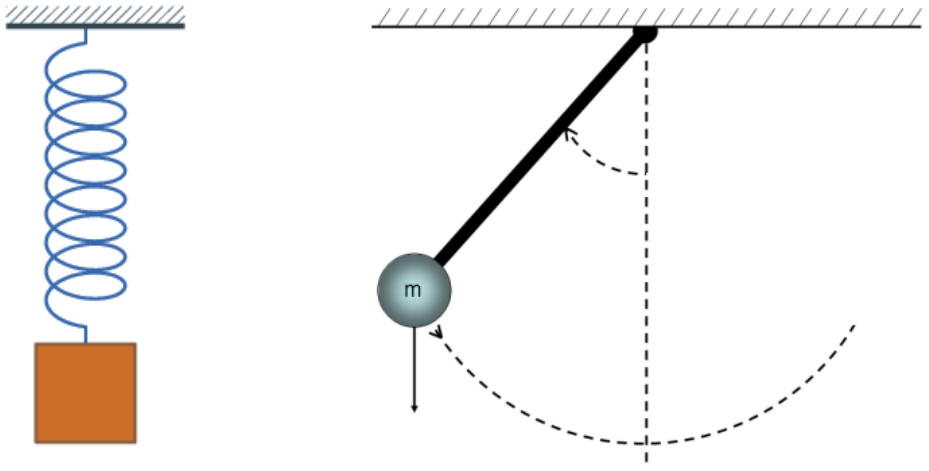
- m = mass constant
- k = spring constant
- y_0 = initial displacement
- y = current displacement
- $v = \dot{y}$ = current velocity

$$m\ddot{y} + ky = 0$$
$$\Leftrightarrow \quad m\dot{v} + ky = 0$$

Harmonic Oscillator in Simulink



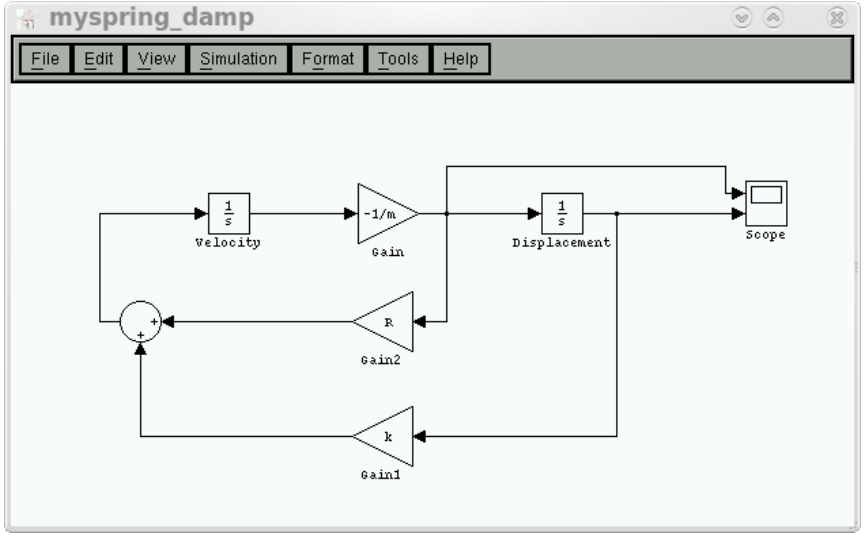
Damped Harmonic Oscillator



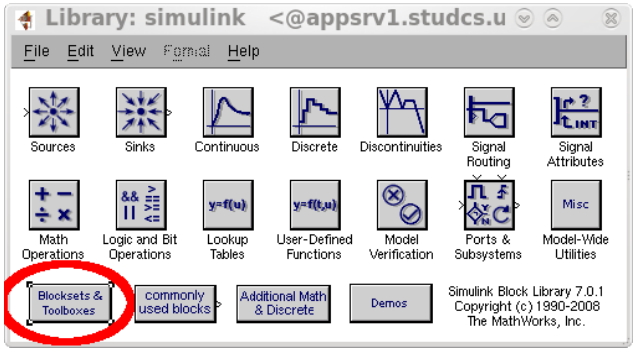
- m = mass constant
- R = damper constant
- k = spring constant
- y_0 = initial displacement
- y = current displacement
- $v = \dot{y}$ = current velocity

$$m\ddot{y} + R\dot{y} + ky = 0$$
$$\Leftrightarrow \quad m\dot{v} + Rv + ky = 0$$

Damped Harmonic Oscillator in Simulink



Stateflow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commonly used blocks
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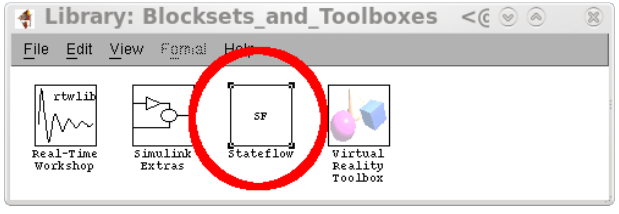
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Real-Time Workshop
Simulink Extras
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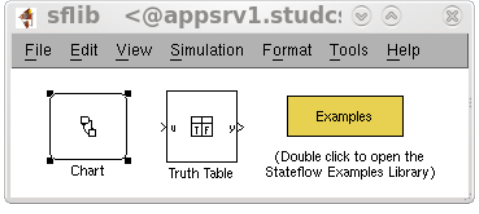
Stateflow
Virtual Reality Toolbox


sflib <@appsrv1.studc
File Edit View Simulation Format Tools Help
Chart
Truth Table
Examples
(Double click to open the Stateflow Examples Library)

Semantics: Statemate vs. Stateflow

Standard (Statemate)

- Any finite number of active events.
- Emitted events are collected and then passed to the entire chart.

Stateflow

- At most one active event.
- Emitted events are immediately passed to the receiver.

Semantics: Statemate vs. Stateflow (2)

Standard (Statemate)

- Non-determinism is allowed.
- Synchronous execution of AND-states.
- Variable changes at the end of the step.

Stateflow

- Non-determinism is not allowed.
- Sequential execution of AND-states.
- Immediate variable changes.

Stateflow Development