6.094

Introduction to Programming in MATLAB

Lecture 5: Symbolics, Simulink®,

File I/O, Building GUIs

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IAP 2010

Outline

(1) Symbolic Math

(2) Simulink

(3) File I/O

(4) Graphical User Interfaces

Symbolic Math Toolbox

- Don’t do nasty calculations by hand!
- Symbolics vs. Numerics

	Advantages	Disadvantages
Symbolic	•Analytical solutions •Lets you intuit things about solution form	•Sometimes can't be solved •Can be overly complicated
Numeric	•Always get a solution •Can make solutions accurate •Easy to code	•Hard to extract a deeper understanding •Num. methods sometimes fail •Can take a while to compute

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 expressions
  - » **d=a*b** → `d = 4/15`
    - ➢ does 1/3*4/5=4/15;
  - » **expand((a-c)^2);**
    - ➢ multiplies out → `ans = 1/9-2/3*c+c^2`
  - » **factor(ans)** → `ans = 1/9*(3*c-1)^2`
    - ➢ factors the expression
  - » **matInv=inv(mat)** →
    - ➢ Computes inverse symbolically

```
ans =
[    -2,     1]
[   3/2, -1/2]
```

Cleaning up Symbolic Statements

» **`pretty(ans)`**

➢ makes it look nicer

```
                    2
1/9 - 2/3 c + c
```

» **`collect(3*x+4*y-1/3*x^2-x+3/2*y)`**

➢ collects terms

```
ans =
2*x+11/2*y-1/3*x^2
```

» **`simplify(cos(x)^2+sin(x)^2)`**

➢ simplifies expressions

```
ans =
1
```

» **`subs('c^2',c,5)`**

```
ans=
25
```

➢ 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)`**

```
ans=
1/49*x^2
```

More Symbolic Operations

- We can do symbolics with matrices too
  - » **mat=sym('[a b;c d]');**
  - » **mat2=mat*[1 3;4 -2];**
    - ➢ compute the product
  - » **d=det(mat)**
    - ➢ compute the determinant
  - » **i=inv(mat)**
    - ➢ find the inverse

```
mat2 =
[   a+4*b, 3*a-2*b]
[   c+4*d, 3*c-2*d]
```

```
d =
a*d-b*c
```

```
i =
[  d/(a*d-b*c), -b/(a*d-b*c)]
[ -c/(a*d-b*c),  a/(a*d-b*c)]
```

- You can access symbolic matrix elements as before
  - » **i(1,2)**

```
ans =
-b/(a*d-b*c)
```

Exercise: Symbolics

- 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

- It's always annoying to integrate by parts. Use **`int`** to do the following integral symbolically and then compute the value by **`subs`**tituting 0 for a and 2 for b: $\int_a^b xe^x dx$

Exercise: Symbolics

- 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

```
» 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')
```

- It's always annoying to integrate by parts. Use **int** to do the following integral symbolically and then compute the value by **subs**tituting 0 for a and 2 for b: $\int_a^b xe^x dx$

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

Outline

(1) Symbolic Math

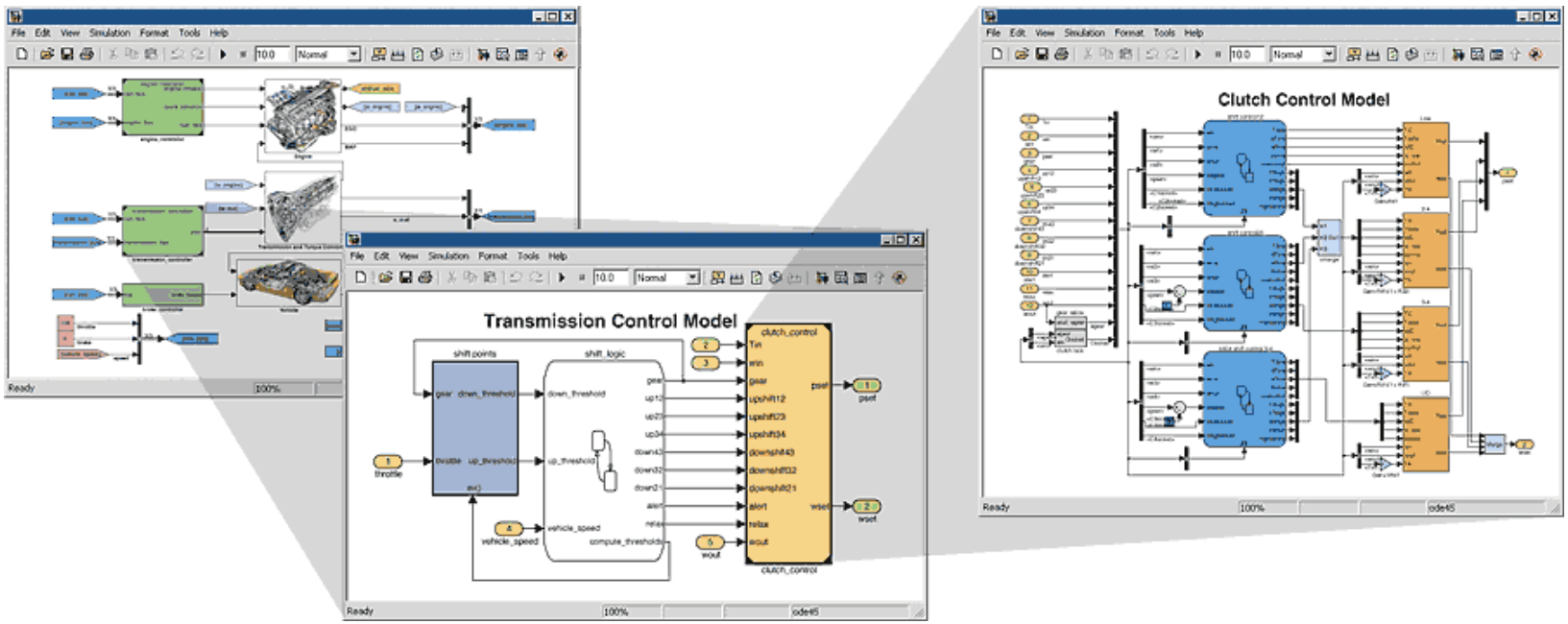
(2) Simulink

(3) File I/O

(4) Graphical User Interfaces

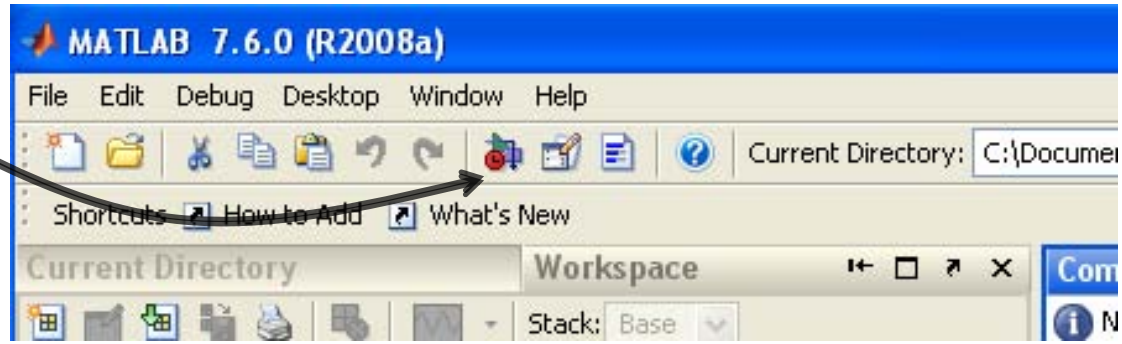
SIMULINK

- Interactive graphical environment
- Block diagram based MATLAB add-on environment
- Design, simulate, implement, and test control, signal processing, communications, and other time-varying systems



Getting Started

- In MATLAB, Start Simulink



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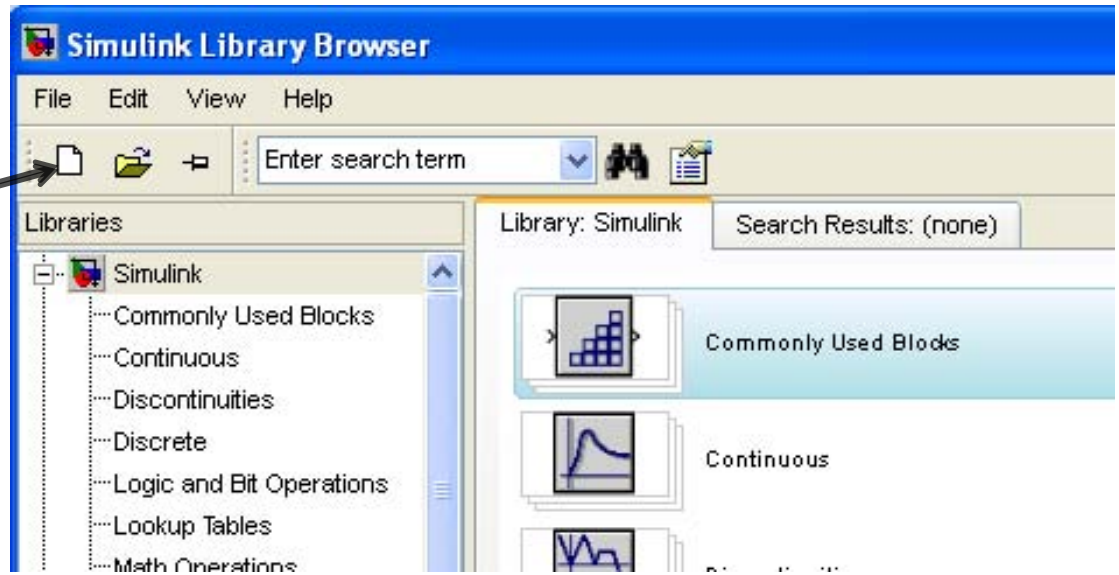
- Create a new Simulink file, similar to how you make a new script



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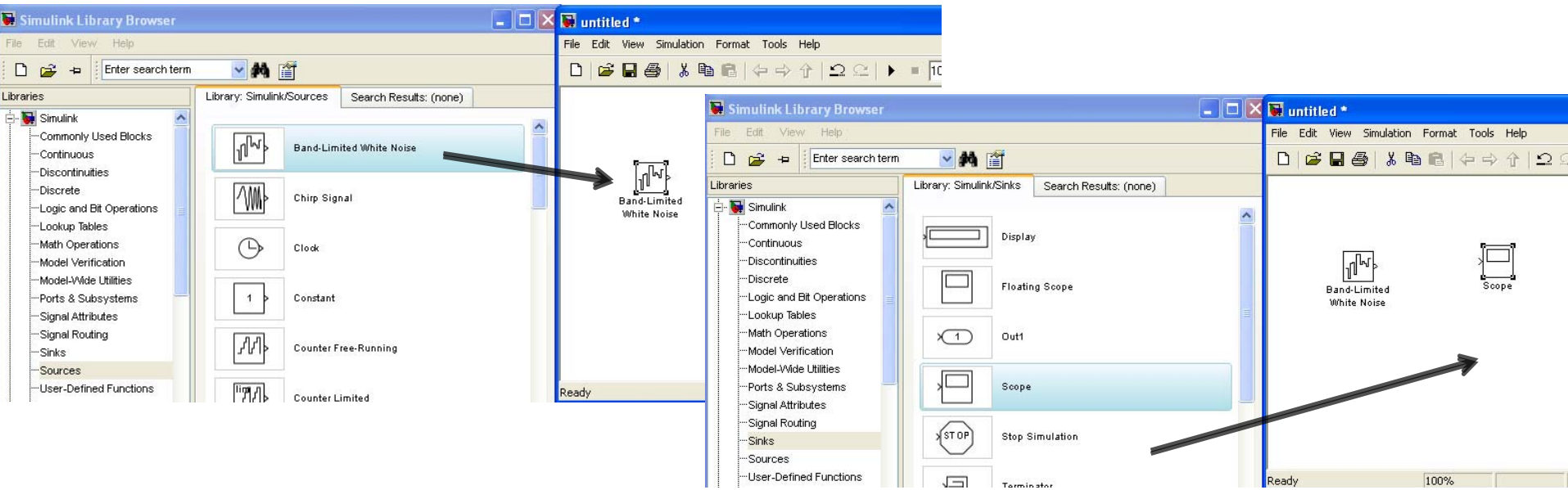
Simulink Library Browser

- The **Library Browser** contains various blocks that you can put into your model
- Examine some blocks:
  - ➢ Click on a library: "Sources"
    - – Drag a block into Simulink: "Band limited white noise"
  - ➢ Visualize the block by going into "Sinks"
    - – Drag a "Scope" into Simulink



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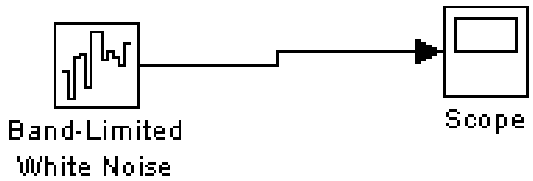
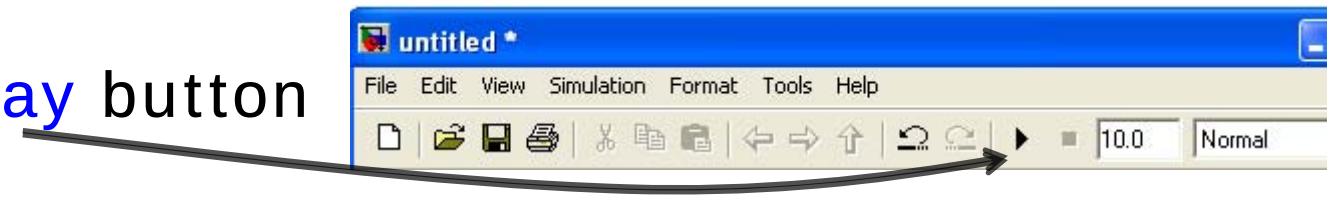
Connections

- Click on the carat/arrow on the right of the band limited white noise box



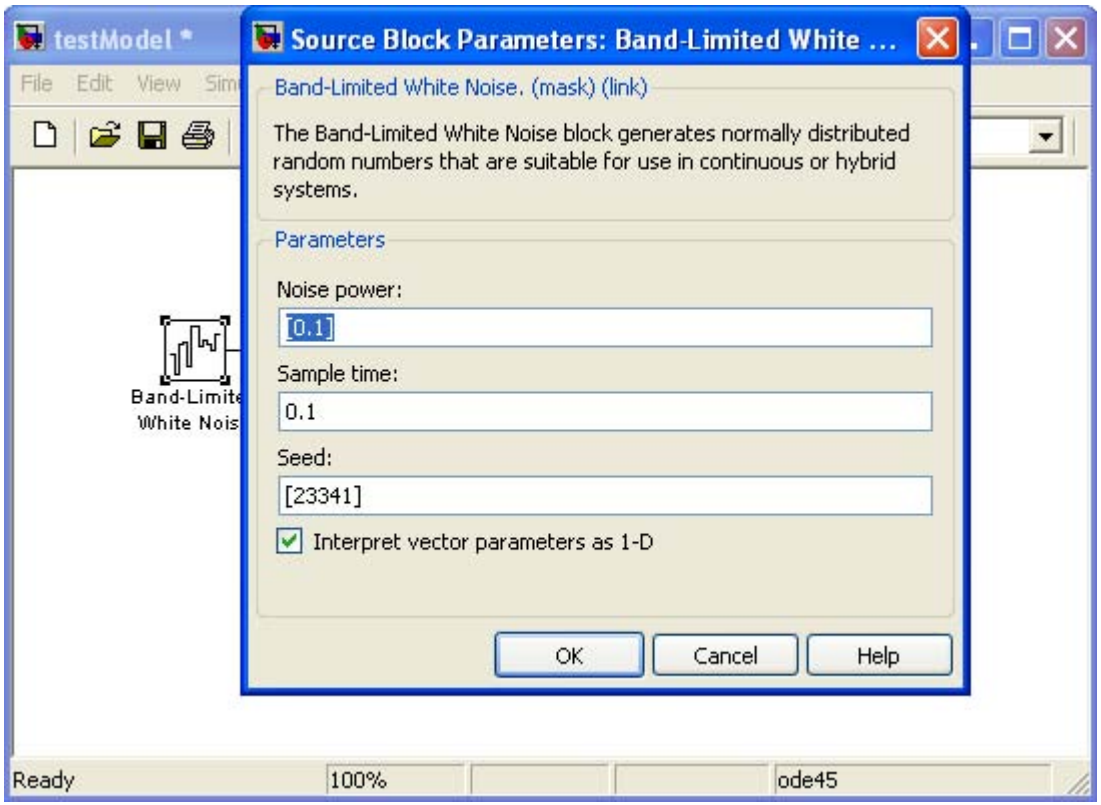
- Drag the line to the scope
  - You'll get a hint saying you can quickly connect blocks by hitting Ctrl
  - Connections between lines represent signals
- Click the play button



- Double click on the scope.
  - This will open up a chart of the variable over the simulation time

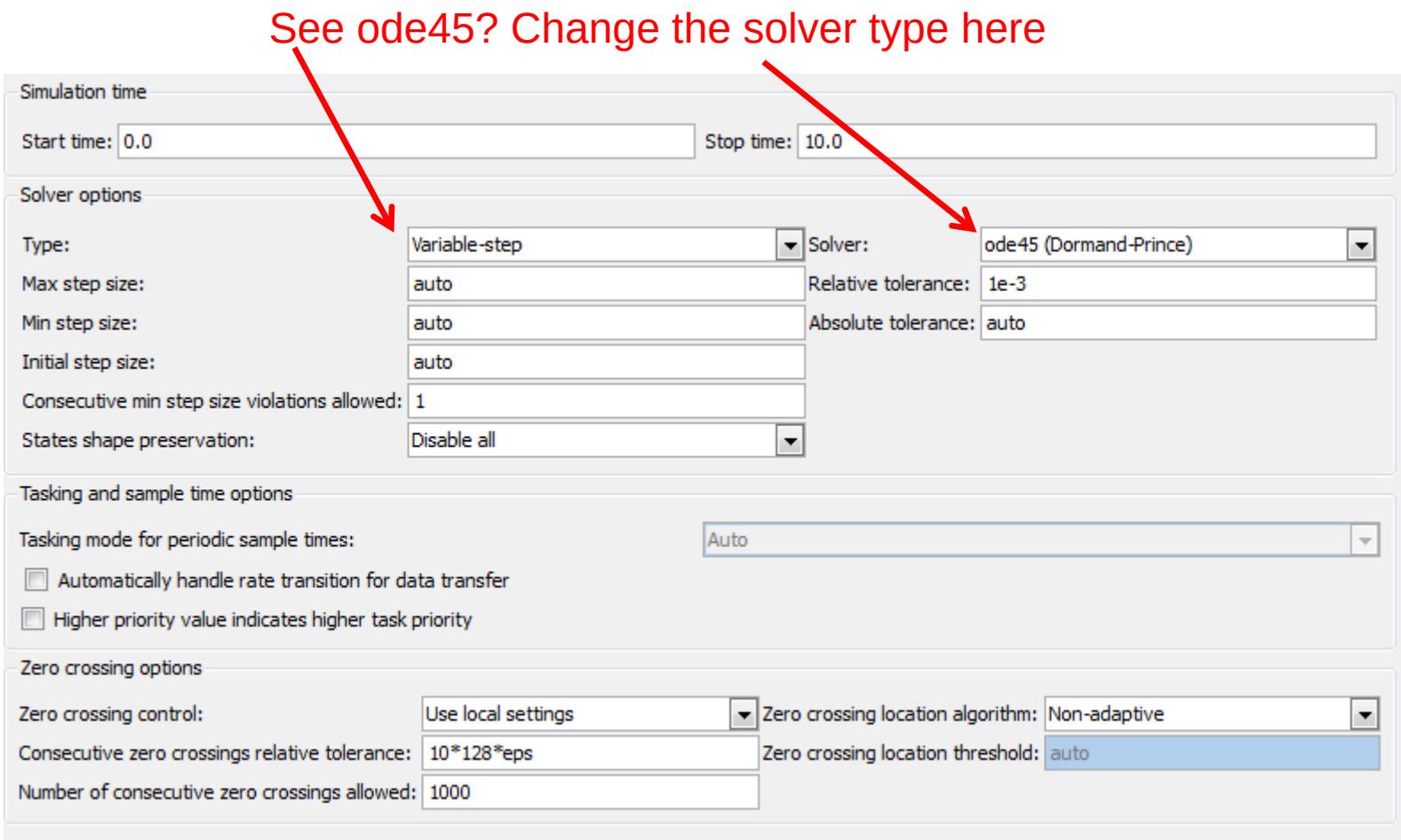
Connections, Block Specification

- To split connections, hold down ‘Ctrl’ when clicking on a connection, and drag it to the target block; or drag backwards from the target block
- To modify properties of a block, double-click it and fill in the property values.



Behind the curtain

- Go to “Simulation”->”Configuration Parameters” at the top menu



Exercise: Simulink

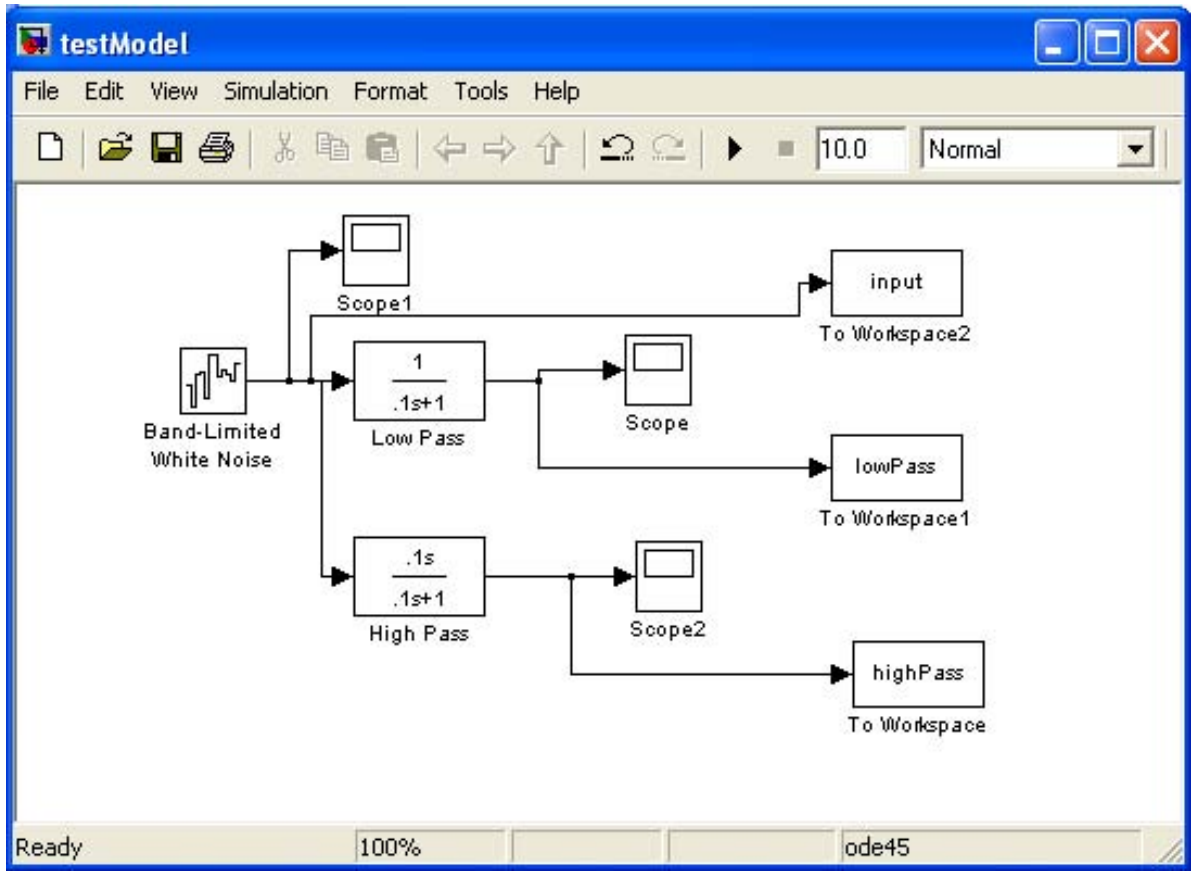
- Take your white noise signal, and split it into high frequency and low frequency components. Use the **Transfer Function** block from **Continuous** and use these transfer functions:

$$LP = \frac{1}{0.1s + 1} \qquad HP = \frac{0.1s}{0.1s + 1}$$

- Hook up scopes to the input and the two outputs
- Send the two outputs to the workspace by using the **to Workspace** block from **Sink**

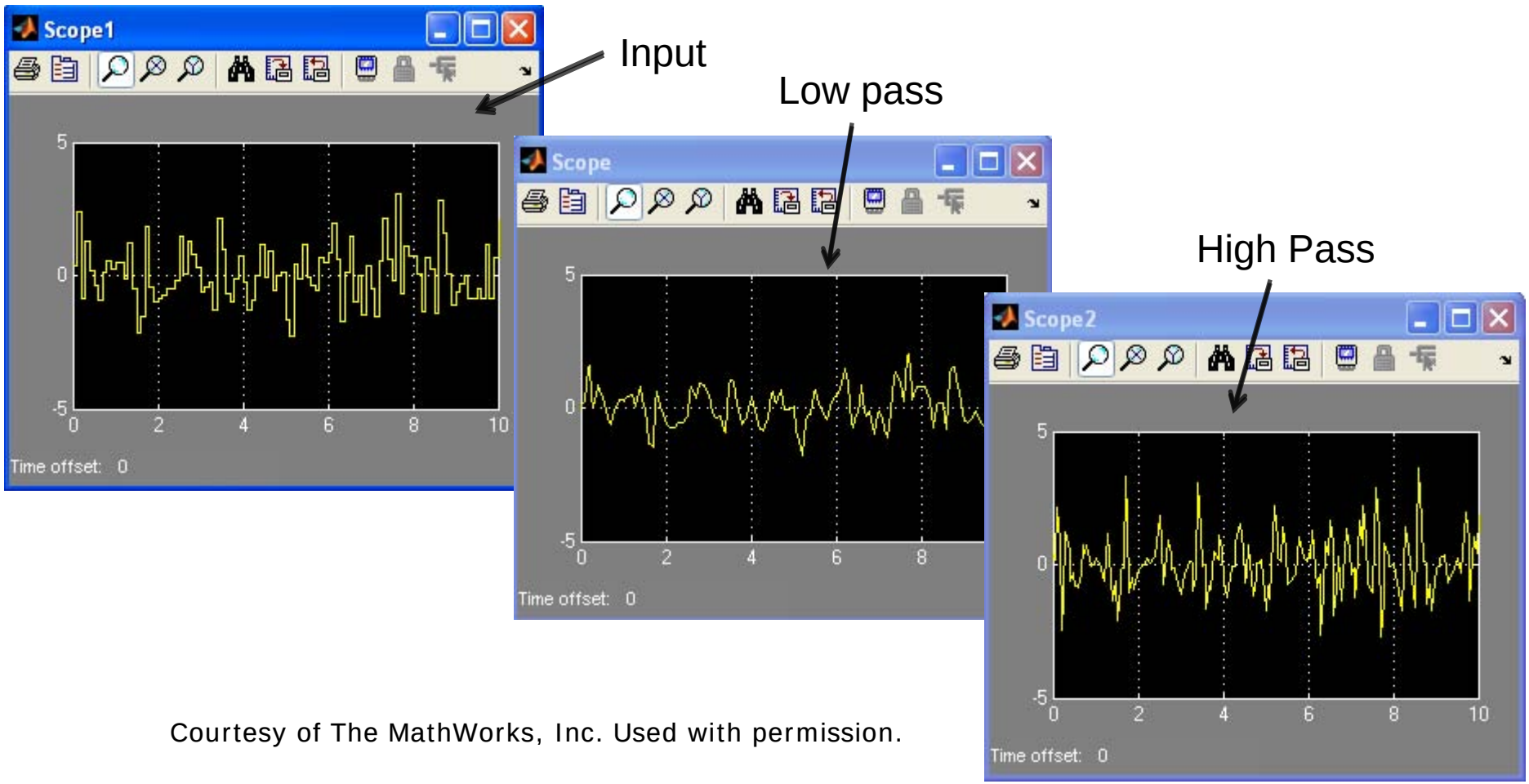
Exercise: Simulink

- The diagram should look like this. To change the **transfer function** parameters, double click the blocks and specify the numerator and denominator as polynomials in s (remember how we defined polynomial vectors before)



Exercise: Simulink

- After running the simulation, double-clicking the scopes will show:



Toolboxes

- Math
  - Takes the signal and performs a math operation
  - » **`Add, subtract, round, multiply, gain, angle`**
- Continuous
  - Adds differential equations to the system
  - » **`Integrals, Derivatives, Transfer Functions, State Space`**
- Discontinuities
  - Adds nonlinearities to your system
- Discrete
  - Simulates discrete difference equations
  - Useful for digital systems

Building systems

- Sources
  - **Step input, white noise, custom input, sine wave, ramp input,**
    - Provides input to your system
- Sinks
  - **Scope: Outputs to plot**
  - **simout: Outputs to a MATLAB vector on workspace**
  - **MATLAB mat file**

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(3) File I/O
(4) Graphical User Interfaces

Importing Data

- MATLAB is a great environment for processing data. If you have a text file with some data:

```
jane joe jimmy
10 11 12
5 4 2
5 6 4
```

- To import data from files on your hard drive, use importdata
  - **`» a=importdata('textFile.txt');`**
    - a is a struct with `data`, `textdata`, and `colheaders` fields

```
a =
            data: [3x3 double]
        textdata: {'jane'  'joe'  'jimmy'}
      colheaders: {'jane'  'joe'  'jimmy'}
```

  - **`» x=a.data;`**
  - **`» names=a.colheaders;`**

Importing Data

- With **importdata**, you can also specify delimiters. For example, for comma separated values, use:
  - » **a=importdata('filename', ', ');**
    - ➢ The second argument tells matlab that the tokens of interest are separated by commas or spaces

- **importdata** is very robust, but sometimes it can have trouble. To read files with more control, use **fscanf** (similar to C/Java), **textread**, **textscan**. See **help** or **doc** for information on how to use these functions

Writing Excel Files

- MATLAB contains specific functions for reading and writing Microsoft Excel files
- To write a matrix to an Excel file, use **xlswrite**

```
» [s,m]=xlswrite('randomNumbers',rand(10,4),...
  'Sheet1'); % we specify the sheet name
```

- You can also write a cell array if you have mixed data:

```
» C={'hello','goodbye';10,-2;-3,4};
» [s,m]=xlswrite('randomNumbers',C,'mixedData');
```

- **s** and **m** contain the 'success' and 'message' output of the write command
- See **doc xlswrite** for more usage options

Reading Excel Files

- Reading excel files is equally easy
- To read from an Excel file, use **`xlsread`**
  - **`[num,txt,raw]=xlsread('randomNumbers.xls');`**
    - Reads the first sheet
    - **`num`** contains numbers, **`txt`** contains strings, **`raw`** is the entire cell array containing everything
  - **`[num,txt,raw]=xlsread('randomNumbers.xls',...`**
    `'mixedData');`
    - Reads the **mixedData** sheet
  - **`[num,txt,raw]=xlsread('randomNumbers.xls',-1);`**
    - Opens the file in an Excel window and lets you click on the data you want!
- See **`doc xlsread`** for even more fancy options

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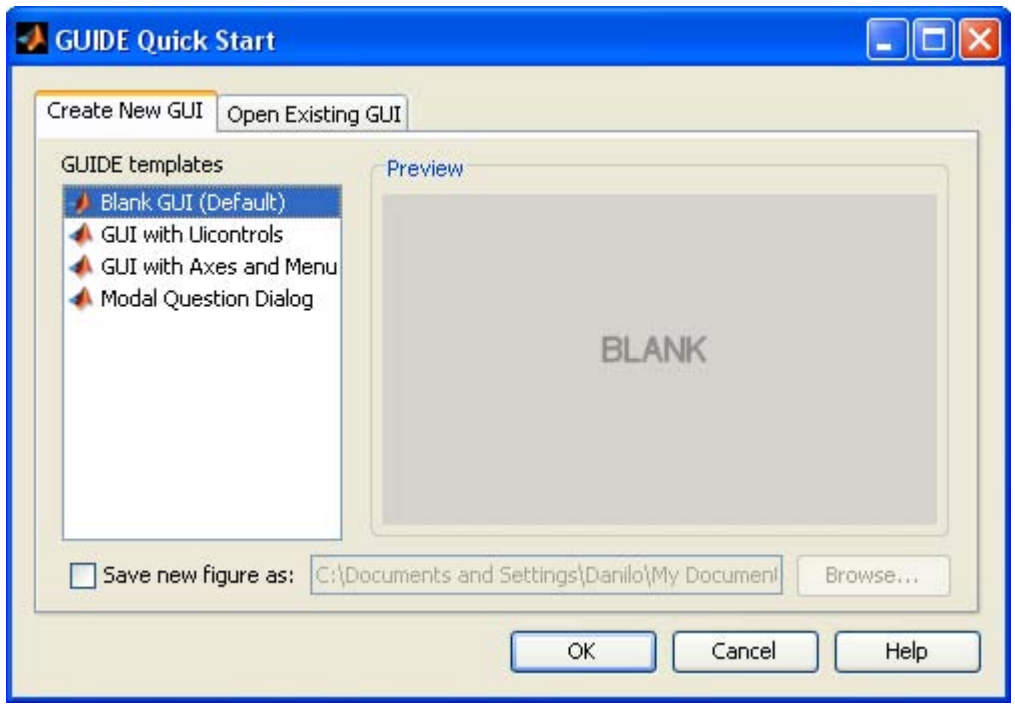
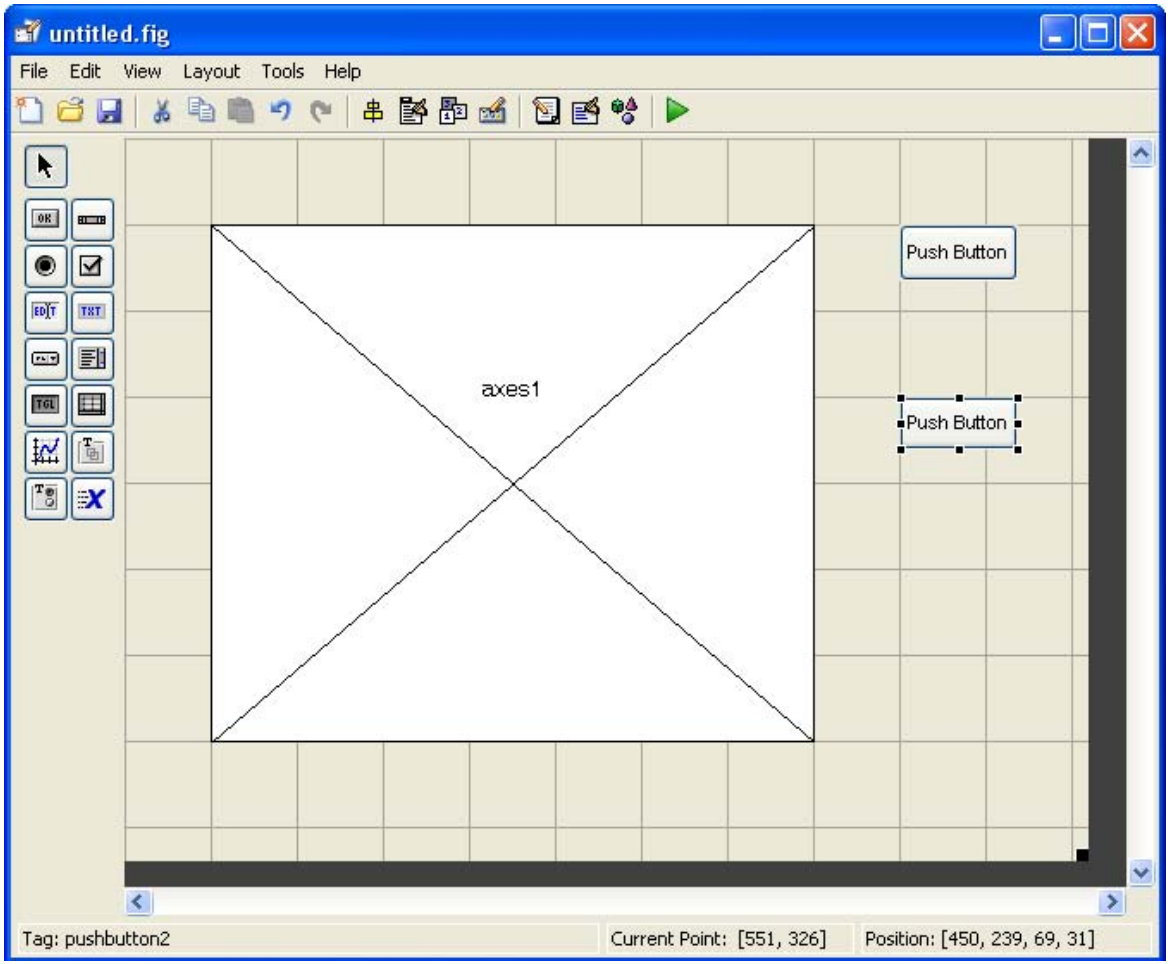
Making GUIs

- It's really easy to make a graphical user interface in MATLAB
- To open the graphical user interface development environment, type **`guide`**
  - » **`guide`**
    - ➢ Select Blank GUI



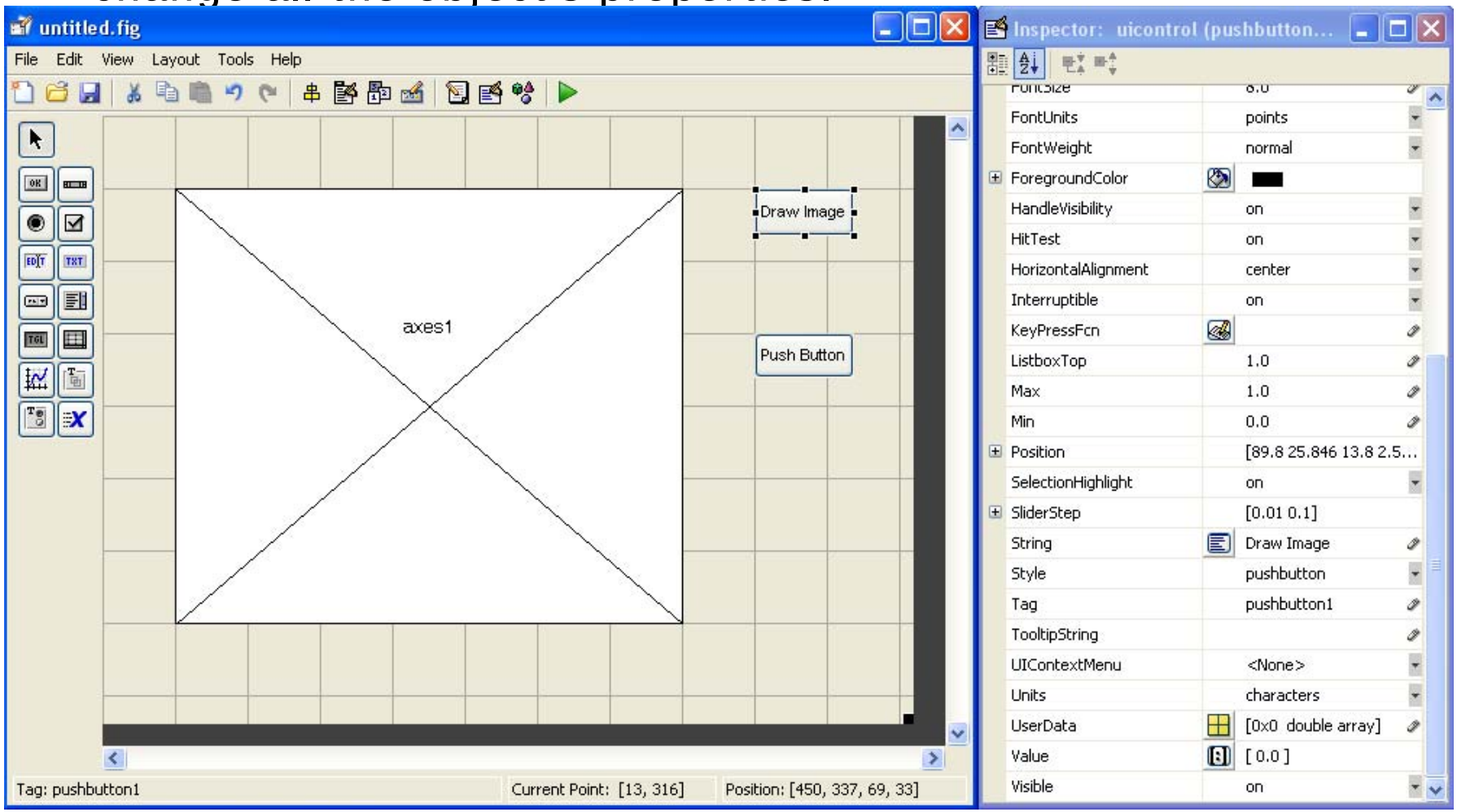
Draw the GUI

- Select objects from the left, and draw them where you want them



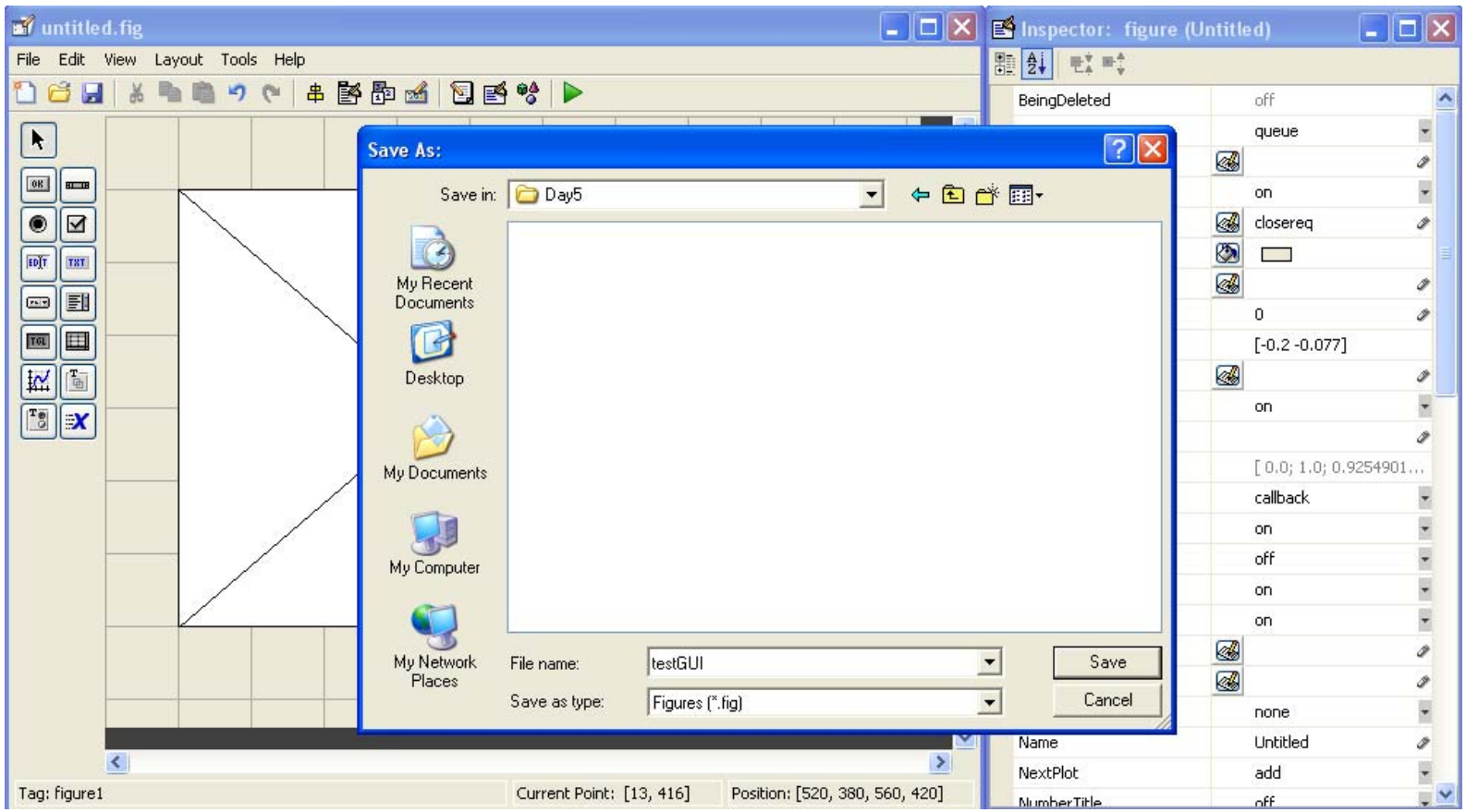
Change Object Settings

- Double-click on objects to open the Inspector. Here you can change all the object's properties.



Save the GUI

- When you have modified all the properties, you can save the GUI
- MATLAB saves the GUI as a .fig file, and generates an MATLAB file!



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Add Functionality to MATLAB file

- To add functionality to your buttons, add commands to the 'Callback' functions in the MATLAB file. For example, when the user clicks the Draw Image button, the **`drawimage_Callback`** function will be called and executed
- All the data for the GUI is stored in the handles, so use **`set`** and **`get`** to get data and change it if necessary
- Any time you change the handles, save it using **`guidata`**

  » **`guidata(handles.Figure1,handles);`**

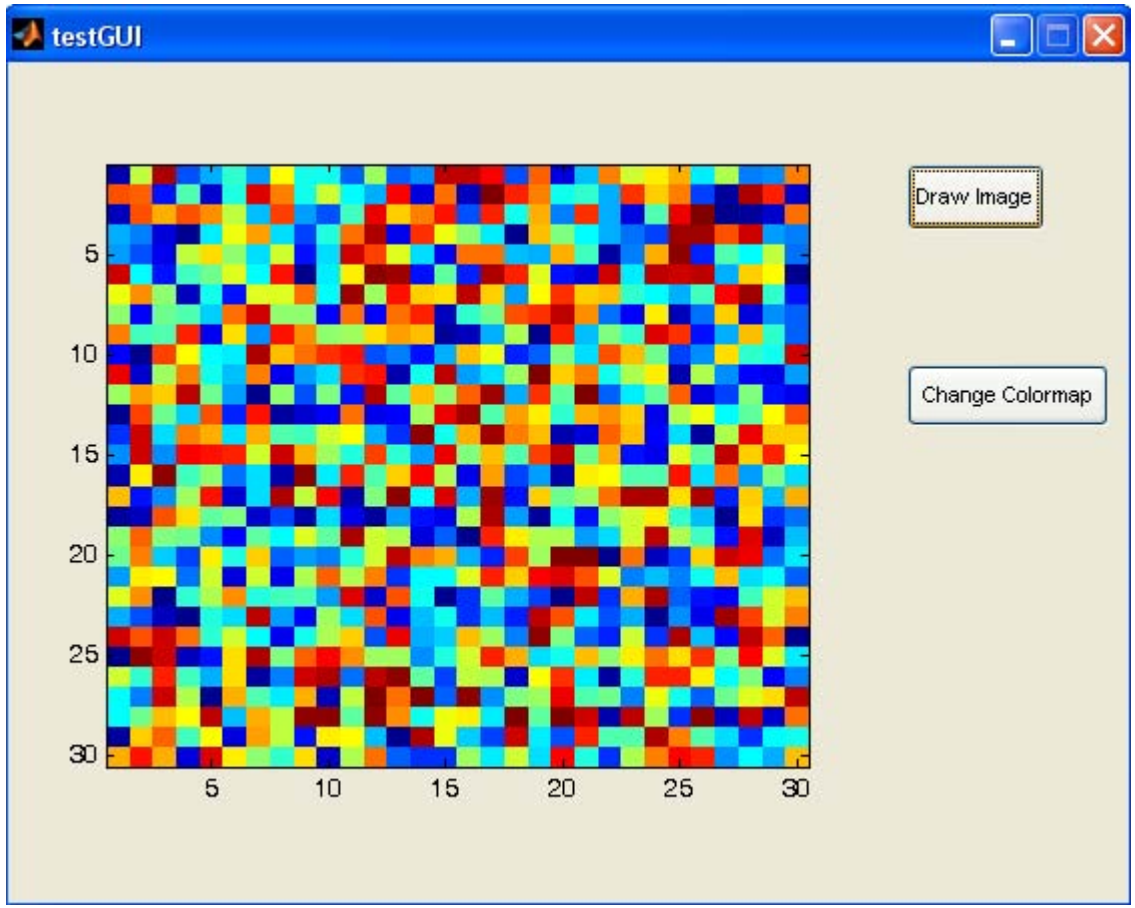
```
75
76      % --- Executes on button press in drawimage.
77      function drawimage_Callback(hObject, eventdata, handles)
78      % hObject    handle to drawimage (see GCBO)
79      % eventdata  reserved - to be defined in a future version of MATLAB
80      % handles    structure with handles and user data (see GUIDATA)
81
82
83      % --- Executes on button press in changeColormap.
84      function changeColormap_Callback(hObject, eventdata, handles)
85      % hObject    handle to changeColormap (see GCBO)
86      % eventdata  reserved - to be defined in a future version of MATLAB
87      % handles    structure with handles and user data (see GUIDATA)
88
```

textFile.txt | numbers.txt | testGUI.m

testGUI

Running the GUI

- To run the GUI, just type its name in the command window and the GUI will pop up. The debugger is really helpful for writing GUIs because it lets you see inside the GUI



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Now you know EVERYTHING!

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January (IAP) 2010