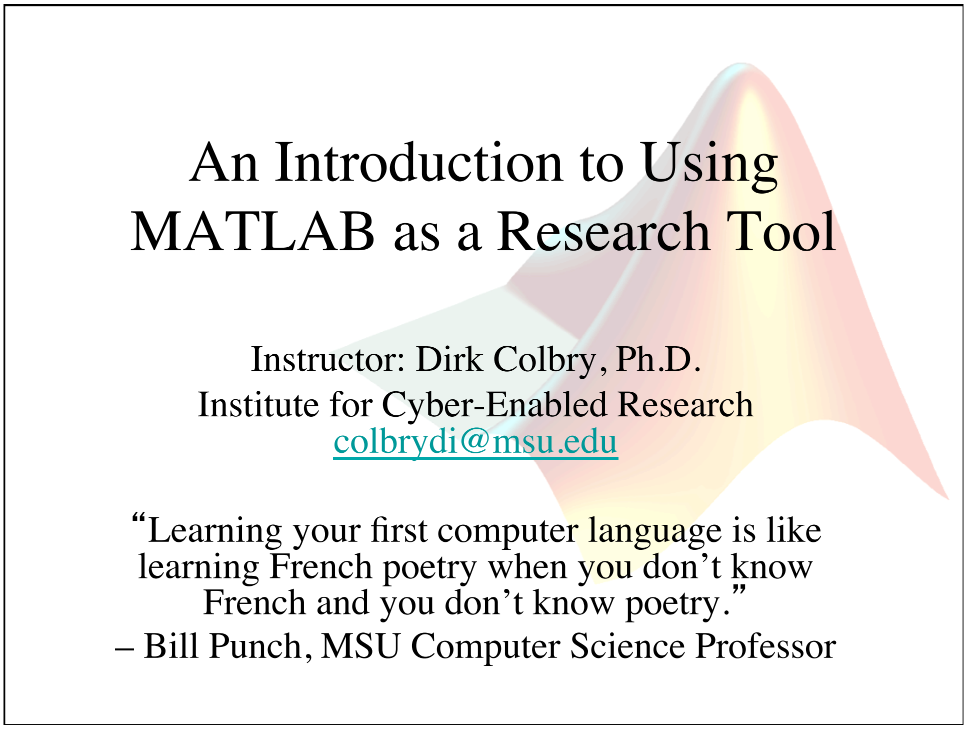

An Introduction to Using MATLAB as a Research Tool

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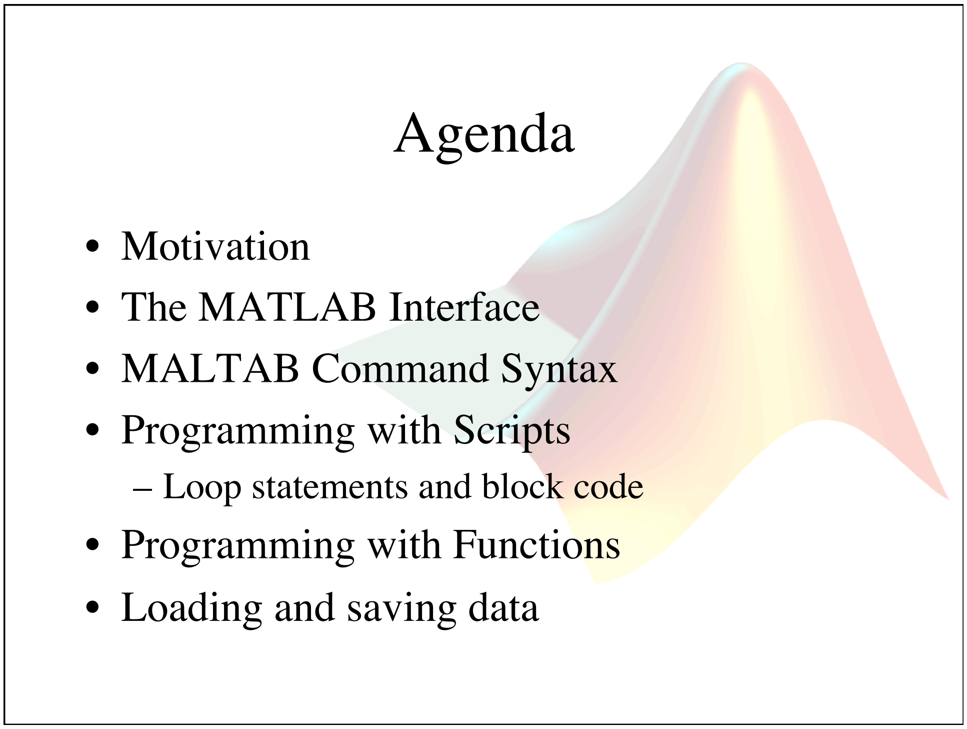
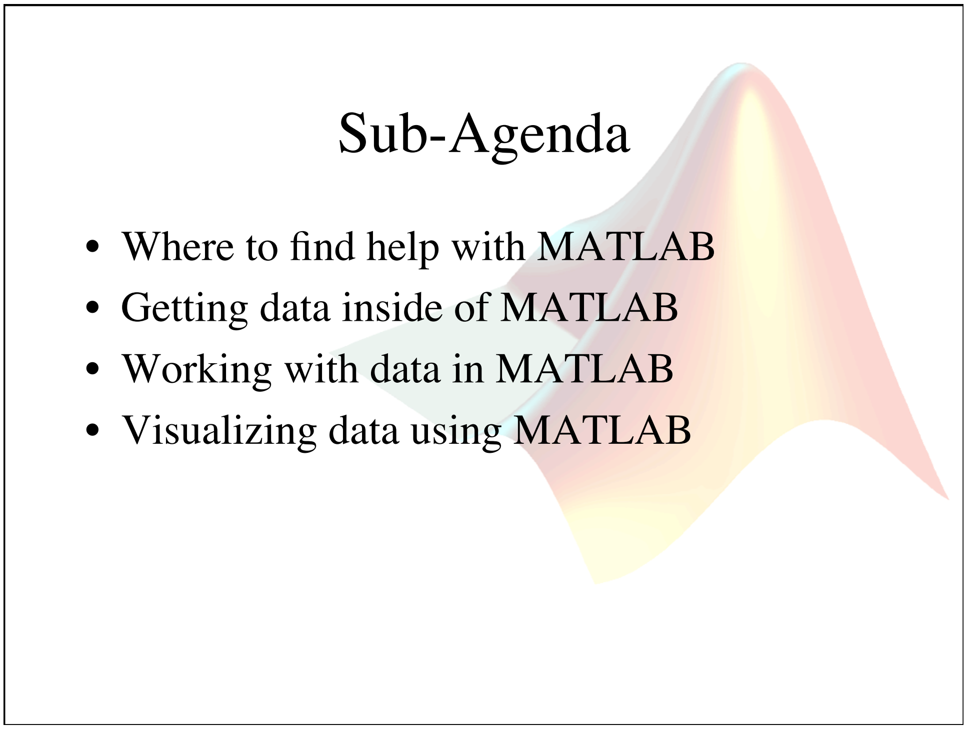
Institute for Cyber-Enabled Research
colbrydi@msu.edu

"Learning your first computer language is like learning French poetry when you don't know French and you don't know poetry."
– Bill Punch, MSU Computer Science Professor



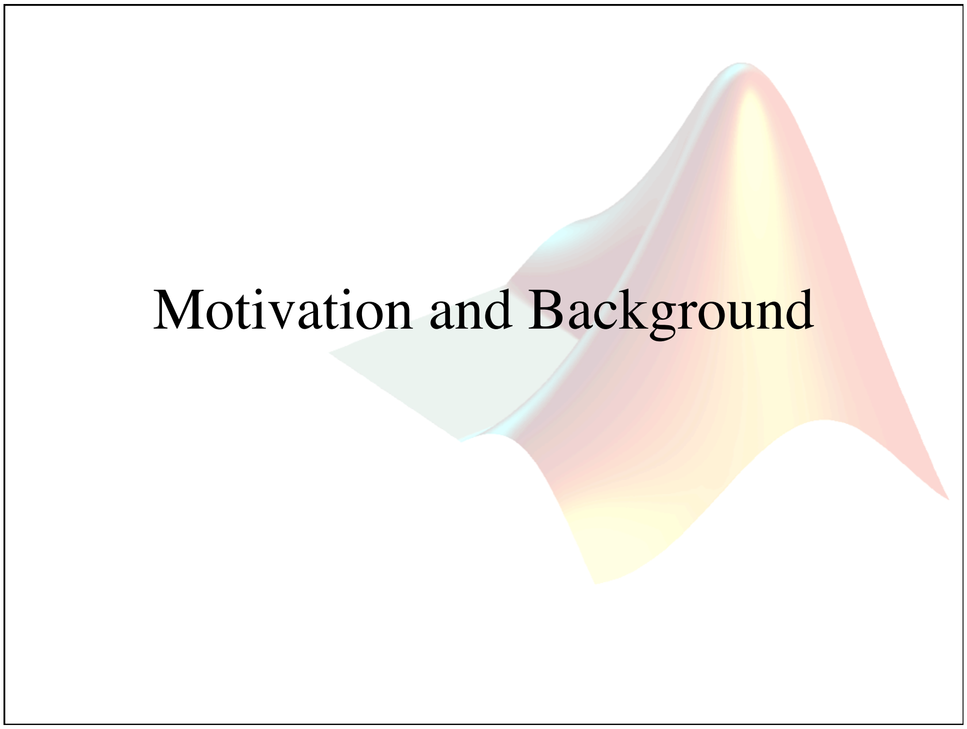
Agenda

- Motivation
- The MATLAB Interface
- MALTAB Command Syntax
- Programming with Scripts
  - – Loop statements and block code
- Programming with Functions
- Loading and saving data

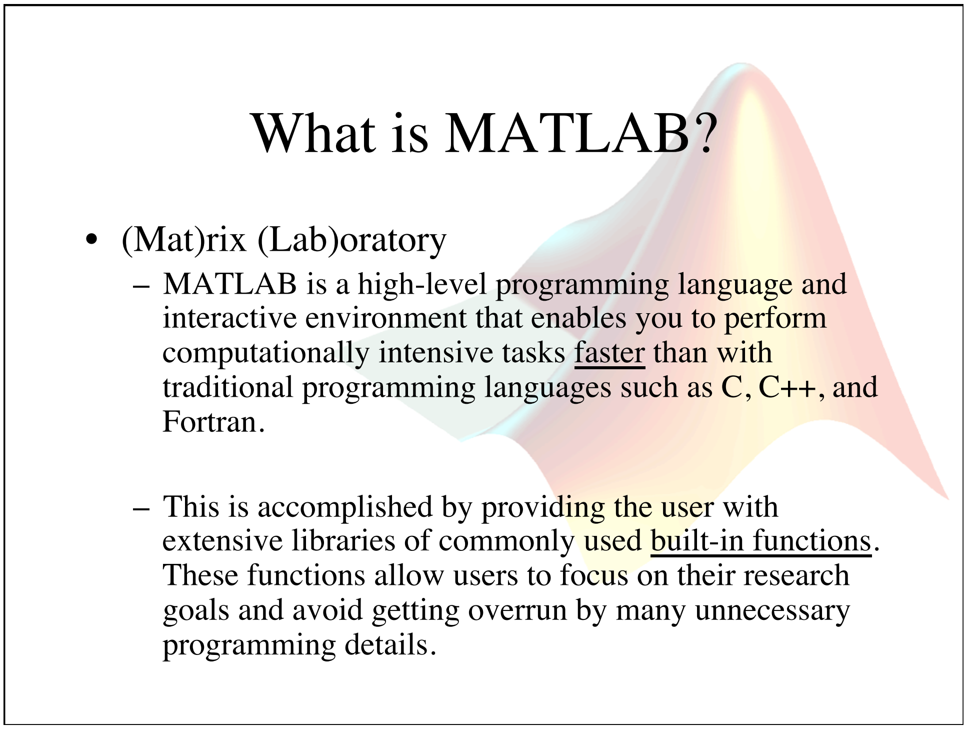


Sub-Agenda

- Where to find help with MATLAB
- Getting data inside of MATLAB
- Working with data in MATLAB
- Visualizing data using MATLAB

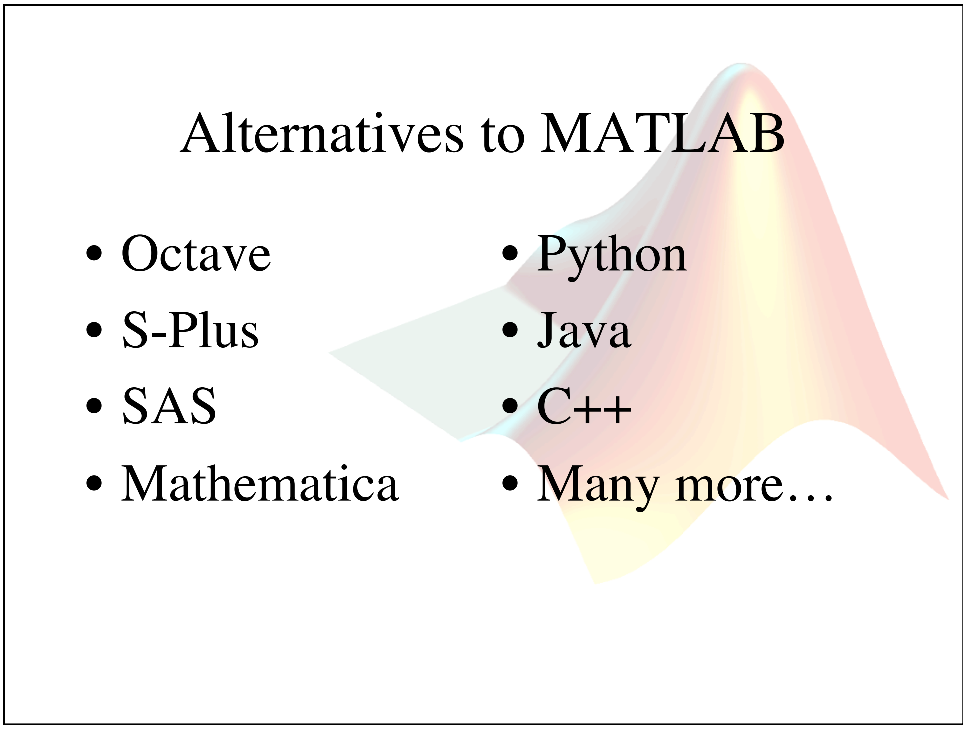


Motivation and Background



What is MATLAB?

- (Mat)rix (Lab)oratory
  - MATLAB is a high-level programming language and interactive environment that enables you to perform computationally intensive tasks faster than with traditional programming languages such as C, C++, and Fortran.
  - This is accomplished by providing the user with extensive libraries of commonly used built-in functions. These functions allow users to focus on their research goals and avoid getting overrun by many unnecessary programming details.



Alternatives to MATLAB

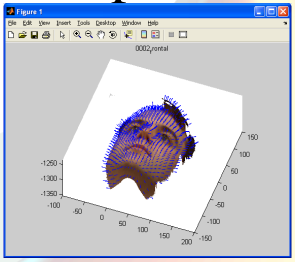
- Octave
- S-Plus
- SAS
- Mathematica
- Python
- Java
- C++
- Many more…

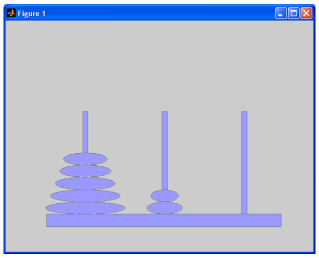
Why use MATLAB?

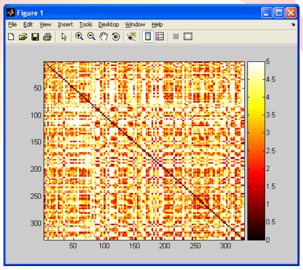
- MATLAB is designed to make it quick and easy to develop programs:
  - Uses an interpretive language, instead of a programming language that needs a compiler
  - Has an extensive library of existing functions
  - There are many existing resources online

A Few Examples

- Data Generation
- Data Analysis
- Data Visualization

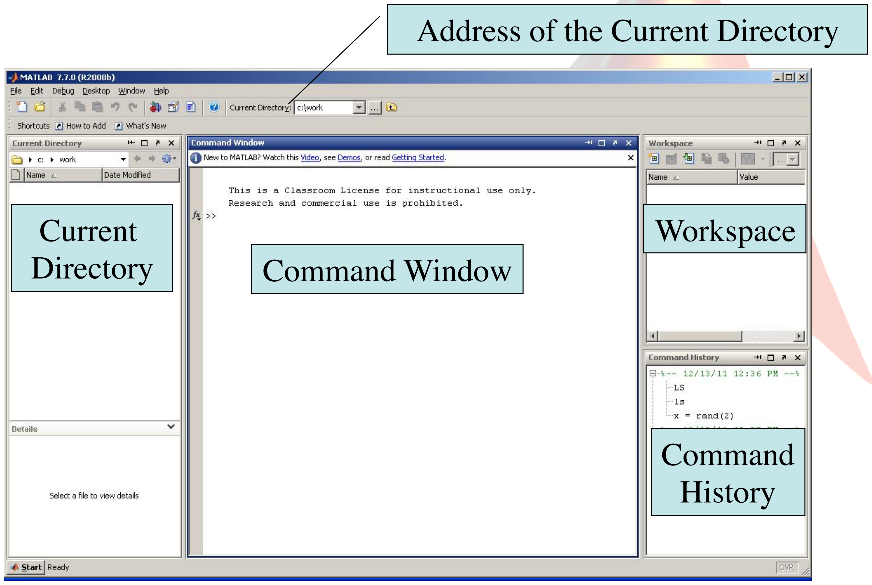






The MATLAB Interface

Navigating the Program



Address of the Current Directory

Current Directory

Command Window

Workspace

Command History

New to MATLAB? Watch this Video, see Demos, or read Getting Started.

```
This is a Classroom License for instructional use only.
Research and commercial use is prohibited.
fx >>
```

```
%-- 12/13/11 12:36 PM --%
LS
ls
x = rand(2)
```

Select a file to view details

Interface Style

- You can drag and drop the different components of the MATLAB interface to make the program look and feel the way you want.
- You can use the ↗ button in the upper right corner of a component to “dock” a window or use the ↘ button to undock a window.
- You can always go back to the default interface arrangement by selecting Desktop→Desktop Layout→Default from the MATLAB menu.

Using MATLAB as a calculator

- Try typing the following examples into the MATLAB command window:

```
» 10 + 20
» sqrt(99)
» r = 2
» C = 2*pi*r^2
```

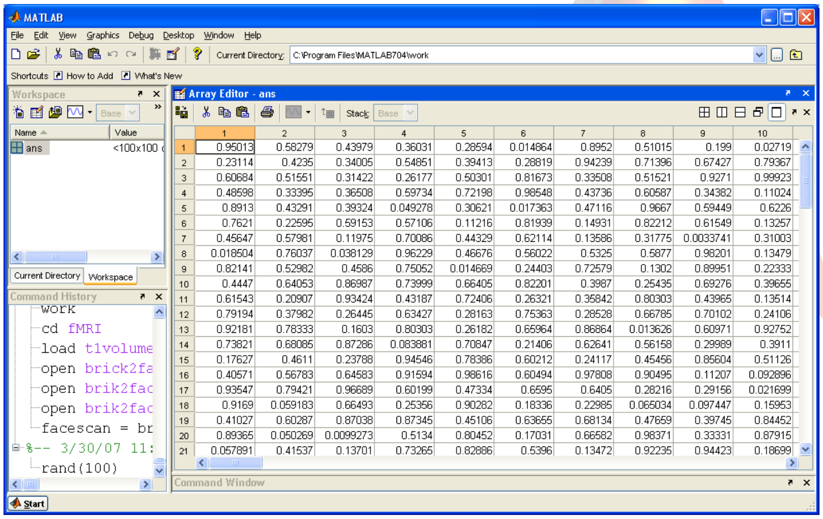
- What variables do you see in the workspace?

MATLAB Variable Editor

- Set up a basic variable:

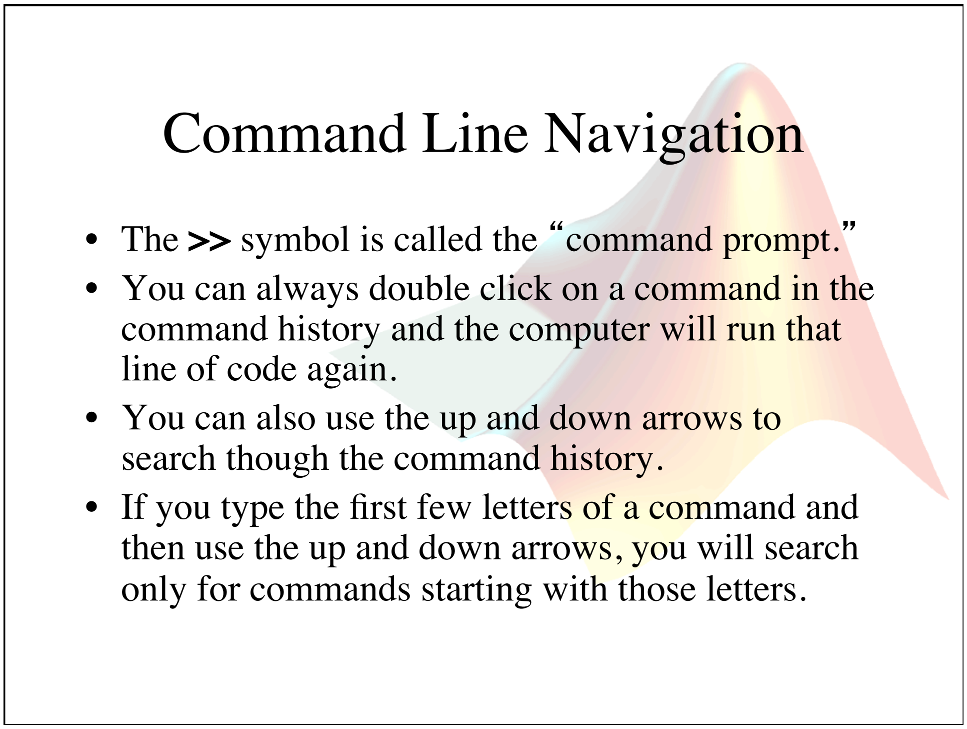
  » `x = 0;`
- Double click on the variable in the workspace.
  - The Variable Editor window will pop up.
- Cut and paste values to and from the Variable editor to Windows excel.

Variable Editor


MATLAB
File Edit View Graphics Debug Desktop Window Help
Current Directory: C:\Program Files\MATLAB704\work
Shortcuts How to Add What's New
Workspace
Base
Name Value
ans <100x100 d
Current Directory Workspace
Command History
Array Editor - ans
Stack: Base
Command Window
Start

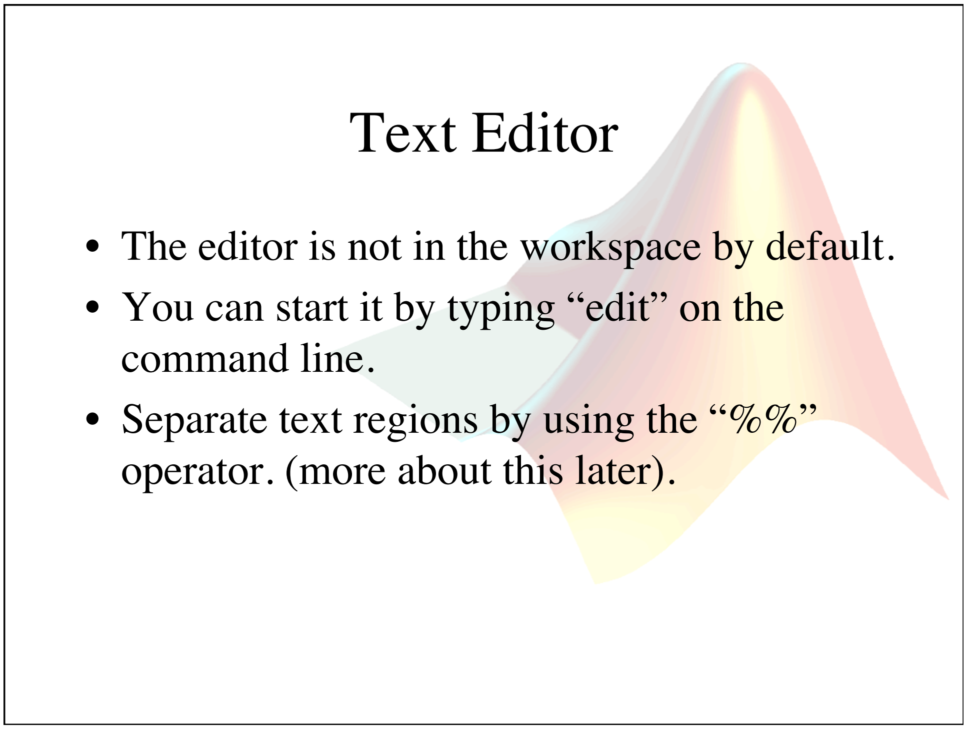
```
  work
  cd fMRI
  load t1volume
  open brick2fa
  open brik2fac
  open brik2fac
  facescan = br
%-- 3/30/07 11:
  rand(100)
```

	1	2	3	4	5	6	7	8	9	10
1	0.95013	0.58279	0.43979	0.36031	0.28594	0.014864	0.8952	0.51015	0.199	0.02719
2	0.23114	0.4235	0.34005	0.54851	0.39413	0.28819	0.94239	0.71396	0.67427	0.79367
3	0.60684	0.51551	0.31422	0.26177	0.50301	0.81673	0.33508	0.51521	0.9271	0.99923
4	0.48598	0.33395	0.36508	0.59734	0.72198	0.98548	0.43736	0.60587	0.34382	0.11024
5	0.8913	0.43291	0.39324	0.049278	0.30621	0.017363	0.47116	0.9667	0.59449	0.6226
6	0.7621	0.22595	0.59153	0.57106	0.11216	0.81939	0.14931	0.82212	0.61549	0.13257
7	0.45647	0.57981	0.11975	0.70086	0.44329	0.62114	0.13586	0.31775	0.0033741	0.31003
8	0.018504	0.76037	0.038129	0.96229	0.46676	0.56022	0.5325	0.5877	0.98201	0.13479
9	0.82141	0.52982	0.4586	0.75052	0.014669	0.24403	0.72579	0.1302	0.89951	0.22333
10	0.4447	0.64053	0.86987	0.73999	0.66405	0.82201	0.3987	0.25435	0.69276	0.39655
11	0.61543	0.20907	0.93424	0.43187	0.72406	0.26321	0.35842	0.80303	0.43965	0.13514
12	0.79194	0.37982	0.26445	0.63427	0.28163	0.75363	0.28528	0.66785	0.70102	0.24106
13	0.92181	0.78333	0.1603	0.80303	0.26182	0.65964	0.86864	0.013626	0.60971	0.92752
14	0.73821	0.68085	0.87286	0.083881	0.70847	0.21406	0.62641	0.56158	0.29989	0.3911
15	0.17627	0.4611	0.23788	0.94546	0.78386	0.60212	0.24117	0.45456	0.85604	0.51126
16	0.40571	0.56783	0.64583	0.91594	0.98616	0.60494	0.97808	0.90495	0.11207	0.092896
17	0.93547	0.79421	0.96689	0.60199	0.47334	0.6595	0.6405	0.28216	0.29156	0.021699
18	0.9169	0.059183	0.66493	0.25356	0.90282	0.18336	0.22985	0.065034	0.097447	0.15953
19	0.41027	0.60287	0.87038	0.87345	0.45106	0.63655	0.68134	0.47659	0.39745	0.84452
20	0.89365	0.050269	0.0099273	0.5134	0.80452	0.17031	0.66582	0.98371	0.33331	0.87915
21	0.057891	0.41537	0.13701	0.73265	0.82886	0.5396	0.13472	0.92235	0.94423	0.18699



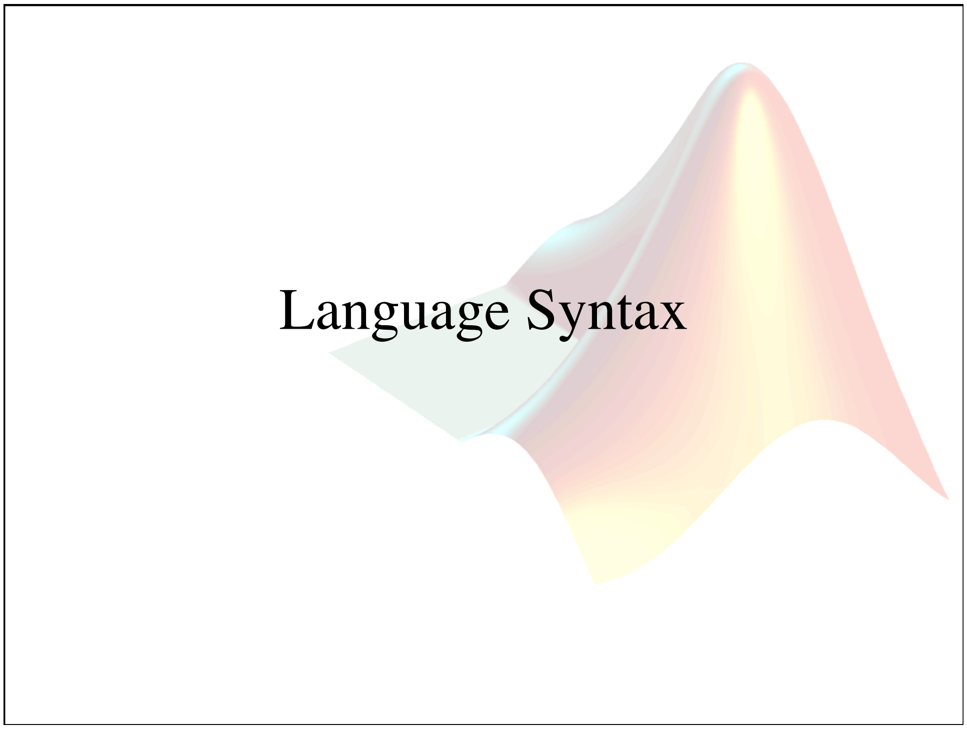
Command Line Navigation

- The **>>** symbol is called the “command prompt.”
- You can always double click on a command in the command history and the computer will run that line of code again.
- You can also use the up and down arrows to search though the command history.
- If you type the first few letters of a command and then use the up and down arrows, you will search only for commands starting with those letters.

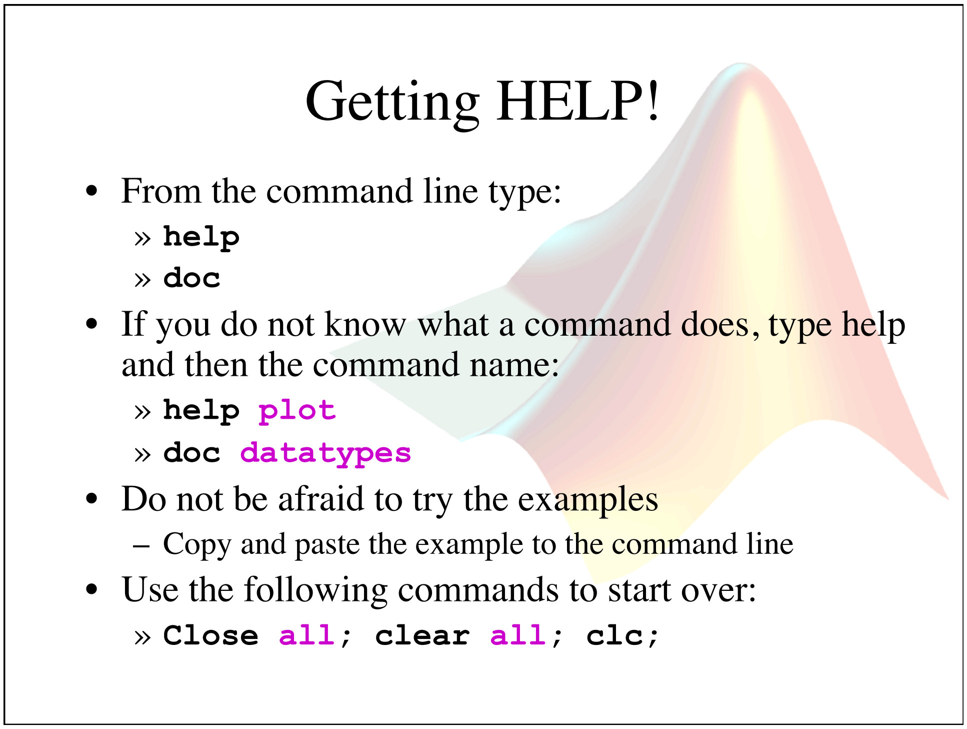


Text Editor

- The editor is not in the workspace by default.
- You can start it by typing “edit” on the command line.
- Separate text regions by using the “%%” operator. (more about this later).



Language Syntax



Getting HELP!

- From the command line type:
  - » **`help`**
  - » **`doc`**
- If you do not know what a command does, type help and then the command name:
  - » **`help plot`**
  - » **`doc datatypes`**
- Do not be afraid to try the examples
  - – Copy and paste the example to the command line
- Use the following commands to start over:
  - » **`Close all; clear all; clc;`**

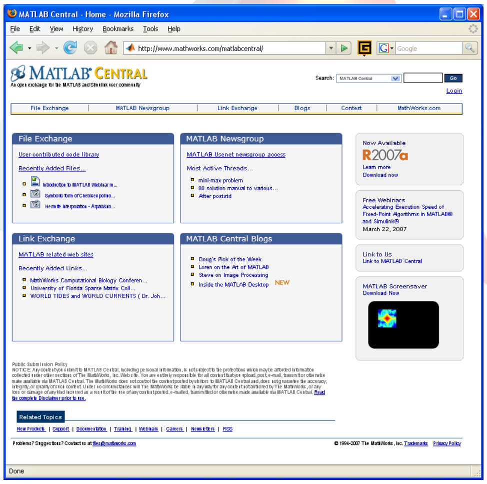
Doing an help Example

- Find a help message with an example:
  - » **`help avifile`**
- Copy the entire help message verbatum to the command window
- See the file this example created:
  - » **`ls`**

MATLAB Central

http://www.mathworks.com/matlabcentral/

- File exchange with free MATLAB software
- Newsgroups and online help



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- Symbolic form of Chebisev polino...
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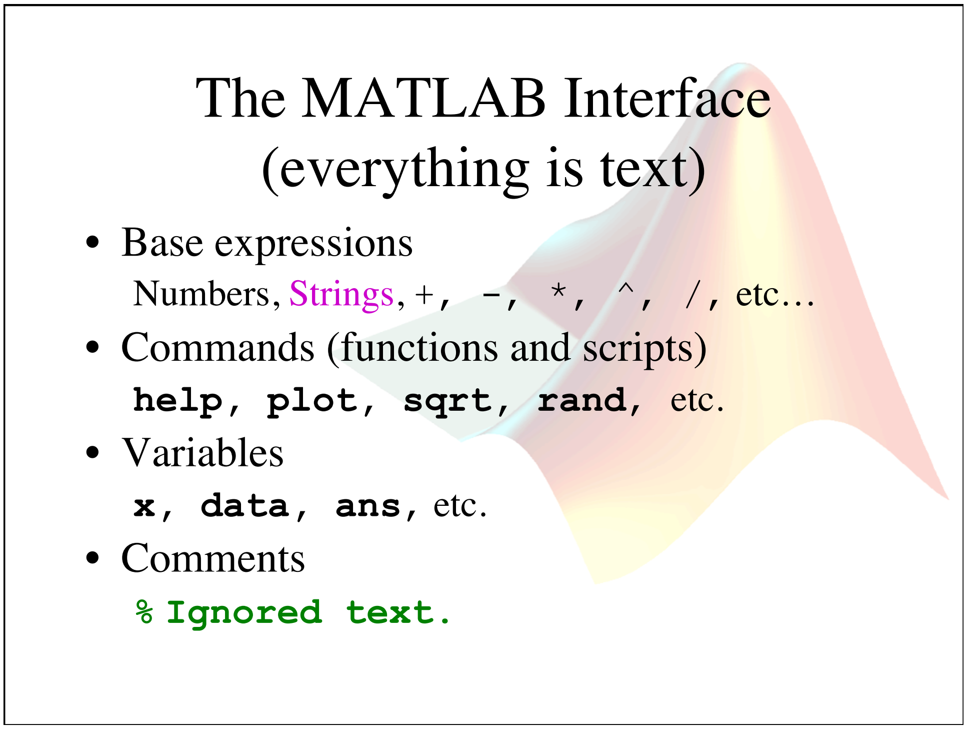


The MATLAB Interface (everything is text)

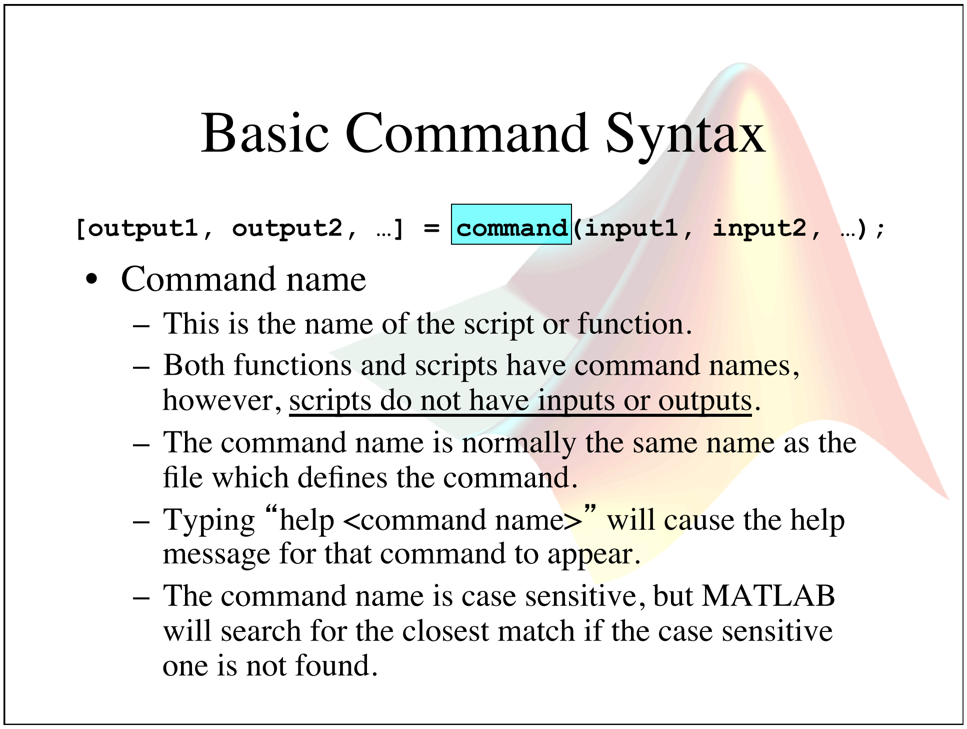
- Base expressions

  Numbers, Strings, `+, -, *, ^, /,` etc…
- Commands (functions and scripts)

  `help, plot, sqrt, rand,` etc.
- Variables

  `x, data, ans,` etc.
- Comments

  `% Ignored text.`



Basic Command Syntax

```
[output1, output2, …] = command(input1, input2, …);
```

- Command name
  - This is the name of the script or function.
  - Both functions and scripts have command names, however, scripts do not have inputs or outputs.
  - The command name is normally the same name as the file which defines the command.
  - Typing "help <command name>" will cause the help message for that command to appear.
  - The command name is case sensitive, but MATLAB will search for the closest match if the case sensitive one is not found.

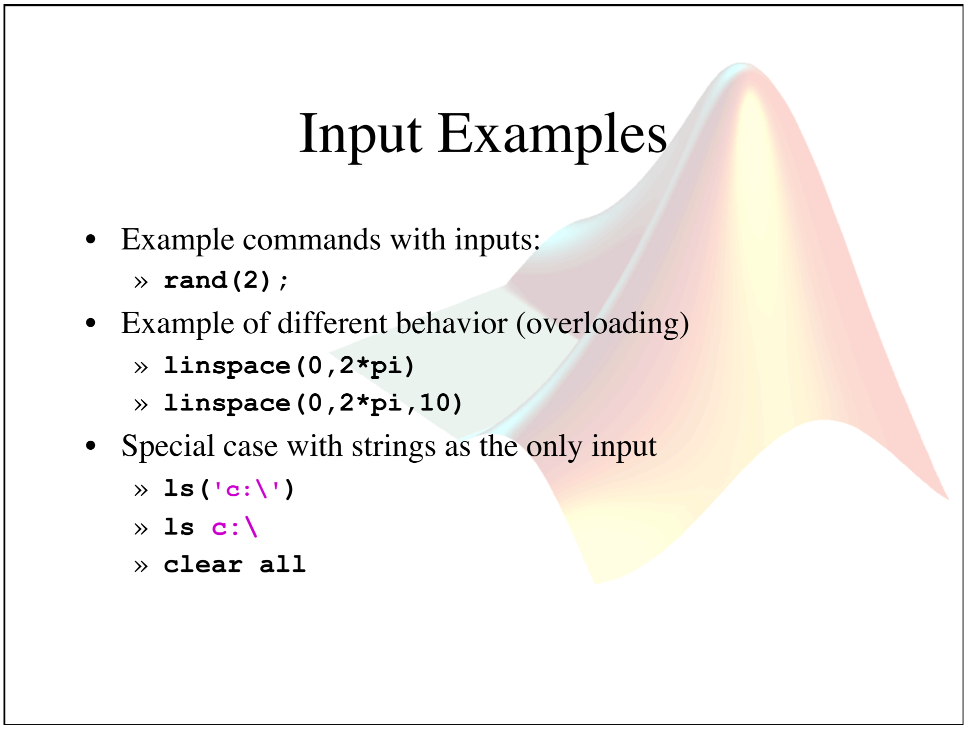
Command Name Examples

- Example Commands:
  - » **`figure`**
  - » **`rand`**
  - » **`ls`**
- Type ‘help’ and then the command names.
- Type ‘open’ and then a command name.
  - Warning: you can edit commands that are open in the editor. Be careful to not make or save any changes to built-in MATLAB commands!
- Try adding capital letters to commands:
  - » **`LS`**
  - » **`RAND`**
  - » **`Figure`**

Basic Command Syntax

```
[output1, output2, …] = command(input1, input2, …);
```

- Inputs:
  - Comma separated list in parentheses.
  - A function is able to take different numbers of inputs and may perform differently for different numbers of inputs.
  - String inputs must be surrounded by single quotes.
  - If the inputs are all strings, the parentheses, commas and single quotes can be replace with white space.
    - Note: in this special case, no outputs will be assigned.
  - Note: scripts do not have inputs.



Input Examples

- Example commands with inputs:

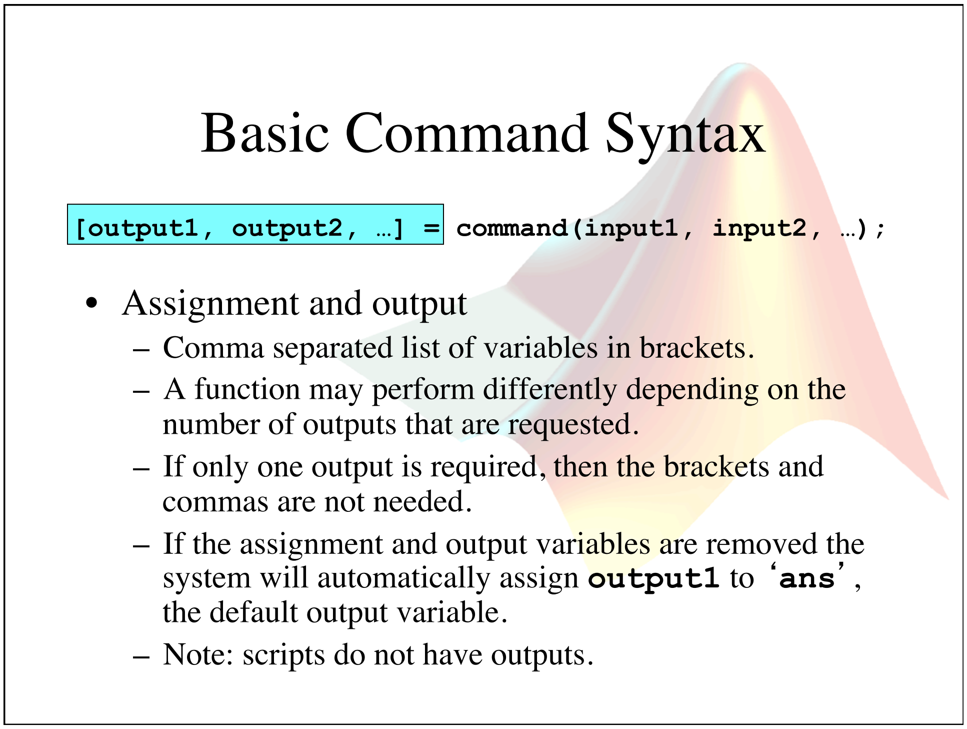
```
» rand(2);
```

- Example of different behavior (overloading)

```
» linspace(0,2*pi)
» linspace(0,2*pi,10)
```

- Special case with strings as the only input

```
» ls('c:\')
» ls c:\
» clear all
```



Basic Command Syntax

```
[output1, output2, …] = command(input1, input2, …);
```

- Assignment and output
  - Comma separated list of variables in brackets.
  - A function may perform differently depending on the number of outputs that are requested.
  - If only one output is required, then the brackets and commas are not needed.
  - If the assignment and output variables are removed the system will automatically assign **`output1`** to '**`ans`**', the default output variable.
  - Note: scripts do not have outputs.

Output Examples

- Example commands with outputs:

```
» x = rand([1,2])
» f = figure
» im = imread('ngc6543a.jpg')
» h = image(im)
» [x, y] = ginput(1)
```

Get 1 x,y input coordinate from the mouse.
(click on the figure)

- Using the default assignment

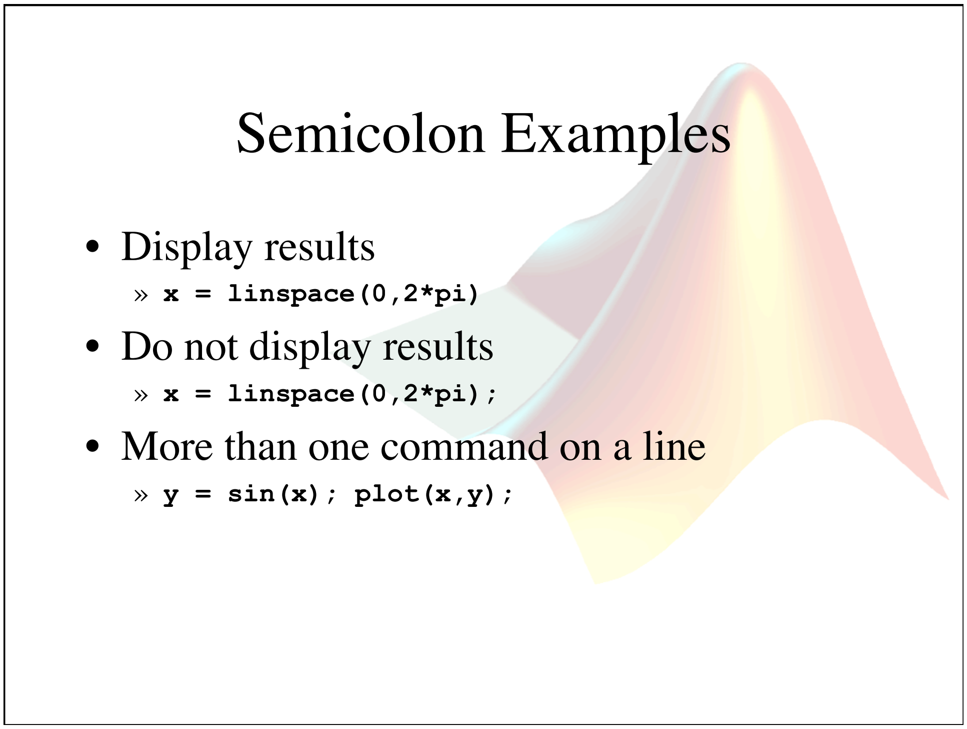
```
» rand(1)
» sqrt(26)
```

Note: if you are working with images consider the image processing toolbox and the newer imshow command.

Basic Command Syntax

```
[output1, output2, …] = command(input1, input2, …);
```

- Display Output semicolon (Optional)
  - If the semicolon is not included, then MATLAB will automatically display the contents of the output variables to the terminal display.
  - If the semicolon is included, then the command will run “quietly” and not output to the terminal display.
- Semicolon also ends a command
  - Two commands can be placed on the same line of input



Semicolon Examples

- Display results

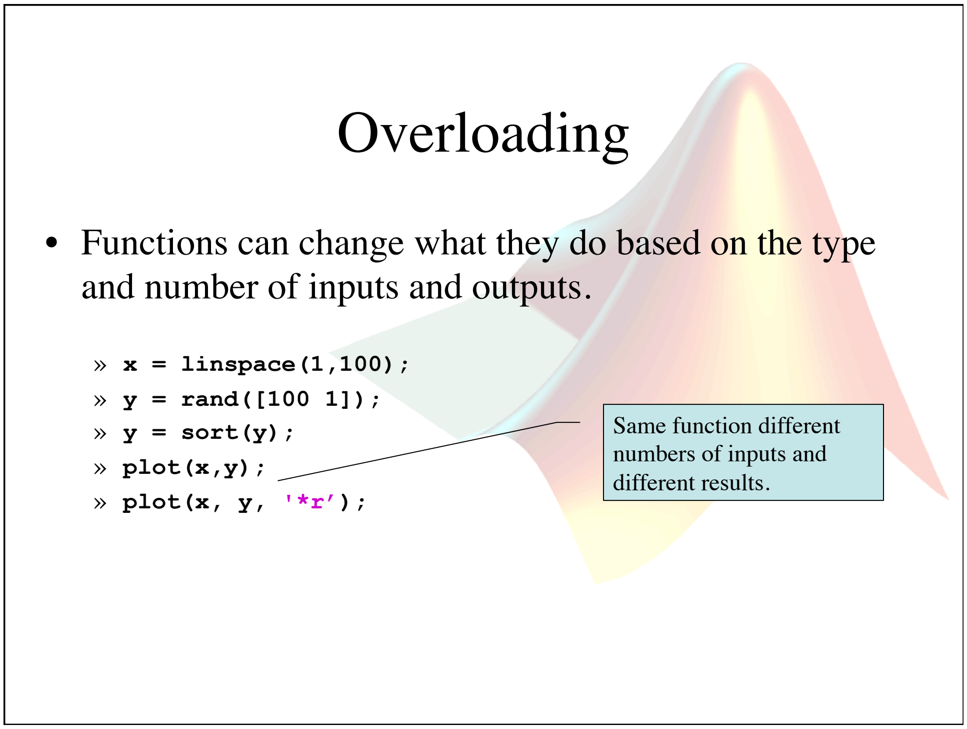
```
» x = linspace(0,2*pi)
```

- Do not display results

```
» x = linspace(0,2*pi);
```

- More than one command on a line

```
» y = sin(x); plot(x,y);
```



Overloading

- Functions can change what they do based on the type and number of inputs and outputs.

```
» x = linspace(1,100);
» y = rand([100 1]);
» y = sort(y);
» plot(x,y);
» plot(x, y, '*r');
```

Same function different numbers of inputs and different results.

Naming Commands and Variables

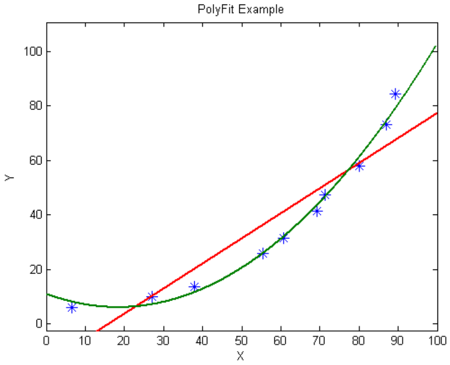
- There are special characters that cannot be used in names, including:

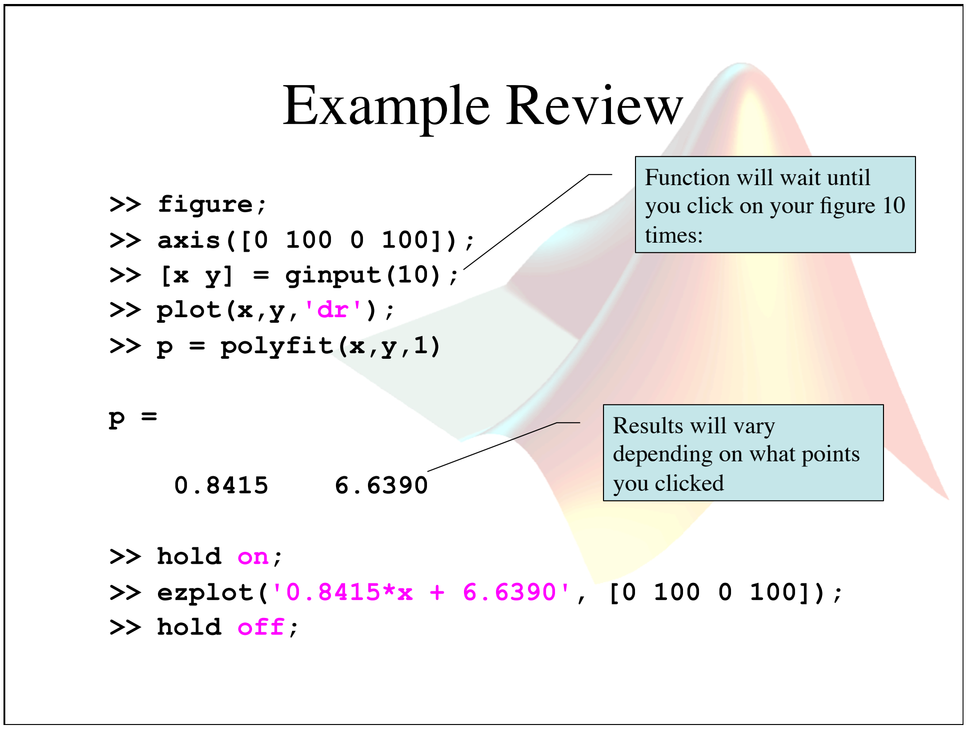
  <space> : \ * & + - () [] {} # % @ etc…
- Names should be short and make sense
- Try not to reuse existing command and variable names
- Some good names include:
  - **`beedata`**
  - **`timedata`**
  - **`videoplotfun`**
  - etc.

  Some bad names include:
  - **`sqrt`**
  - **`var`**
  - **`a, b, c, d, e,`**
  - etc.

Project 1: Fitting Polynomial Functions

- Use the following set of functions to input data, display them in a figure and fit a polynomial to the data. (Hint: use the help command.)
  - » **`figure`**
  - » **`axis`**
  - » **`ginput`**
  - » **`plot`**
  - » **`polyfit`**
  - » **`hold`**
  - » **`ezplot`**



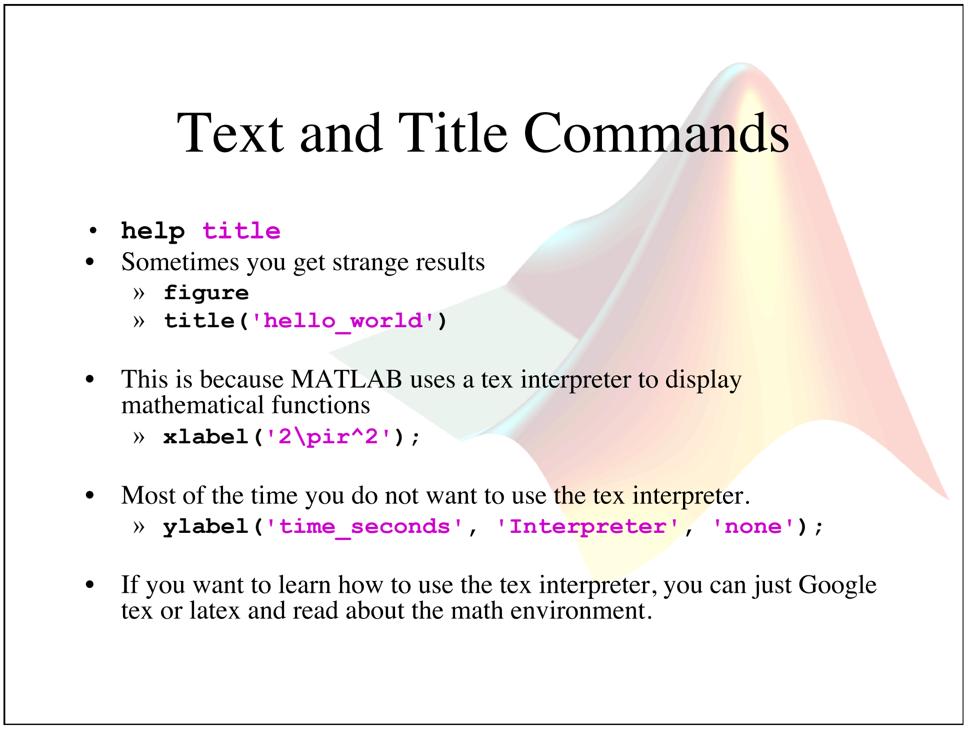


Example Review

```
>> figure;
>> axis([0 100 0 100]);
>> [x y] = ginput(10);
>> plot(x,y,'dr');
>> p = polyfit(x,y,1)

p =

    0.8415    6.6390

>> hold on;
>> ezplot('0.8415*x + 6.6390', [0 100 0 100]);
>> hold off;
```

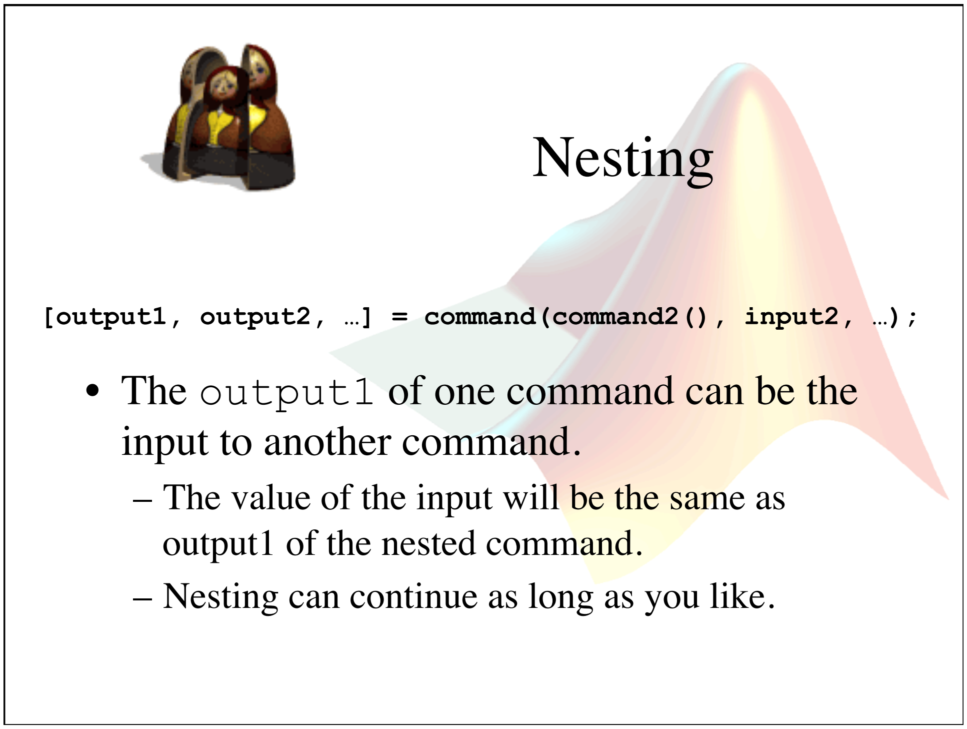
Function will wait until you click on your figure 10 times:

Results will vary depending on what points you clicked



Text and Title Commands

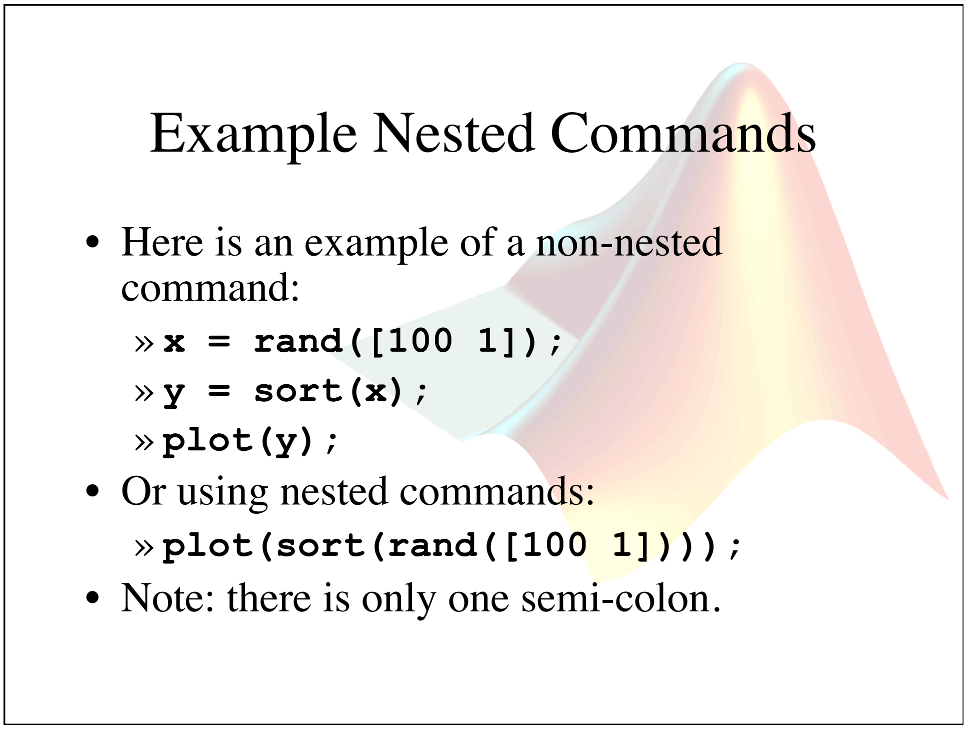
- **help title**
- Sometimes you get strange results
  - » **figure**
  - » **title('hello_world')**
- This is because MATLAB uses a tex interpreter to display mathematical functions
  - » **xlabel('2\pir^2');**
- Most of the time you do not want to use the tex interpreter.
  - » **ylabel('time_seconds', 'Interpreter', 'none');**
- If you want to learn how to use the tex interpreter, you can just Google tex or latex and read about the math environment.



Nesting

```
[output1, output2, …] = command(command2(), input2, …);
```

- The `output1` of one command can be the input to another command.
  - The value of the input will be the same as output1 of the nested command.
  - Nesting can continue as long as you like.



Example Nested Commands

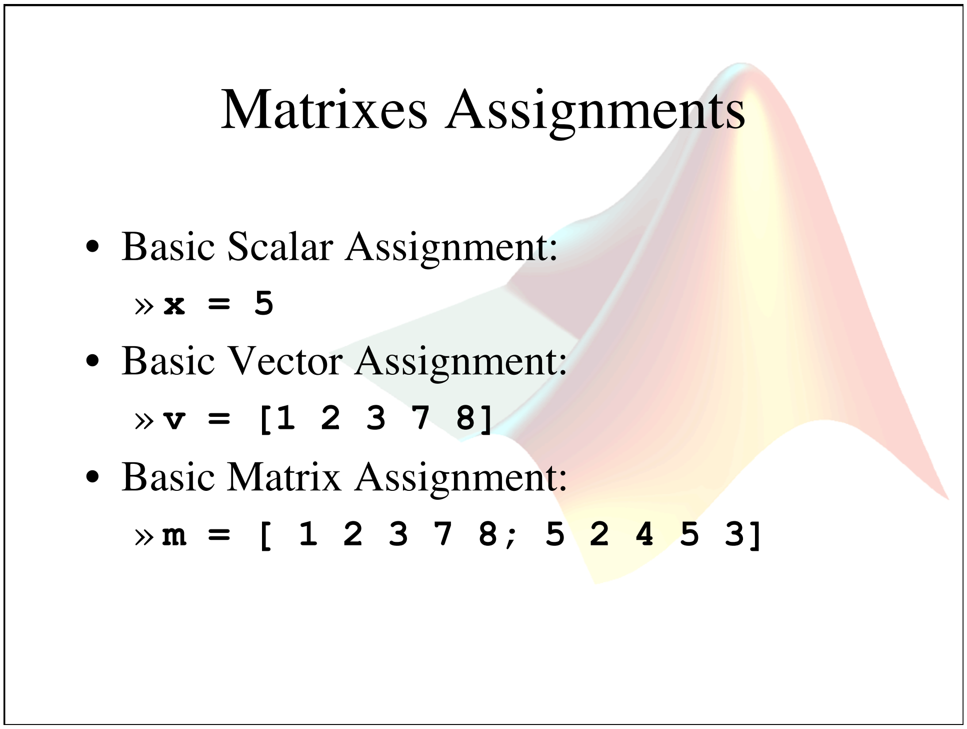
- Here is an example of a non-nested command:

```
»x = rand([100 1]);
»y = sort(x);
»plot(y);
```

- Or using nested commands:

```
»plot(sort(rand([100 1])));
```

- Note: there is only one semi-colon.



Matrixes Assignments

- Basic Scalar Assignment:

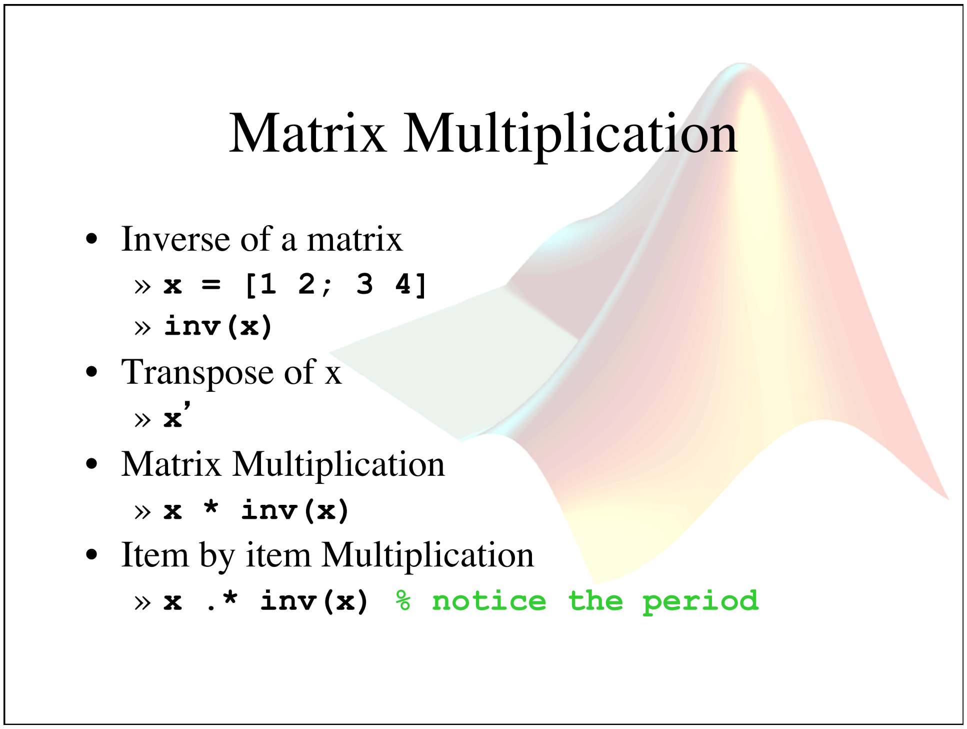
```
» x = 5
```

- Basic Vector Assignment:

```
» v = [1 2 3 7 8]
```

- Basic Matrix Assignment:

```
» m = [ 1 2 3 7 8; 5 2 4 5 3]
```



Matrix Multiplication

- Inverse of a matrix

```
» x = [1 2; 3 4]
» inv(x)
```

- Transpose of x

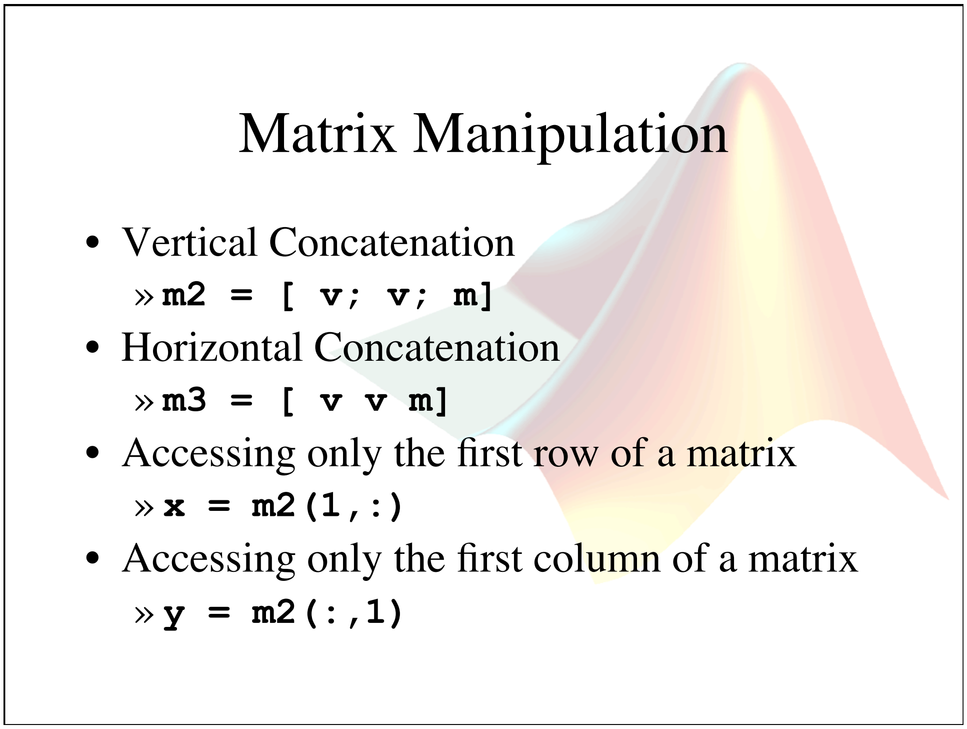
```
» x'
```

- Matrix Multiplication

```
» x * inv(x)
```

- Item by item Multiplication

```
» x .* inv(x) % notice the period
```



Matrix Manipulation

- Vertical Concatenation

```
» m2 = [ v; v; m]
```

- Horizontal Concatenation

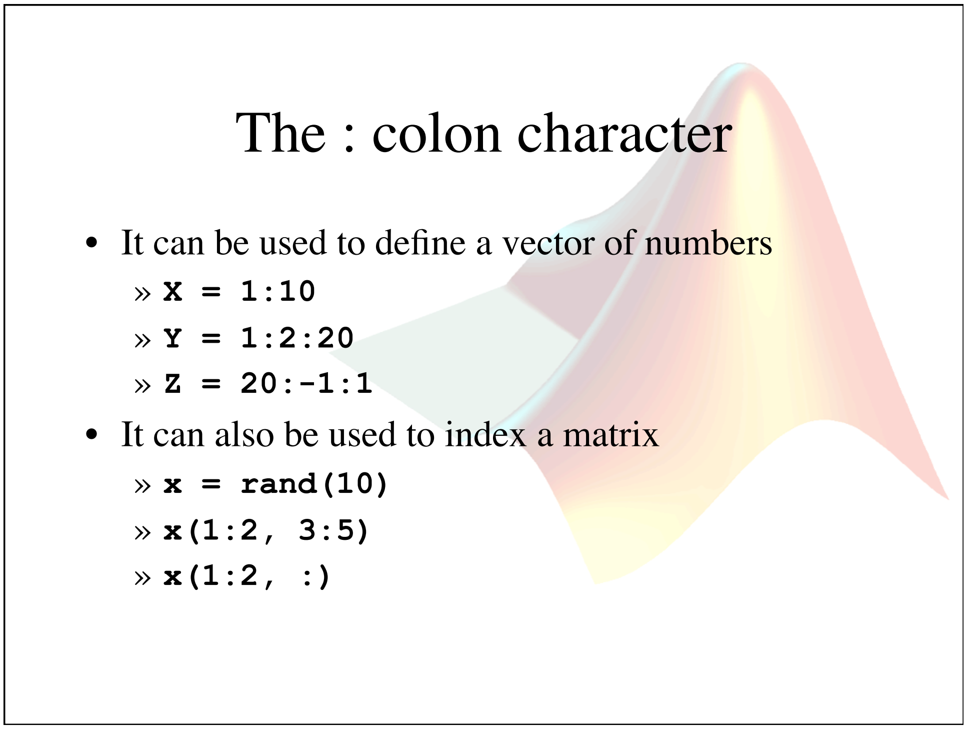
```
» m3 = [ v v m]
```

- Accessing only the first row of a matrix

```
» x = m2(1,:)
```

- Accessing only the first column of a matrix

```
» y = m2(:,1)
```



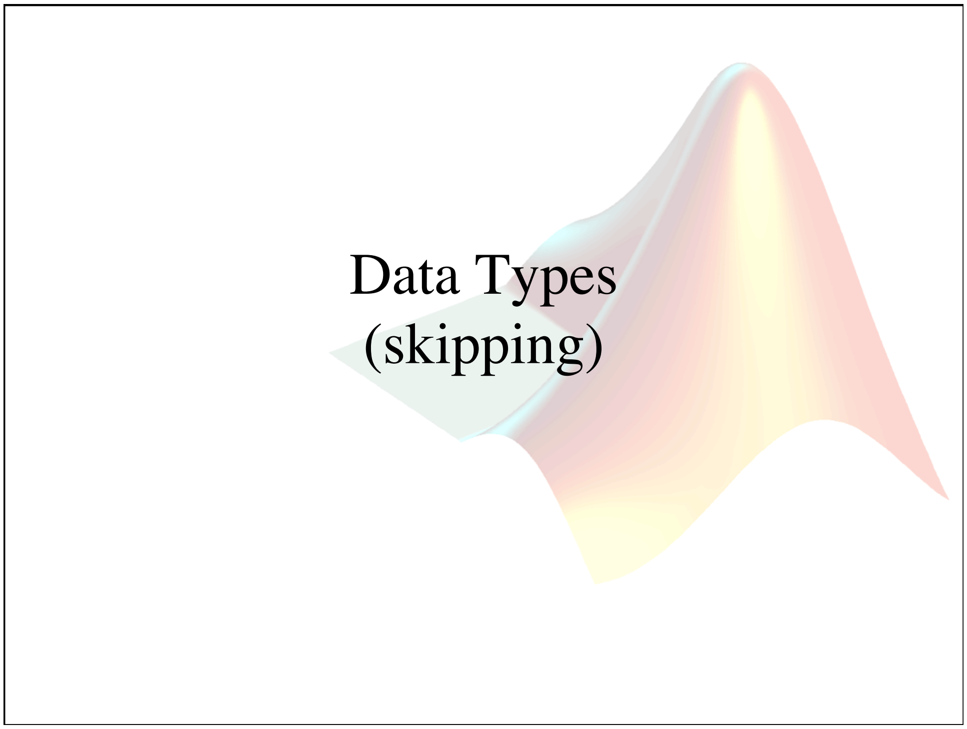
The : colon character

- It can be used to define a vector of numbers

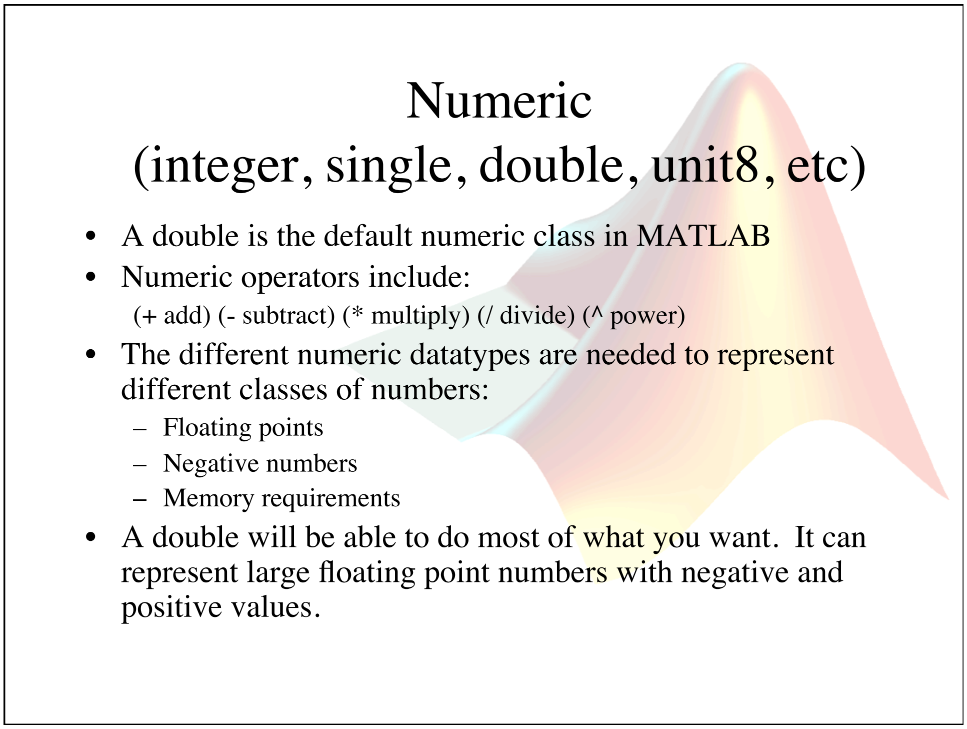
```
» X = 1:10
» Y = 1:2:20
» Z = 20:-1:1
```

- It can also be used to index a matrix

```
» x = rand(10)
» x(1:2, 3:5)
» x(1:2, :)
```

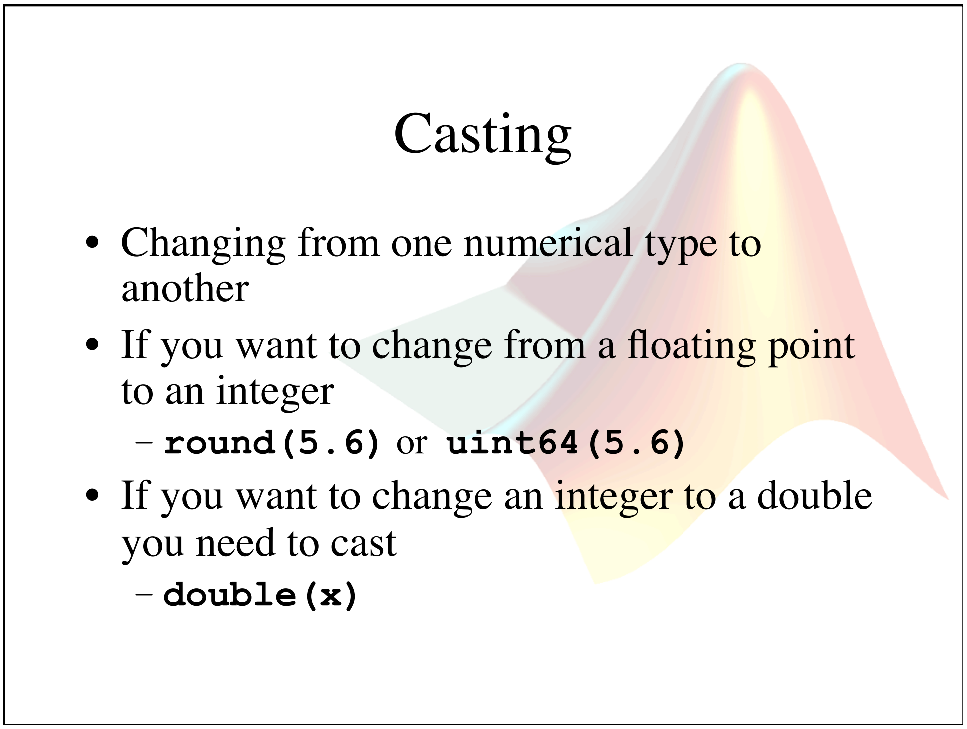


Data Types (skipping)



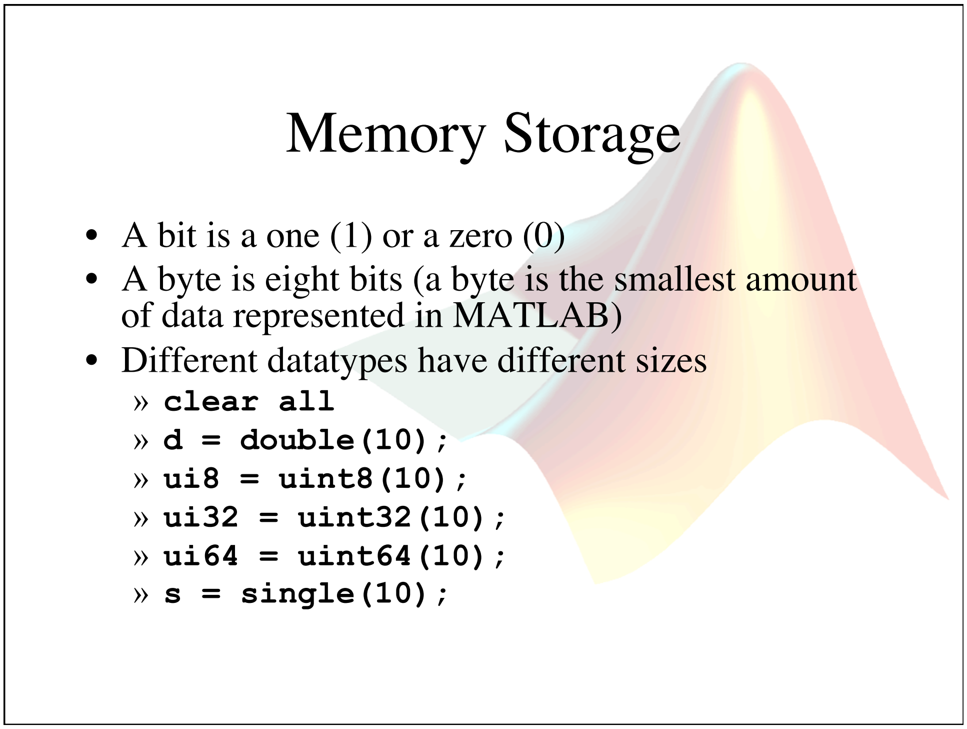
Numeric (integer, single, double, unit8, etc)

- A double is the default numeric class in MATLAB
- Numeric operators include:
  (+ add) (- subtract) (* multiply) (/ divide) (^ power)
- The different numeric datatypes are needed to represent different classes of numbers:
  - Floating points
  - Negative numbers
  - Memory requirements
- A double will be able to do most of what you want. It can represent large floating point numbers with negative and positive values.



Casting

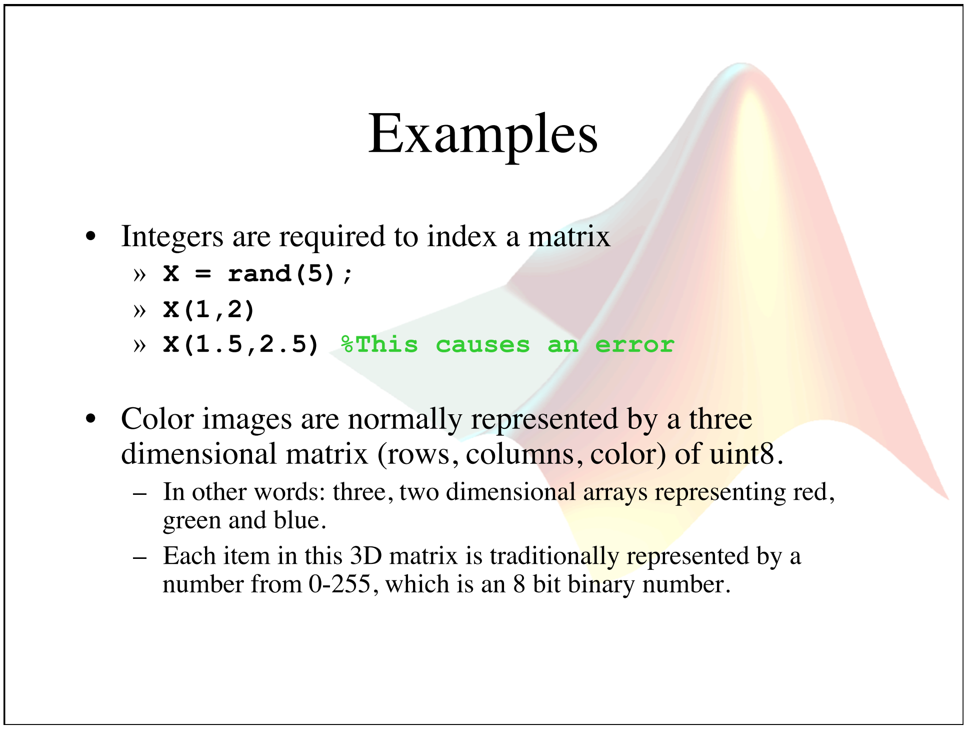
- Changing from one numerical type to another
- If you want to change from a floating point to an integer
  - **`round(5.6)`** or **`uint64(5.6)`**
- If you want to change an integer to a double you need to cast
  - **`double(x)`**



Memory Storage

- A bit is a one (1) or a zero (0)
- A byte is eight bits (a byte is the smallest amount of data represented in MATLAB)
- Different datatypes have different sizes

```
» clear all
» d = double(10);
» ui8 = uint8(10);
» ui32 = uint32(10);
» ui64 = uint64(10);
» s = single(10);
```

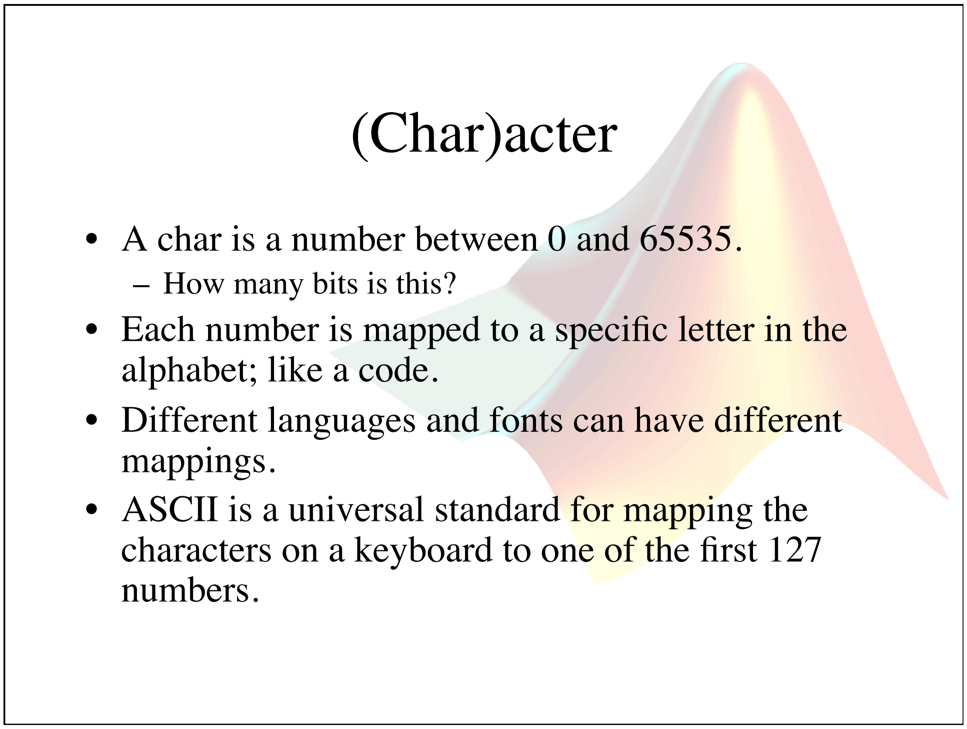


Examples

- Integers are required to index a matrix

```
» X = rand(5);
» X(1,2)
» X(1.5,2.5) %This causes an error
```

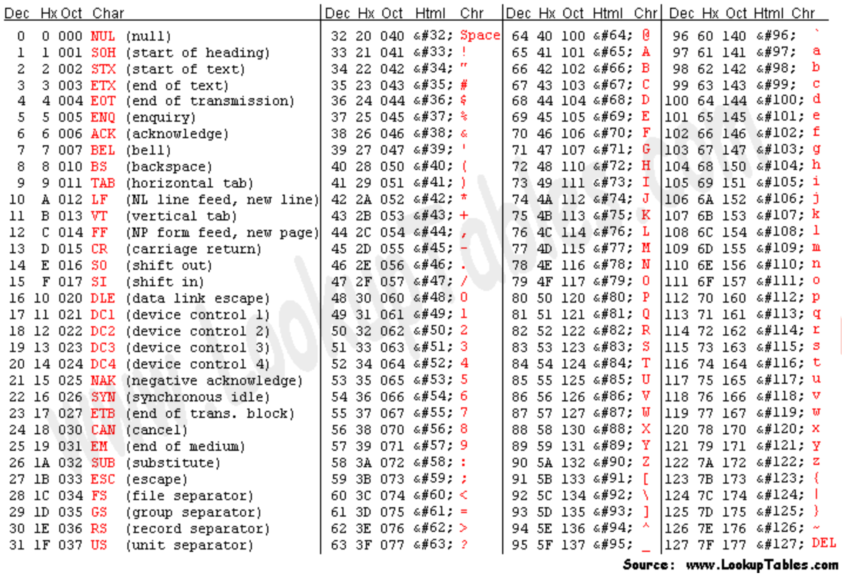
- Color images are normally represented by a three dimensional matrix (rows, columns, color) of uint8.
  - In other words: three, two dimensional arrays representing red, green and blue.
  - Each item in this 3D matrix is traditionally represented by a number from 0-255, which is an 8 bit binary number.



(Char)acter

- A char is a number between 0 and 65535.
  - How many bits is this?
- Each number is mapped to a specific letter in the alphabet; like a code.
- Different languages and fonts can have different mappings.
- ASCII is a universal standard for mapping the characters on a keyboard to one of the first 127 numbers.

ASCII – American Standard Code for Information Interchange



Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040	&#32;	Space	64	40	100	&#64;	@	96	60	140	&#96;	`
1	1	001	SOH (start of heading)	33	21	041	&#33;	!	65	41	101	&#65;	A	97	61	141	&#97;	a
2	2	002	STX (start of text)	34	22	042	&#34;	"	66	42	102	&#66;	B	98	62	142	&#98;	b
3	3	003	ETX (end of text)	35	23	043	&#35;	#	67	43	103	&#67;	C	99	63	143	&#99;	c
4	4	004	EOT (end of transmission)	36	24	044	&#36;	$	68	44	104	&#68;	D	100	64	144	&#100;	d
5	5	005	ENQ (enquiry)	37	25	045	&#37;	%	69	45	105	&#69;	E	101	65	145	&#101;	e
6	6	006	ACK (acknowledge)	38	26	046	&#38;	&	70	46	106	&#70;	F	102	66	146	&#102;	f
7	7	007	BEL (bell)	39	27	047	&#39;	'	71	47	107	&#71;	G	103	67	147	&#103;	g
8	8	010	BS (backspace)	40	28	050	&#40;	(	72	48	110	&#72;	H	104	68	150	&#104;	h
9	9	011	TAB (horizontal tab)	41	29	051	&#41;	)	73	49	111	&#73;	I	105	69	151	&#105;	i
10	A	012	LF (NL line feed, new line)	42	2A	052	&#42;	*	74	4A	112	&#74;	J	106	6A	152	&#106;	j
11	B	013	VT (vertical tab)	43	2B	053	&#43;	+	75	4B	113	&#75;	K	107	6B	153	&#107;	k
12	C	014	FF (NP form feed, new page)	44	2C	054	&#44;	,	76	4C	114	&#76;	L	108	6C	154	&#108;	l
13	D	015	CR (carriage return)	45	2D	055	&#45;	-	77	4D	115	&#77;	M	109	6D	155	&#109;	m
14	E	016	SO (shift out)	46	2E	056	&#46;	.	78	4E	116	&#78;	N	110	6E	156	&#110;	n
15	F	017	SI (shift in)	47	2F	057	&#47;	/	79	4F	117	&#79;	O	111	6F	157	&#111;	o
16	10	020	DLE (data link escape)	48	30	060	&#48;	0	80	50	120	&#80;	P	112	70	160	&#112;	p
17	11	021	DC1 (device control 1)	49	31	061	&#49;	1	81	51	121	&#81;	Q	113	71	161	&#113;	q
18	12	022	DC2 (device control 2)	50	32	062	&#50;	2	82	52	122	&#82;	R	114	72	162	&#114;	r
19	13	023	DC3 (device control 3)	51	33	063	&#51;	3	83	53	123	&#83;	S	115	73	163	&#115;	s
20	14	024	DC4 (device control 4)	52	34	064	&#52;	4	84	54	124	&#84;	T	116	74	164	&#116;	t
21	15	025	NAK (negative acknowledge)	53	35	065	&#53;	5	85	55	125	&#85;	U	117	75	165	&#117;	u
22	16	026	SYN (synchronous idle)	54	36	066	&#54;	6	86	56	126	&#86;	V	118	76	166	&#118;	v
23	17	027	ETB (end of trans. block)	55	37	067	&#55;	7	87	57	127	&#87;	W	119	77	167	&#119;	w
24	18	030	CAN (cancel)	56	38	070	&#56;	8	88	58	130	&#88;	X	120	78	170	&#120;	x
25	19	031	EM (end of medium)	57	39	071	&#57;	9	89	59	131	&#89;	Y	121	79	171	&#121;	y
26	1A	032	SUB (substitute)	58	3A	072	&#58;	:	90	5A	132	&#90;	Z	122	7A	172	&#122;	z
27	1B	033	ESC (escape)	59	3B	073	&#59;	;	91	5B	133	&#91;	[	123	7B	173	&#123;	{
28	1C	034	FS (file separator)	60	3C	074	&#60;	<	92	5C	134	&#92;	\	124	7C	174	&#124;	|
29	1D	035	GS (group separator)	61	3D	075	&#61;	=	93	5D	135	&#93;	]	125	7D	175	&#125;	}
30	1E	036	RS (record separator)	62	3E	076	&#62;	>	94	5E	136	&#94;	^	126	7E	176	&#126;	~
31	1F	037	US (unit separator)	63	3F	077	&#63;	?	95	5F	137	&#95;	_	127	7F	177	&#127;	DEL

Source: www.LookupTables.com

Understanding Characters

- A string is just a vector of characters:

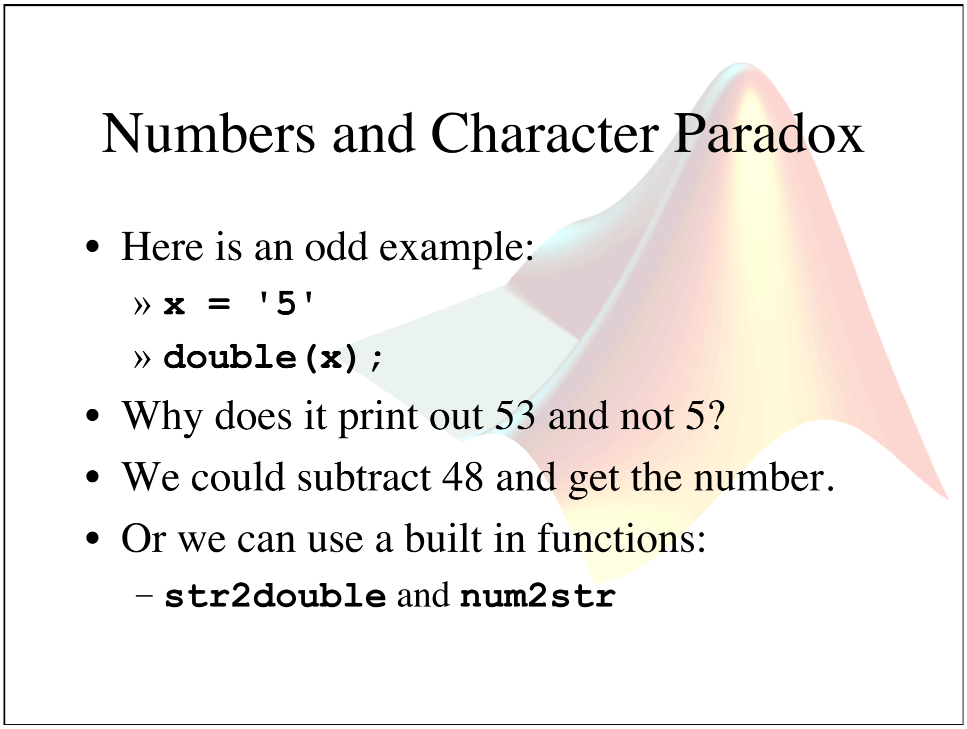
```
» x = 'hello'
» y = 'world'
» x + y
» [x y]
» [x ' ' y]
```

- An integer from 0-255 can be turned into a character:

```
» x = [72 73];
» x = char(x)
```

- Or you can change a character back into its number:

```
» x = 'Hello World';
» double(x);
```

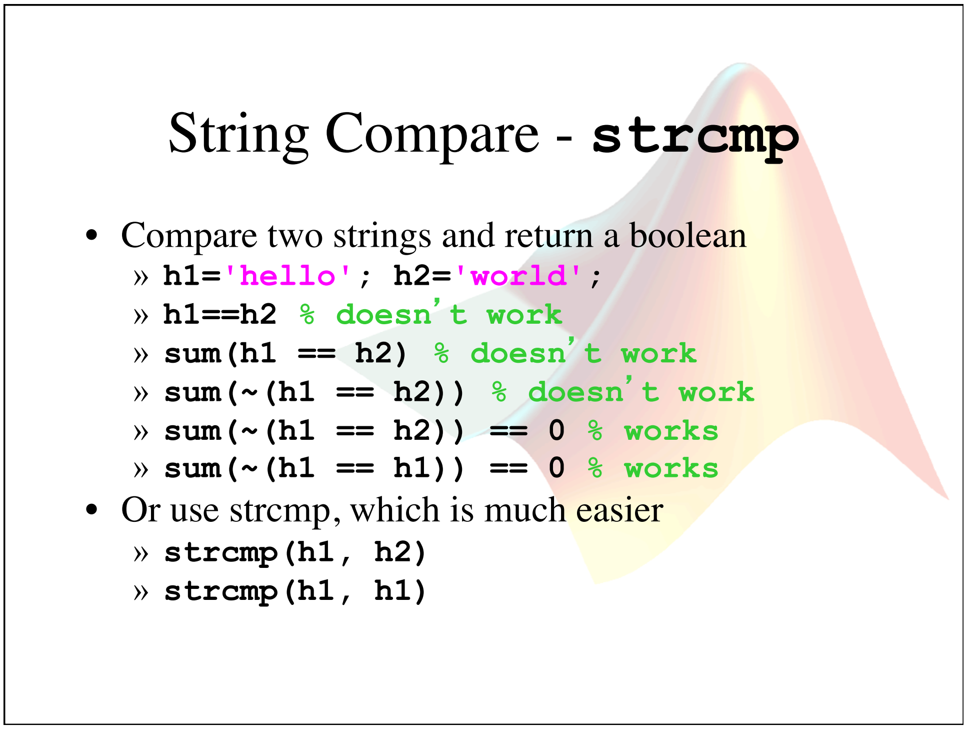


Numbers and Character Paradox

- Here is an odd example:

```
» x = '5'
» double(x);
```

- Why does it print out 53 and not 5?
- We could subtract 48 and get the number.
- Or we can use a built in functions:
  - **str2double** and **num2str**



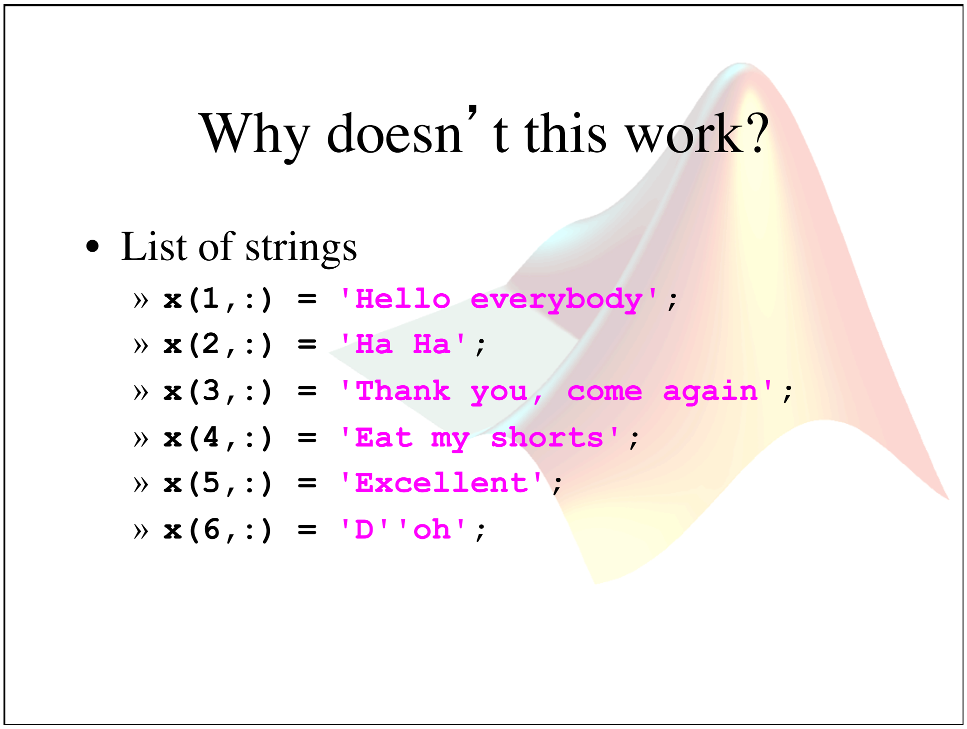
String Compare - strcmp

- Compare two strings and return a boolean

```
» h1='hello'; h2='world';
» h1==h2 % doesn't work
» sum(h1 == h2) % doesn't work
» sum(~(h1 == h2)) % doesn't work
» sum(~(h1 == h2)) == 0 % works
» sum(~(h1 == h1)) == 0 % works
```

- Or use strcmp, which is much easier

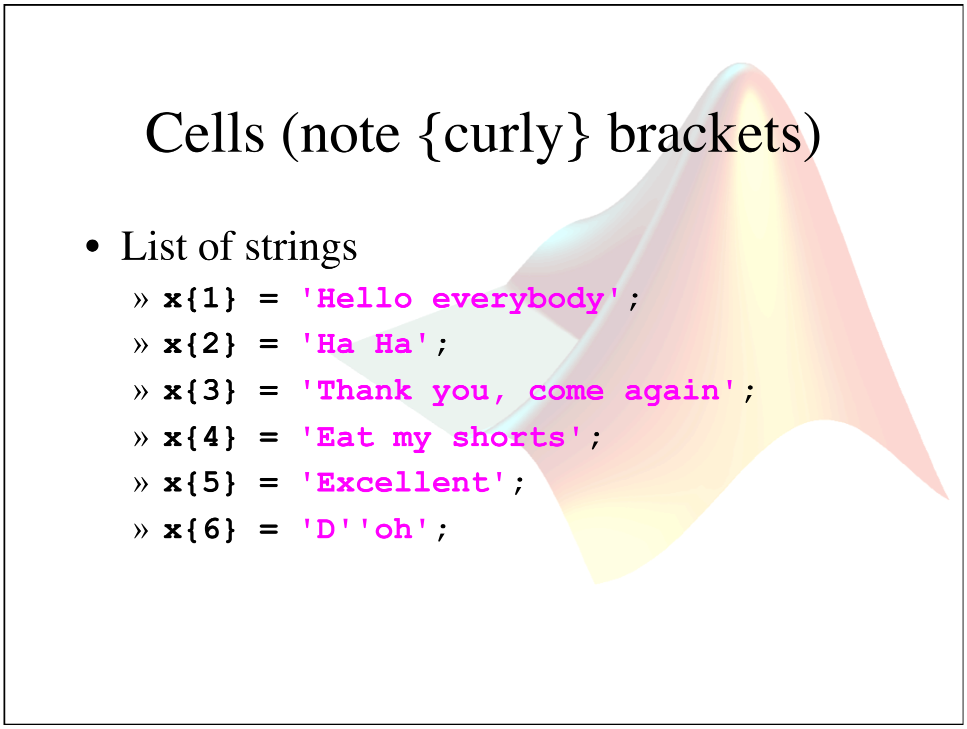
```
» strcmp(h1, h2)
» strcmp(h1, h1)
```



Why doesn’t this work?

- List of strings

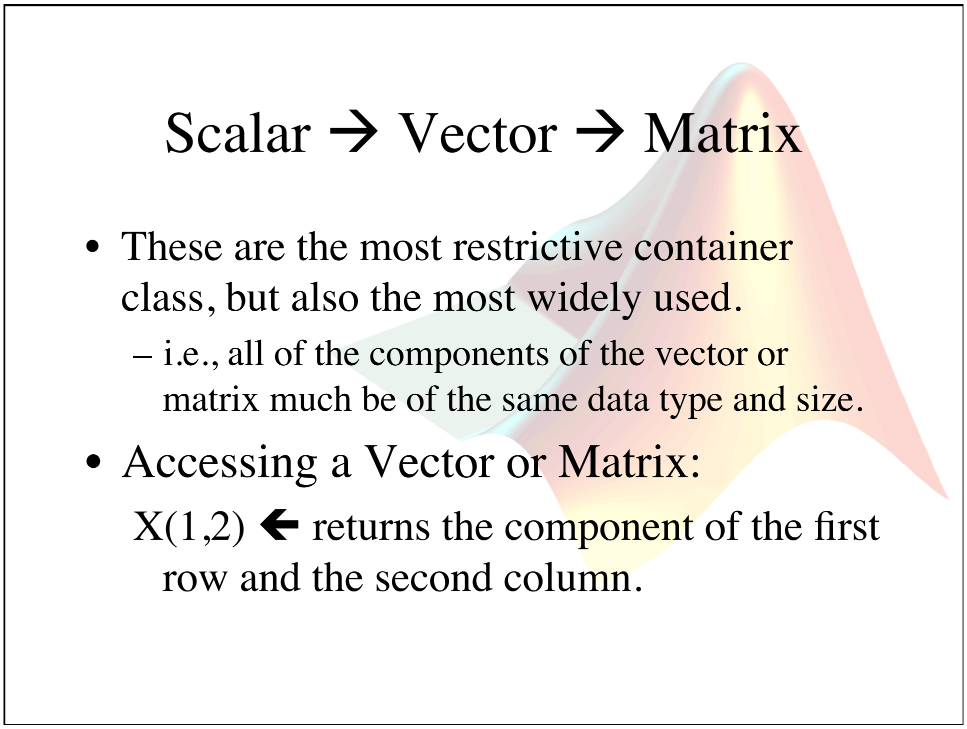
```
» x(1,:) = 'Hello everybody';
» x(2,:) = 'Ha Ha';
» x(3,:) = 'Thank you, come again';
» x(4,:) = 'Eat my shorts';
» x(5,:) = 'Excellent';
» x(6,:) = 'D''oh';
```



Cells (note {curly} brackets)

- List of strings

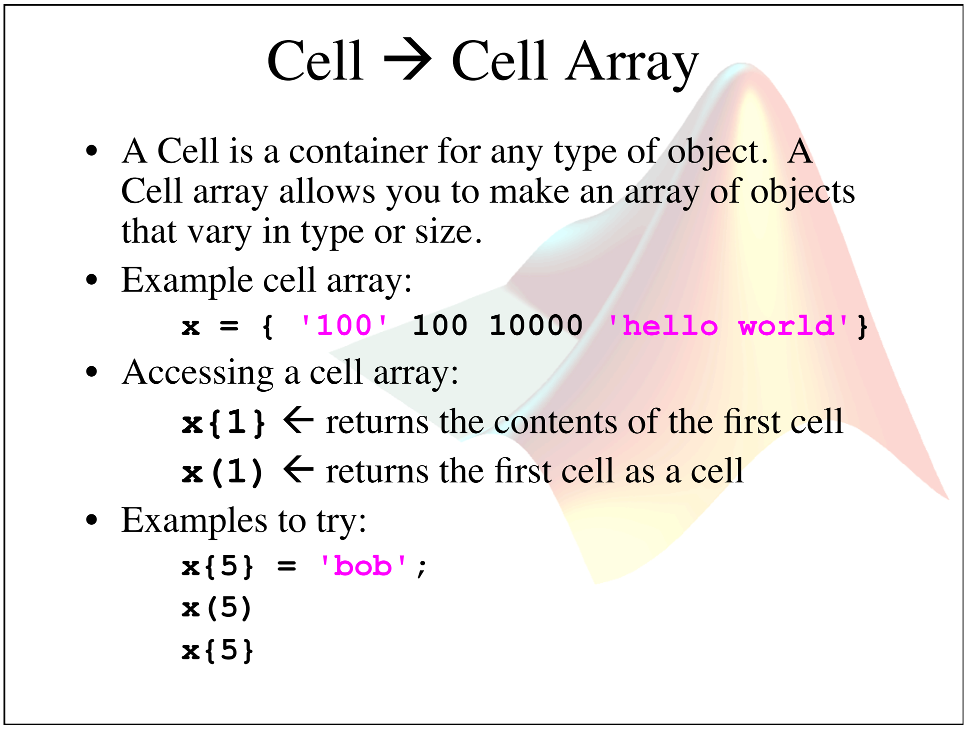
```
» x{1} = 'Hello everybody';
» x{2} = 'Ha Ha';
» x{3} = 'Thank you, come again';
» x{4} = 'Eat my shorts';
» x{5} = 'Excellent';
» x{6} = 'D''oh';
```



Scalar → Vector → Matrix

- These are the most restrictive container class, but also the most widely used.
  - i.e., all of the components of the vector or matrix much be of the same data type and size.
- Accessing a Vector or Matrix:

  X(1,2) ← returns the component of the first row and the second column.



Cell → Cell Array

- A Cell is a container for any type of object. A Cell array allows you to make an array of objects that vary in type or size.
- Example cell array:

```
x = { '100' 100 10000 'hello world'}
```

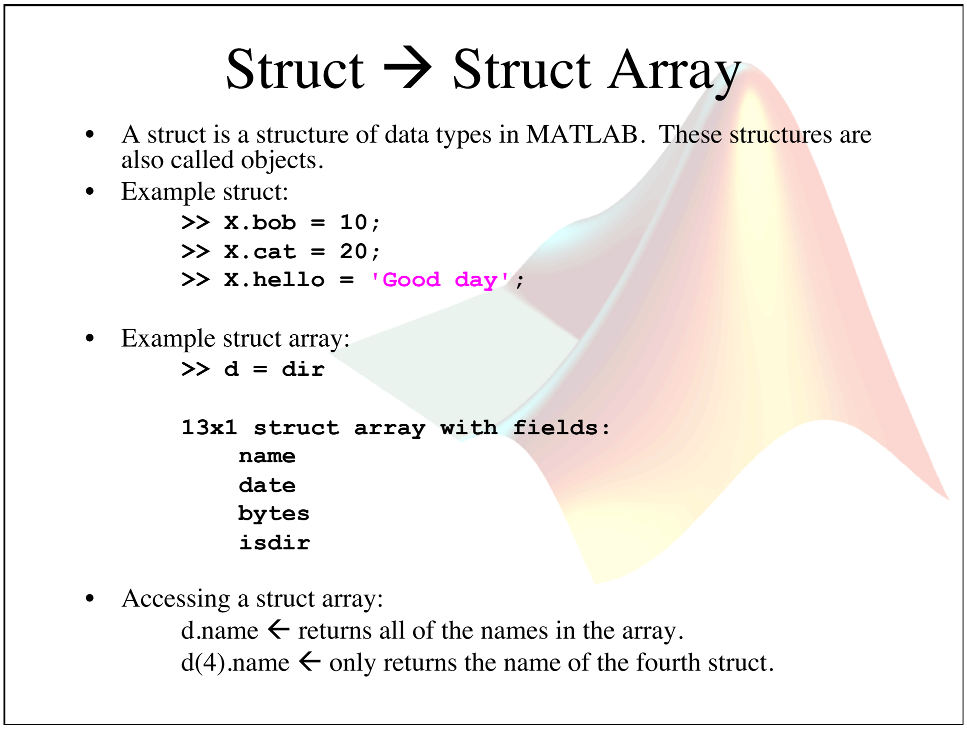
- Accessing a cell array:

  x{1} ← returns the contents of the first cell

  x(1) ← returns the first cell as a cell

- Examples to try:

```
x{5} = 'bob';
x(5)
x{5}
```



Struct → Struct Array

- A struct is a structure of data types in MATLAB. These structures are also called objects.
- Example struct:

```
>> X.bob = 10;
>> X.cat = 20;
>> X.hello = 'Good day';
```

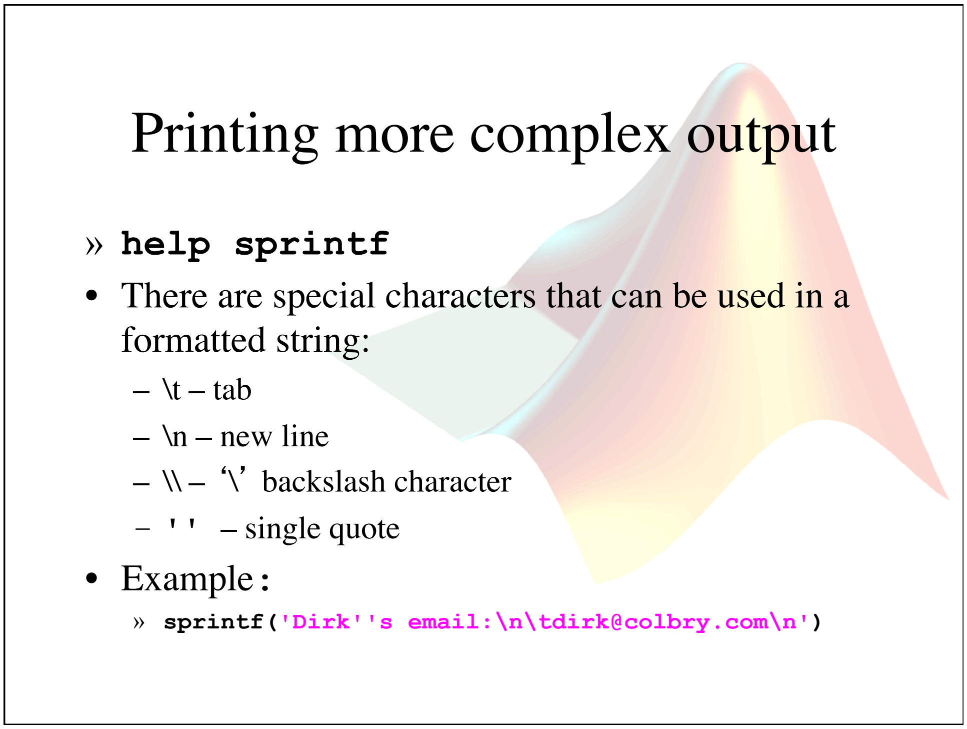
- Example struct array:

```
>> d = dir

13x1 struct array with fields:
    name
    date
    bytes
    isdir
```

- Accessing a struct array:

  d.name ← returns all of the names in the array.

  d(4).name ← only returns the name of the fourth struct.



Printing more complex output

» **`help sprintf`**

- There are special characters that can be used in a formatted string:
  - \t – tab
  - \n – new line
  - \\ – '\' backslash character
  - `''` – single quote
- Example:

```
» sprintf('Dirk''s email:\n\tdirk@colbry.com\n')
```

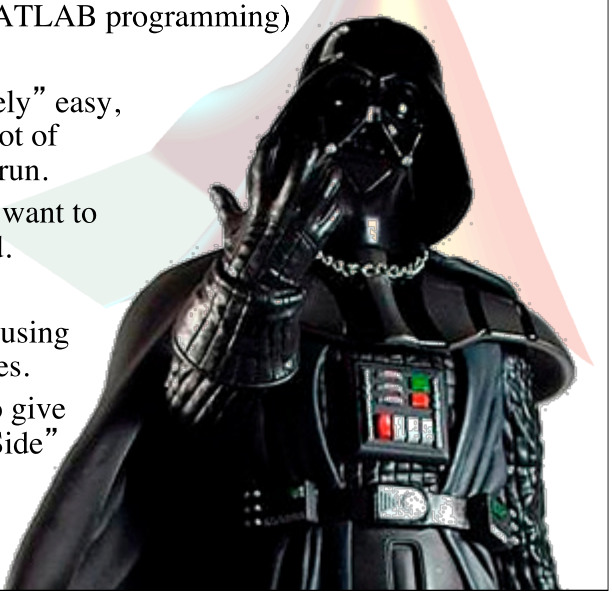
Programming With Scripts

Scripts

(The “Dark Side” of MATLAB programming)

- Scripts are “seductively” easy, but will cause you a lot of problems in the long run.
- Most of the time you want to use a function instead.

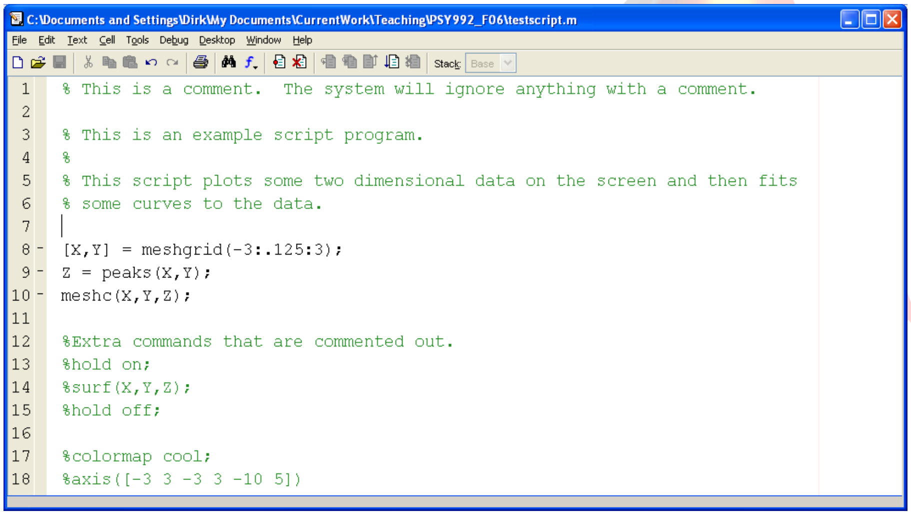
- However, we will be using scripts in our examples.
- Just remember, not to give in to the “Dark Side”



Scripts

- Put all of your commands in a single text file (you can use MATLAB's built-in editor).
- Name the file with the .m extension (filename.m).
- Type in the text file name to run the commands.
- Script do not have their own workspace. Instead, they use the current workspace. (I will explain this more when I talk about functions.)

Example Script


C:\Documents and Settings\Dirk\My Documents\CurrentWork\Teaching\PSY992_F06\testscript.m
File Edit Text Cell Tools Debug Desktop Window Help
Stack: Base

```
% This is a comment.  The system will ignore anything with a comment.

% This is an example script program.
%
% This script plots some two dimensional data on the screen and then fits
% some curves to the data.

[X,Y] = meshgrid(-3:.125:3);
Z = peaks(X,Y);
meshc(X,Y,Z);

%Extra commands that are commented out.
%hold on;
%surf(X,Y,Z);
%hold off;

%colormap cool;
%axis([-3 3 -3 3 -10 5])
```

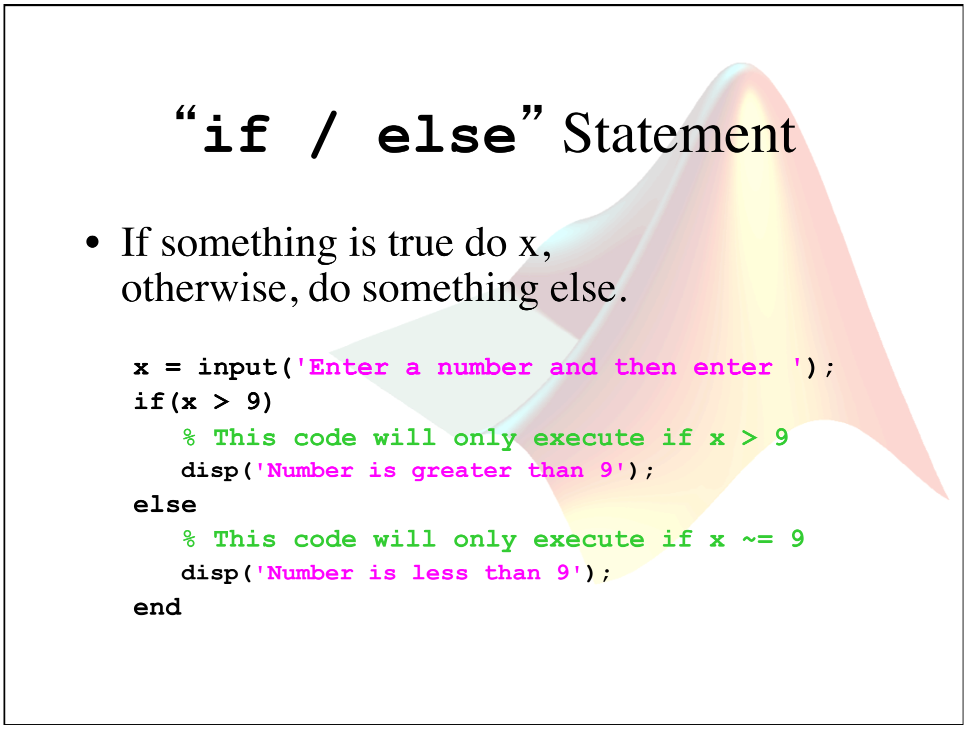
Crop Image Example

- A grayscale image is a matrix of values between 0 and 255.

```
im = imread('ngc6543a.jpg');
image(im);

im2 = im(70:530, 90:520, :);
image(im2);
```

- Note: Images can get warped
  - (type "**`axis off equal;`**" to see a clean image).

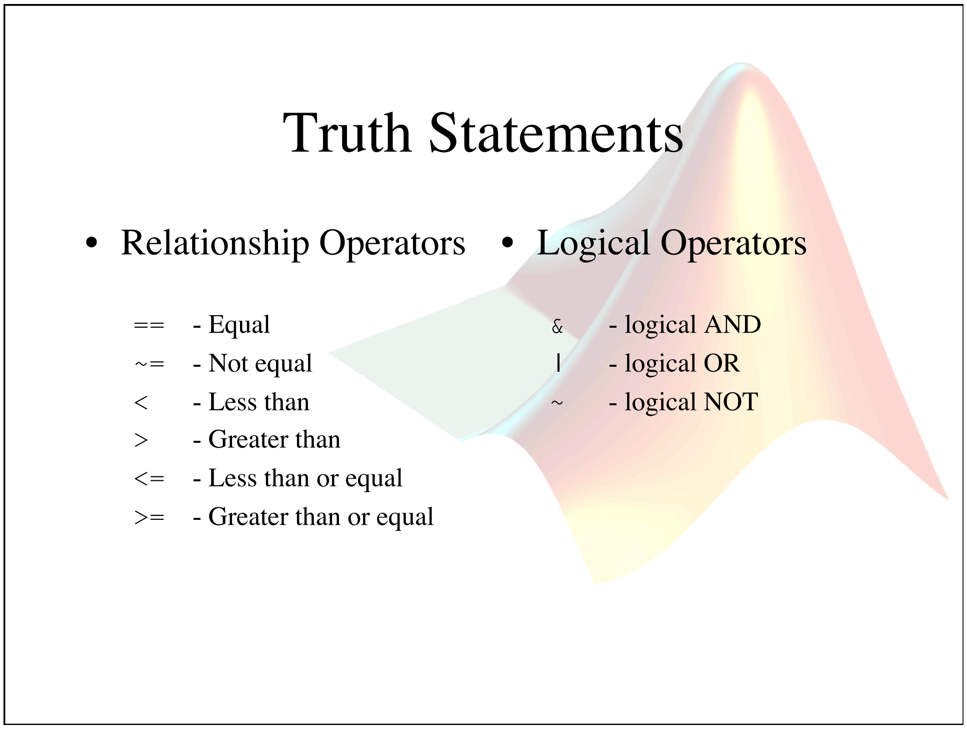
Block Code



“if / else” Statement

- If something is true do x, otherwise, do something else.

```
x = input('Enter a number and then enter ');
if(x > 9)
   % This code will only execute if x > 9
   disp('Number is greater than 9');
else
   % This code will only execute if x ~= 9
   disp('Number is less than 9');
end
```



Truth Statements

- Relationship Operators

==	- Equal
~=	- Not equal
<	- Less than
>	- Greater than
<=	- Less than or equal
>=	- Greater than or equal

- Logical Operators

&	- logical AND
|	- logical OR
~	- logical NOT

“for” Statement

- Cycle though a vector one item at a time

```
figure;
hold on;
a = [0 100 0 100];
axis(a);
for i = 1:10
  [x(i) y(i)] = ginput(1);
  plot(x,y,'*');
  axis(a);
end
```

Response time experiment

- Write a script that measures the response time of a user.
- Outline of the task:
  - Describe research objective
  - Flow chart the program
  - Look up the necessary functions
  - Write the program

Group Practice

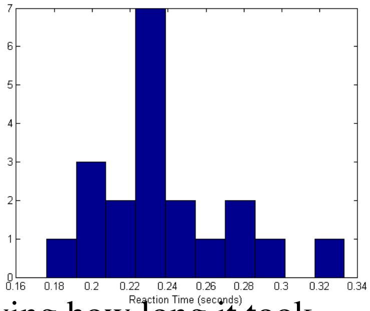
Lets turn this into a script (hint: use num2str)

```
>> figure;
>> axis([0 100 0 100]);
>> [x y] = ginput(10);
>> plot(x,y,'dr');
>> p = polyfit(x,y,1)

p =

    0.8415    6.6390

>> hold on;
>> ezplot('0.8415*x + 6.6390', [0 100 0 100]);
>> hold off;
```

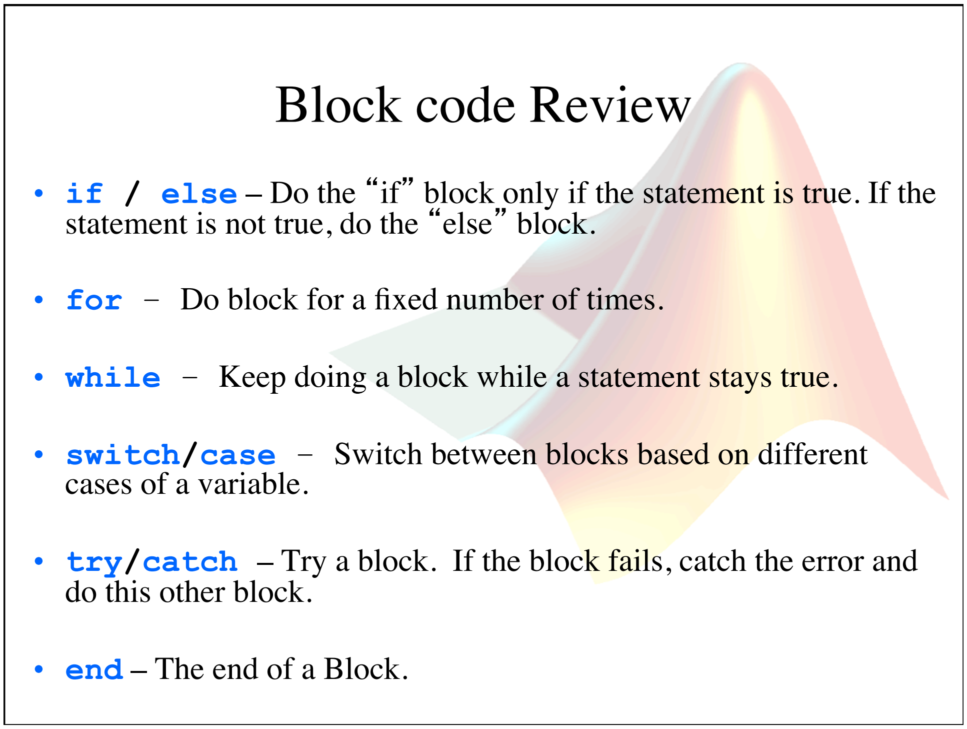
Project 2: Response time experiment

- Write a script that waits for a random amount of time between 1 and 2 seconds and then asks for user input (return key). Repeat 20 times.

```
for, end
rand
pause
tic, toc
beep
input
Hist
```

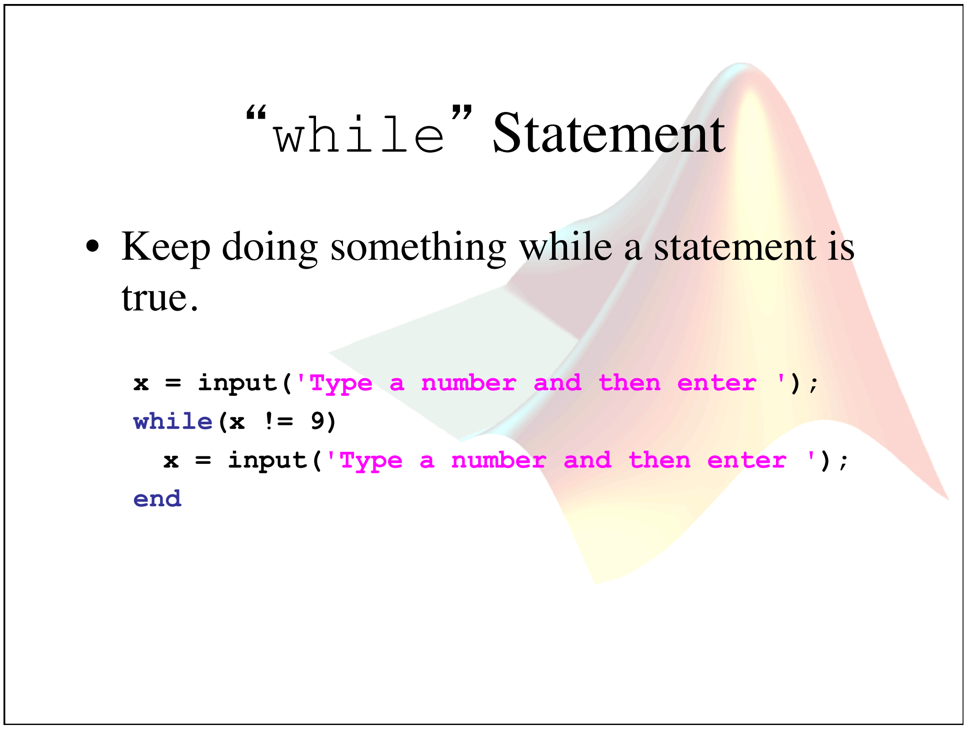


- Display a histogram showing how long it took between prompting the user and getting a response.



Block code Review

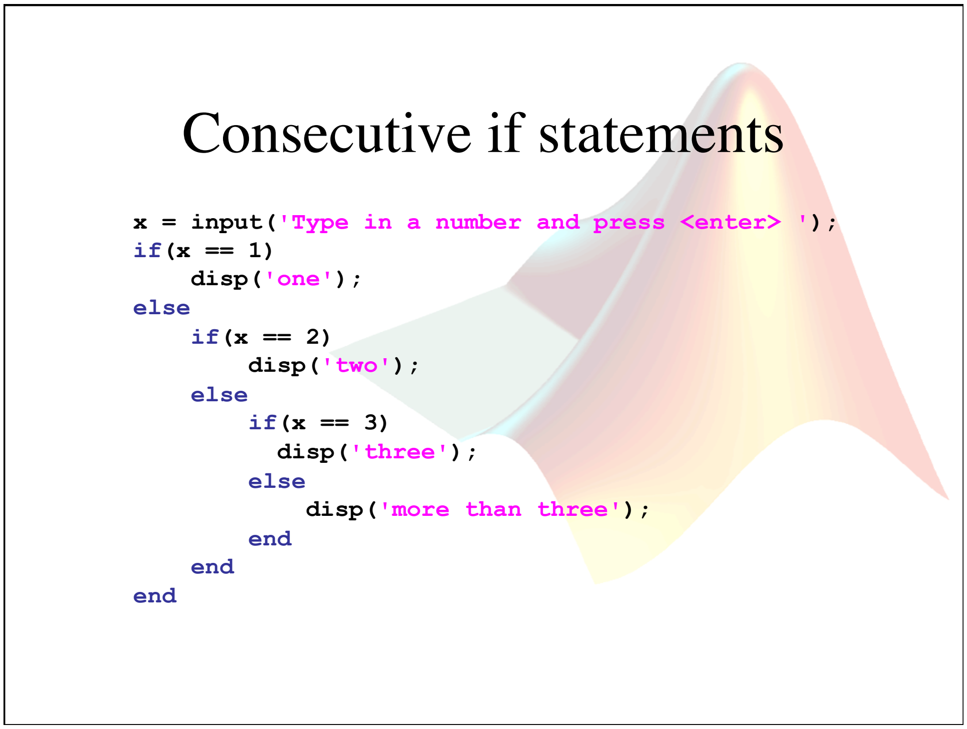
- `if / else` – Do the "if" block only if the statement is true. If the statement is not true, do the "else" block.
- `for` – Do block for a fixed number of times.
- `while` – Keep doing a block while a statement stays true.
- `switch/case` – Switch between blocks based on different cases of a variable.
- `try/catch` – Try a block. If the block fails, catch the error and do this other block.
- `end` – The end of a Block.



"`while`" Statement

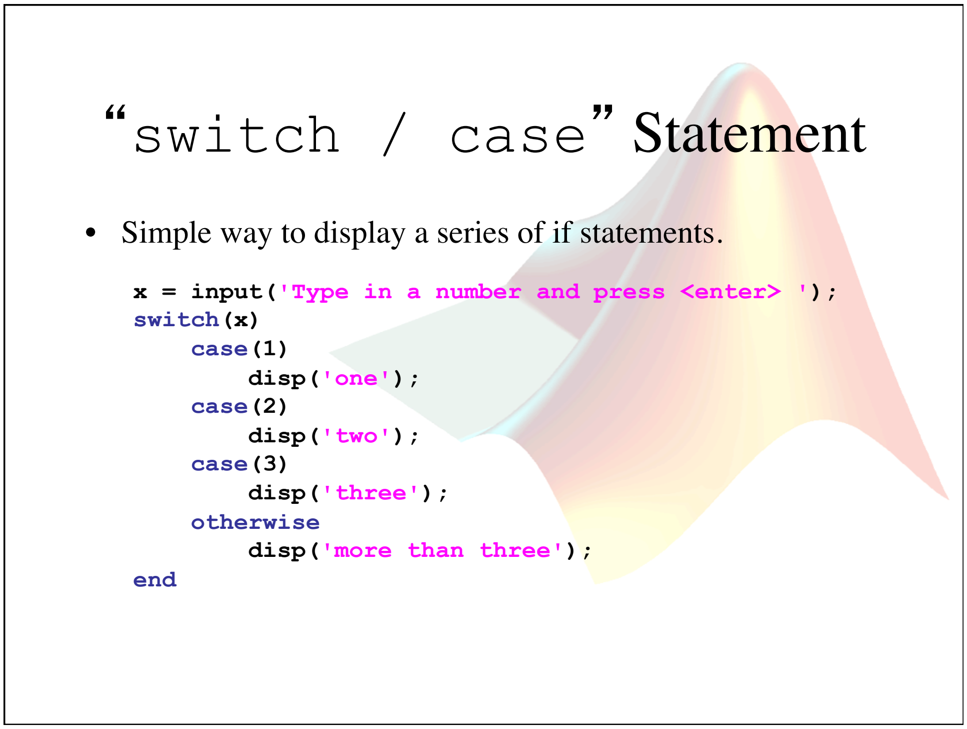
- Keep doing something while a statement is true.

```
x = input('Type a number and then enter ');
while(x != 9)
  x = input('Type a number and then enter ');
end
```



Consecutive if statements

```
x = input('Type in a number and press <enter> ');
if(x == 1)
  disp('one');
else
  if(x == 2)
    disp('two');
  else
    if(x == 3)
     disp('three');
    else
      disp('more than three');
    end
  end
end
```



“switch / case” Statement

- Simple way to display a series of if statements.

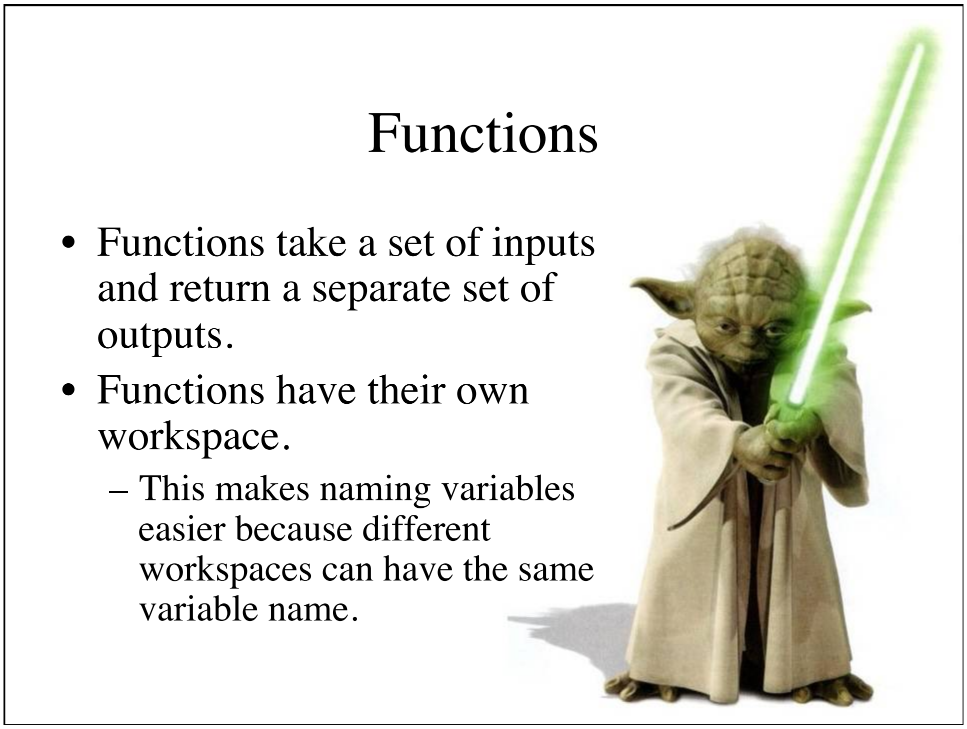
```
x = input('Type in a number and press <enter> ');
switch(x)
  case(1)
    disp('one');
  case(2)
    disp('two');
  case(3)
    disp('three');
  otherwise
    disp('more than three');
end
```

“`try / catch`” Statement

- Try to do a command, if there is an error, address it and move on.

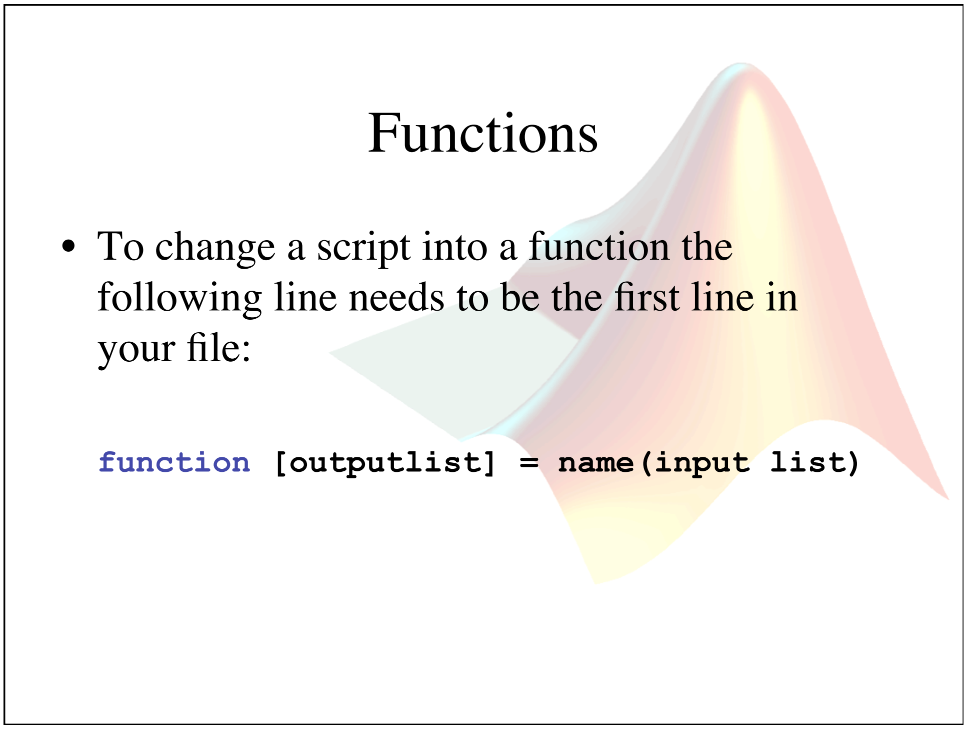
```
name = input('Type in an image file name with '' marks ');
try
    im = imread(name);
    image(im);
catch
    disp('could not open file');
end
disp('program did not exit');
```

Function Programming



Functions

- Functions take a set of inputs and return a separate set of outputs.
- Functions have their own workspace.
  - This makes naming variables easier because different workspaces can have the same variable name.

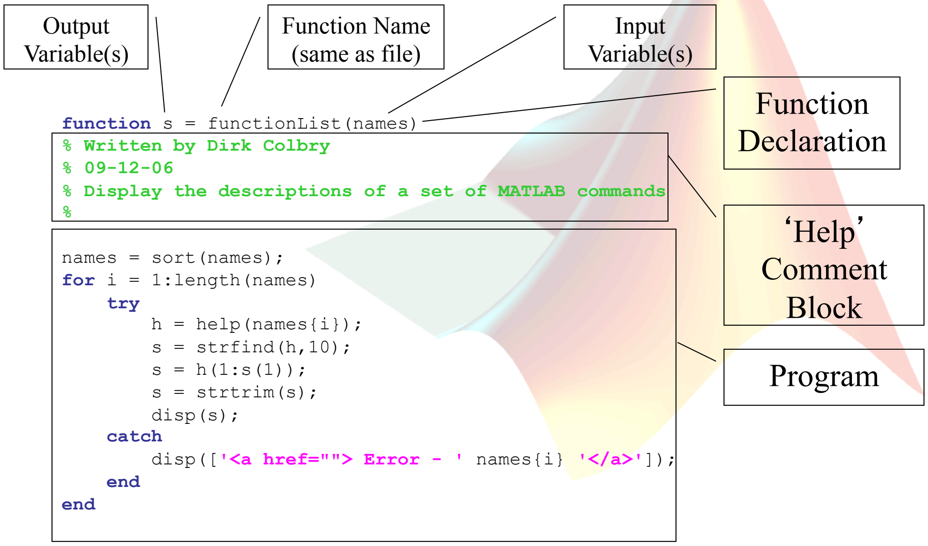


Functions

- To change a script into a function the following line needs to be the first line in your file:

```
function [outputlist] = name(input list)
```

Example Function (functionList.m)



Output Variable(s)

Function Name (same as file)

Input Variable(s)

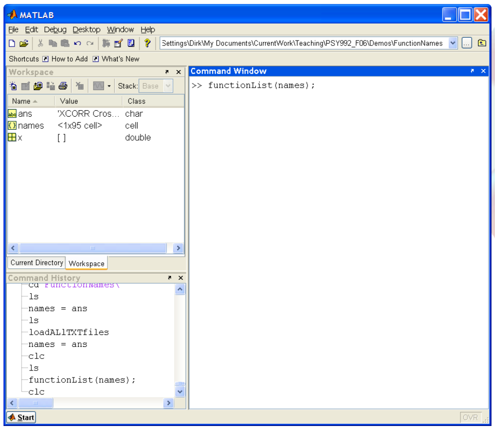
Function Declaration

'Help' Comment Block

Program

```
function s = functionList(names)
% Written by Dirk Colbry
% 09-12-06
% Display the descriptions of a set of MATLAB commands
%

names = sort(names);
for i = 1:length(names)
    try
        h = help(names{i});
        s = strfind(h,10);
        s = h(1:s(1));
        s = strtrim(s);
        disp(s);
    catch
        disp(['<a href=""> Error - ' names{i} '</a>']);
    end
end
```

Every function has its own workspace



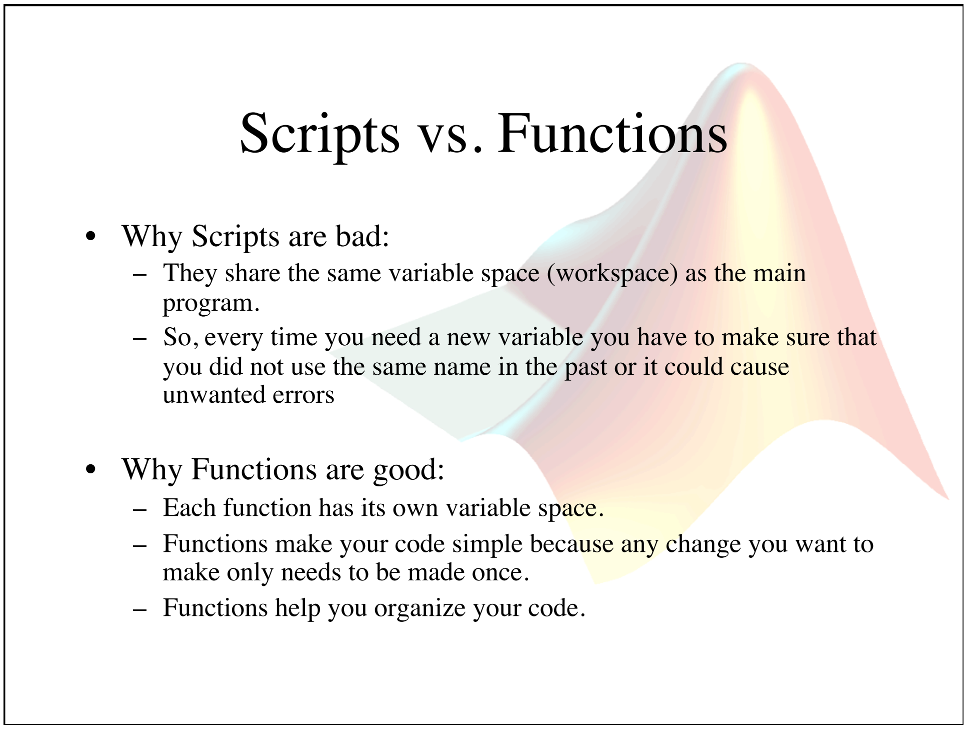
MATLAB
File Edit Debug Desktop Window Help
Settings\Dirk\My Documents\CurrentWork\Teaching\PSY992_F06\Demos\FunctionNames
Shortcuts How to Add What's New
Workspace
Stack: Base
Current Directory
Workspace
Command History
Command Window
Start
OVR

Name	Value	Class
ans	'XCORR Cros...	char
names	<1x95 cell>	cell
x	[ ]	double

```
cd FunctionNames\
ls
names = ans
ls
loadALlTXTfiles
names = ans
clc
ls
functionList(names);
clc
```

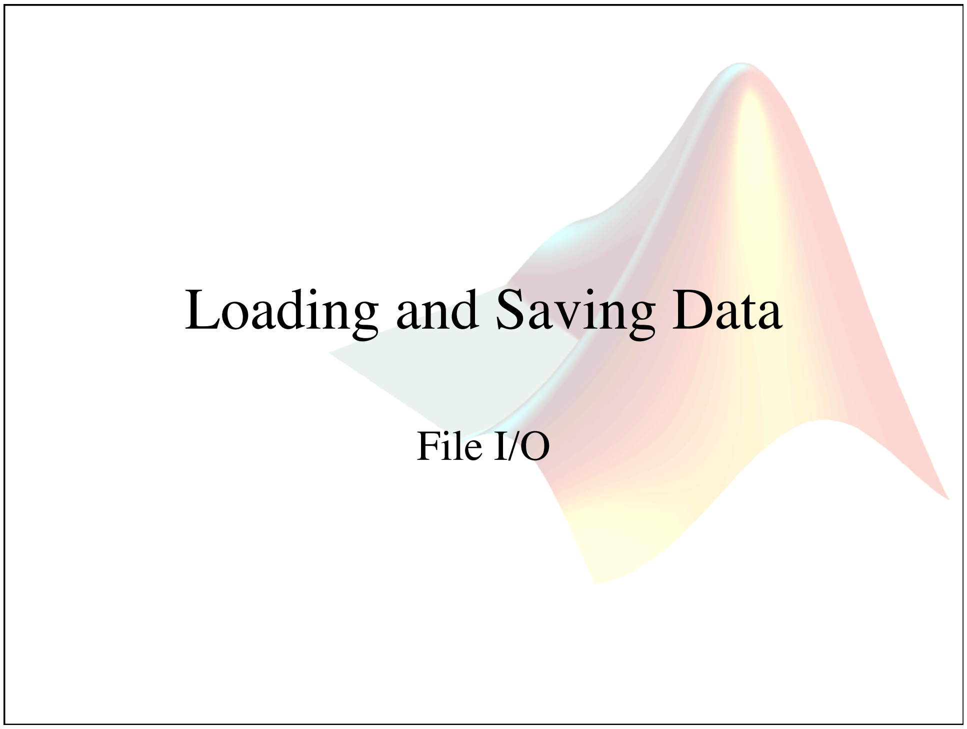
```
>> functionList(names);
```

- When a function starts, its workspace only contains the inputs to the function (plus some special variables).
- When a function exits, only the output variables are in the main workspace.
- Variables that are inside and outside of the workspace are different, regardless of the variable names.
- For instance, if the variable 'x' is in the main workspace and there is also a variable named 'x' in my function workspace, they can have different values and it will not cause an error



Scripts vs. Functions

- Why Scripts are bad:
  - They share the same variable space (workspace) as the main program.
  - So, every time you need a new variable you have to make sure that you did not use the same name in the past or it could cause unwanted errors
- Why Functions are good:
  - Each function has its own variable space.
  - Functions make your code simple because any change you want to make only needs to be made once.
  - Functions help you organize your code.



Loading and Saving Data

File I/O

Saving and restarting MATLAB

- At any point you can save your MATLAB session:

```
>> save(‘mysession’);
```

- Then you can exit MATLAB and reload your session latter:

```
>> load(‘mysession’);
```

Types of files

- Just like variables, every file is a group of numbers.
- The program needs to know what the numbers mean in order to read the files.
- Since the numbers could mean anything, some standards have been adopted that make reading the file easier.
- There are generally two major classes of files, ASCII and Binary.

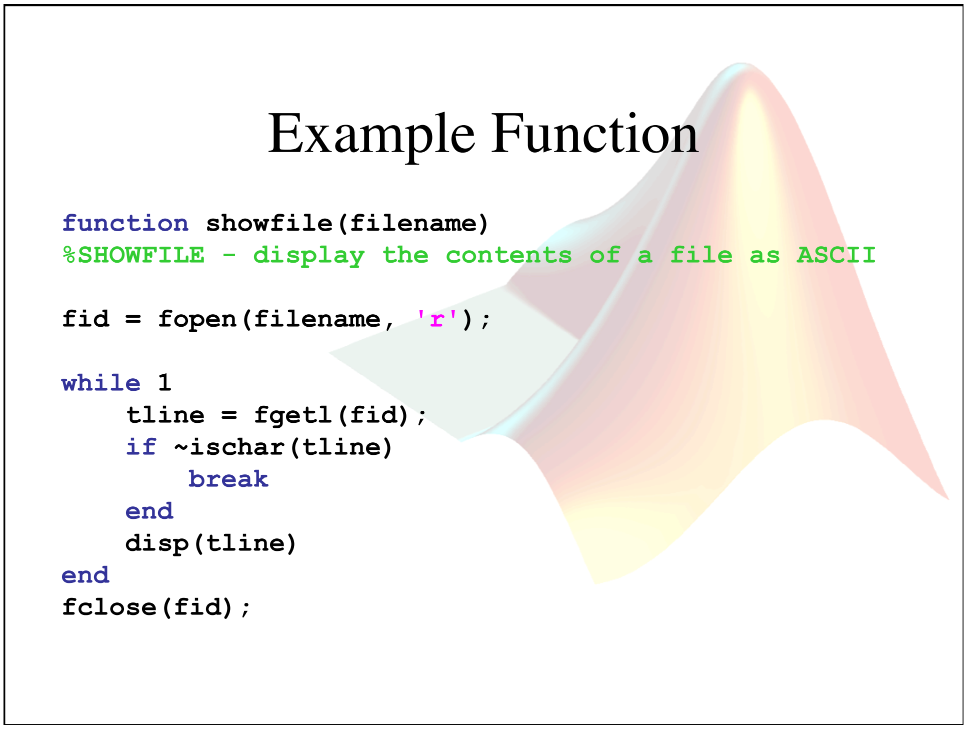
All files are given a file ID

- The **`fopen`** command opens a file and returns the file ID.
- Any command that can read or write to a file will normally take the file ID as an input.
  - **`fread, fwrite, fprintf, fgets, fgetl, fscanf, fseek, etc.`**
- After you are done accessing the file you should always use the **`fclose`** command.

fopen

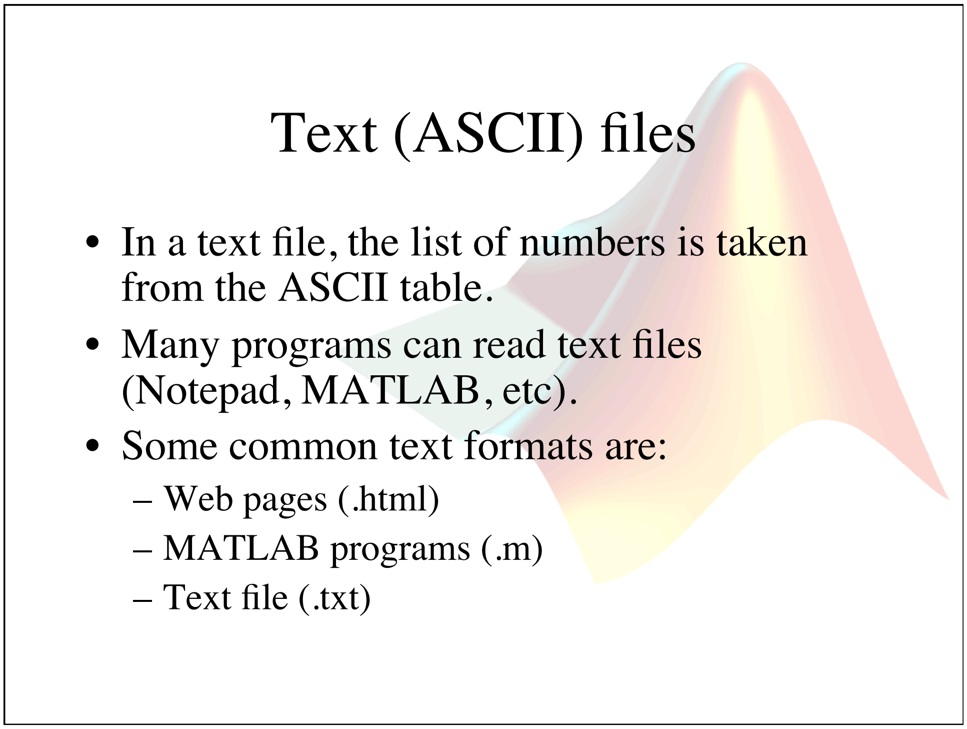
- **`fid = fopen(filename, permissions)`**
- The permissions string can include:

– `'r'`	`read`
– `'w'`	`write (create if necessary)`
– `'a'`	`append (create if necessary)`
– `'r+'`	`read and write (do not create)`
– `'w+'`	`truncate or create for read and write`
– `'a+'`	`read and append (create if necessary)`
– `'W'`	`write without automatic flushing`
– `'A'`	`append without automatic flushing`



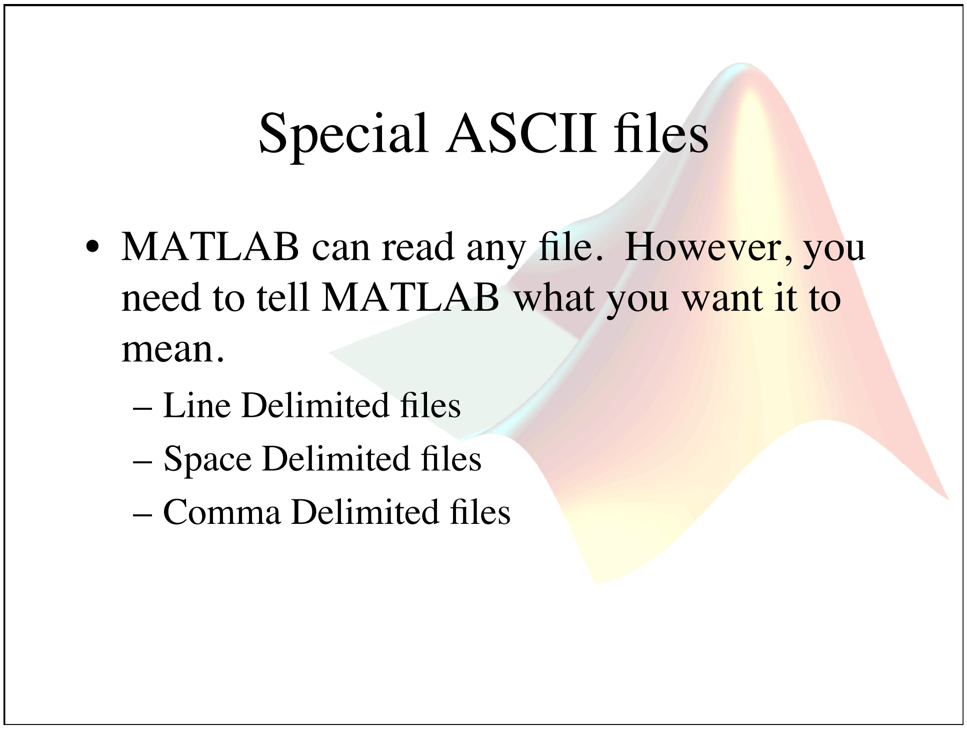
Example Function

```
function showfile(filename)
%SHOWFILE - display the contents of a file as ASCII

fid = fopen(filename, 'r');

while 1
    tline = fgetl(fid);
    if ~ischar(tline)
        break
    end
    disp(tline)
end
fclose(fid);
```



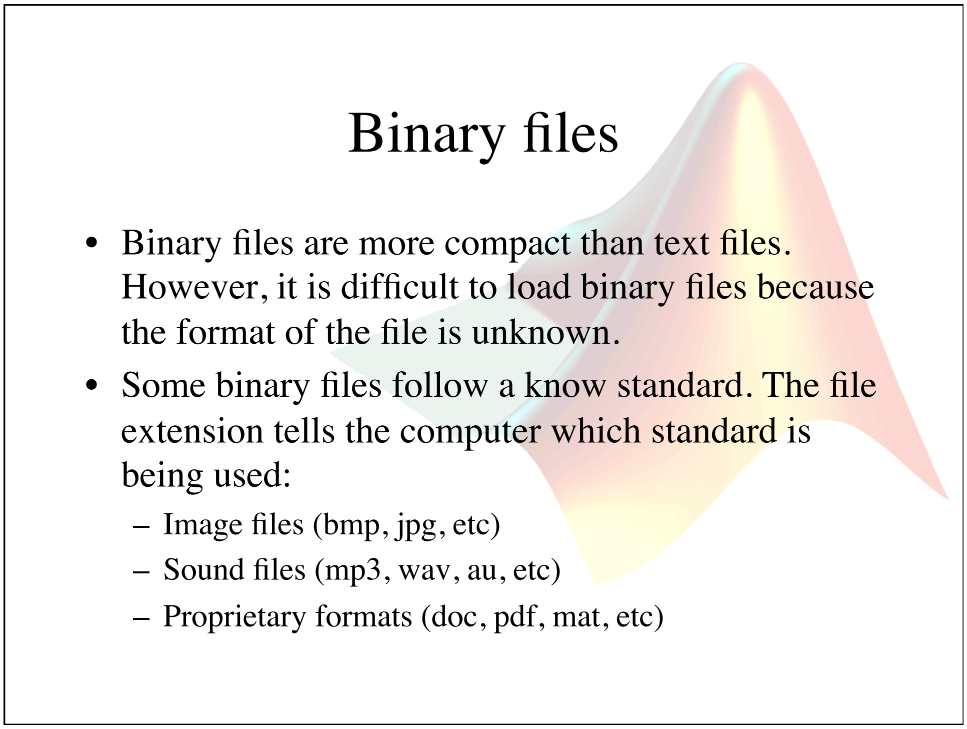
Text (ASCII) files

- In a text file, the list of numbers is taken from the ASCII table.
- Many programs can read text files (Notepad, MATLAB, etc).
- Some common text formats are:
  - Web pages (.html)
  - MATLAB programs (.m)
  - Text file (.txt)



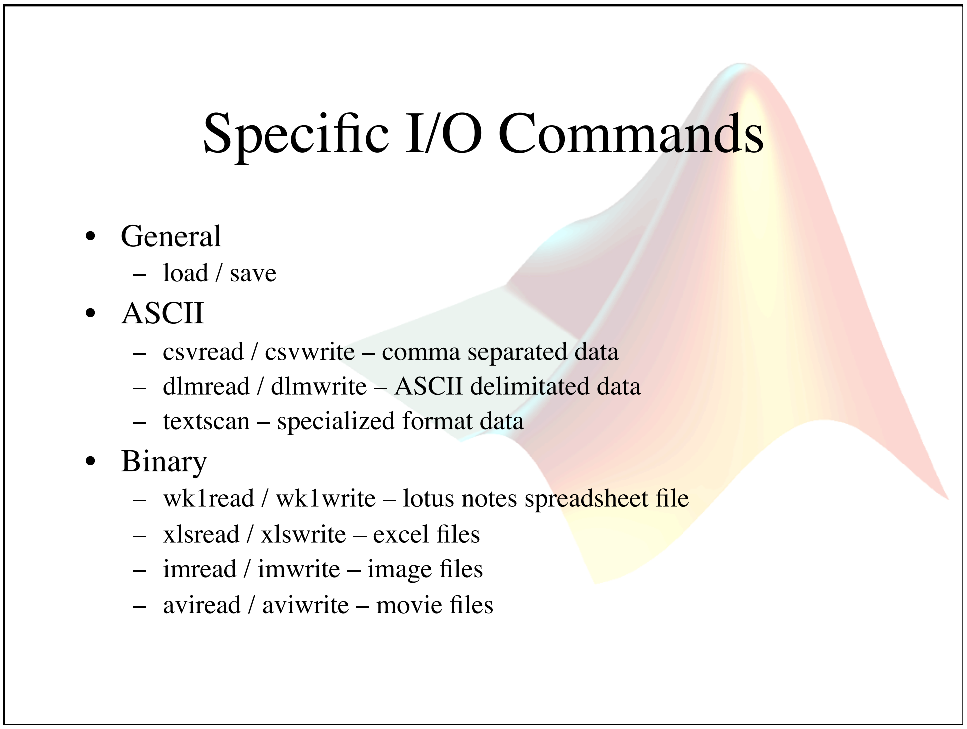
Special ASCII files

- MATLAB can read any file. However, you need to tell MATLAB what you want it to mean.
  - Line Delimited files
  - Space Delimited files
  - Comma Delimited files



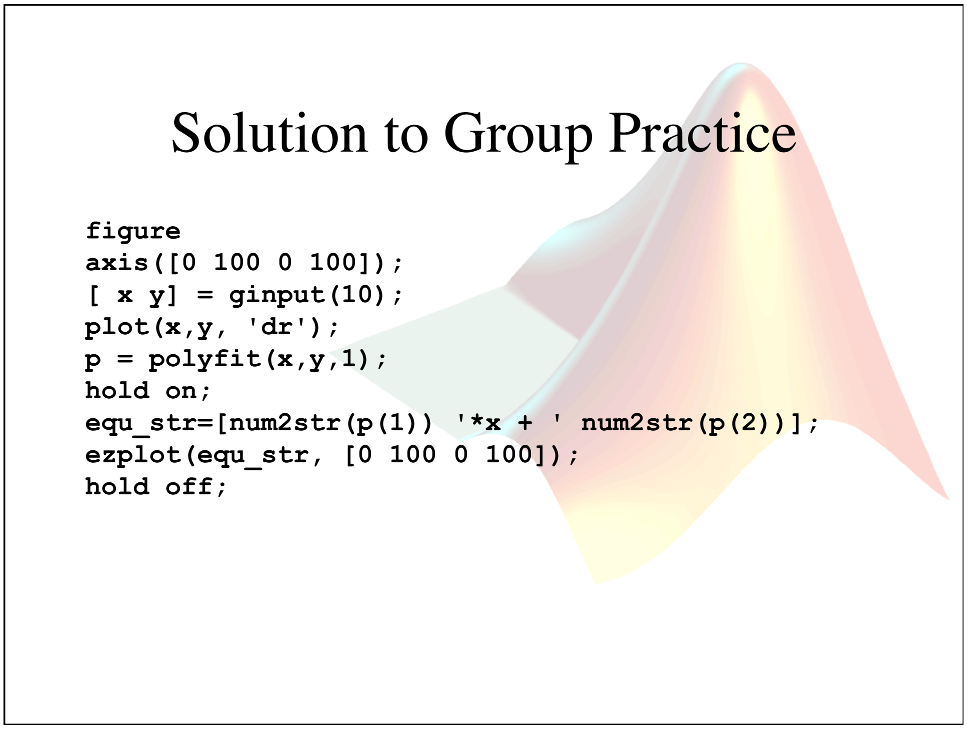
Binary files

- Binary files are more compact than text files. However, it is difficult to load binary files because the format of the file is unknown.
- Some binary files follow a know standard. The file extension tells the computer which standard is being used:
  - Image files (bmp, jpg, etc)
  - Sound files (mp3, wav, au, etc)
  - Proprietary formats (doc, pdf, mat, etc)



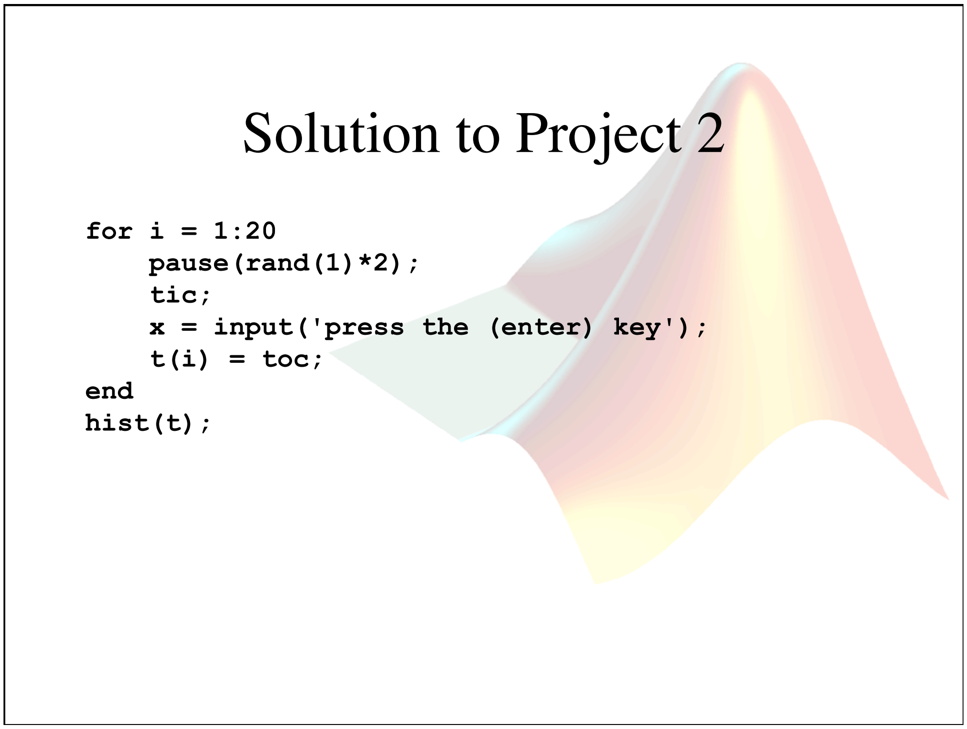
Specific I/O Commands

- General
  - load / save
- ASCII
  - csvread / csvwrite – comma separated data
  - dlmread / dlmwrite – ASCII delimitated data
  - textscan – specialized format data
- Binary
  - wk1read / wk1write – lotus notes spreadsheet file
  - xlsread / xlswrite – excel files
  - imread / imwrite – image files
  - aviread / aviwrite – movie files



Solution to Group Practice

```
figure
axis([0 100 0 100]);
[ x y] = ginput(10);
plot(x,y, 'dr');
p = polyfit(x,y,1);
hold on;
equ_str=[num2str(p(1)) '*x + ' num2str(p(2))];
ezplot(equ_str, [0 100 0 100]);
hold off;
```



Solution to Project 2

```
for i = 1:20
    pause(rand(1)*2);
    tic;
    x = input('press the (enter) key');
    t(i) = toc;
end
hist(t);
```