Notes

Notes

Introc	luction to Matl	ab	
Eug	geniy E. Mikhailov		
The C	College of William & Mary		
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	Lecture 02		
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Eugeniy Mikhailov (W&M) Matlab variable types	Practical Computing	Lecture 02	1/20
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Matlab variable types			
 integer 			

123, -345, 0

Matlab variable types

integer

123, -345, 0

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- real or float

 - 12.2344
 5.445454
 engineering notation
 - 4.2323e-9 = 4.2323 × 10⁻⁹

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Matlab variable types

integer

- 123, -345, 0
- real or float
 - 12.2344
 - 5.445454
 - engineering notation
 - 4.2323e-9 = 4.2323 × 10⁻⁹
- complex
 - $i = \sqrt{-1} = 1i$
 - 34.23+21.21i
 - (1+1i) * (1-1i) = 2

. ∂• Eugeniy Mikhailov (W&M) Practical Computing Lecture 02 0/00 Matlab variable types Notes integer 123, -345, 0 real or float • 12.2344 • 5.445454 engineering notation • 4.2323e-9 = 4.2323 × 10⁻⁹ • complex • $i = \sqrt{-1} = 1i$ • 34.23+21.21i • (1+1i) * (1-1i) = 2 • strings (put your words inside apostrophes) • handy for file names and messages • 'programming is fun' • s='Williamsburg' Eugeniy Mikhailov (W&M) Practical Computing Lecture 02 2/26 Some built in constants and functions Notes • $\pi = 3.141592653589793238462643383279502 \cdots$ • use pi • trigonometry functions By default angle is in radians But can be done in degrees • sin, cos, tan, cot • sind, cosd, tand, cotd • asin, acos, atan, acot • asind, acosd, atand, acotd sin(pi/2)=1 sind(90)=1 • hyperbolic functions • sinh, cosh, tanh, coth \bullet asinh, acosh, atanh, acoth logarithms natural log • base of 10 log10 o power • x^y use x^y or alternatively power (x, y) • e^y use exp (y) Eugeniy Mikhailov (W&M) Practical Computing Lecture 02 Assignment operator Notes x = 1.2 + 3.4

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Assignment operator

x = 1.2 + 3.4

Despite the look = is not an equality operator. = is an assignment operator.

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x = 1.2 + 3.4

Despite the look = is not an equality operator.

= is an assignment operator.

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Assignment operator

The expression above should be read as

• evaluate expression at the right hand side of equality symbol

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- assign the result of the RHS to the variable on the left hand sign
- now variable x holds the value 4.6

We are free to use the value of the variable \times in any further expressions

> x + 4.2 ans = 8.8

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Efficient editing - Tab-completition

Notes

Once you typed some expressions in "Command window"

- type couple of first symbols of variable or function name
- hit tab and you will get

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- either fully typed name (if it is unique)
- or little chart with choices
 - use <up> or <down> arrows to choose
 - alternatively <Ctrl-p>, <Ctrl-n>
 then hit <enter> to make your choise
 - a monthic conterp to make your ones

Help related commands

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These are the most important commands

- \bullet docsearch word
 - will search for word in the help files and show up matched help files
 example: docsearch trigonometry

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- help name
 - output short help text into "Command window" about
 - function/method named name
 - example: help sin
- doc name
 - show a reference page about function/method named name in the help browser
 - usually has more information compare to help name
 - example: doc sin

Operator Precedence

Look at the following Matlab expression

-2^4*5 + tan(pi/8+pi/8)^2

Guess the answer.

Operator Precedence

Look at the following Matlab expression

-2^4*5 + tan(pi/8+pi/8)^2

Guess the answer.

- (2^4)*5 + (tan((pi/8+pi/8)))^2

Operator Precedence

Look at the following Matlab expression

```
-2^4*5 + tan(pi/8+pi/8)^2
```

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Guess the answer.

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```
- (2^4)*5 + (tan( (pi/8+pi/8) ))^2
```

```
- (16)*5 + (tan( (pi/4) ))^2
```

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 Operator Precedence
 Look at the following Matlab expression

 -2^4*5 + tan (pi/8+pi/8)^2

Guess the answer.

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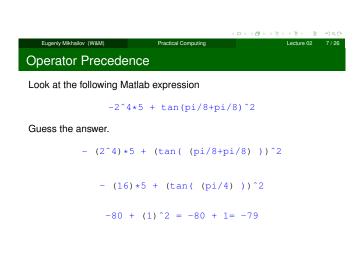
Operator Precedence

Look at the following Matlab expression

-2^4*5 + tan(pi/8+pi/8)^2

Guess the answer.

- $(2^4) * 5 + (tan((pi/8+pi/8)))^2$
 - $(16) * 5 + (tan((pi/4)))^2$
 - $-80 + (1)^2 = -80 + 1$



Operator Precedence

Look at the following Matlab expression

-2^4*5 + tan(pi/8+pi/8)^2

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Guess the answer.

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- (2^4)*5 + (tan((pi/8+pi/8)))^2
 - $-(16)*5+(tan((pi/4)))^2$

 $-80 + (1)^2 = -80 + 1 = -79$

Rule of thumb: if not sure use extra parentheses ()

Operator Precedence

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Look at the following Matlab expression

 $-2^{4}+5 + \tan(pi/8+pi/8)^2$

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Guess the answer.

- $(2^4) * 5 + (tan((pi/8+pi/8)))^2$

$$-(16)*5+(tan((pi/4)))^2$$

 $-80 + (1)^2 = -80 + 1 = -79$

Rule of thumb: if not sure use extra parentheses ()

- Read more by executing doc precedence
- or searching for 'precedence' in the help browser.

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Matrices

Recall that Matlab stands for Matrix Laboratory

- So deep inside everything is a matrix (array)
- $\bullet\,$ a number is the case of 1 \times 1 matrix

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Recall that Matlab stands for Matrix Laboratory

- So deep inside everything is a matrix (array)
- $\bullet\,$ a number is the case of 1 \times 1 matrix

Let's create a 3×5 matrix (3 rows and 5 columns)

Mz =
0 0 0 0 0
0 0 0 0 0
0 0 0 0 0

This is not the only way, but it is one which make sure that matrix is filled with zeros

Note: it is possible to have more than 2 dimensional arrays.

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Ma	Matrix elements assignment									
>>	Mz(2, 4) = 1	%	2nd row,	4th	column	1				
Mz	=									
0	0	0	0	0						
-				-						
0	0	0	1	0						
0	0	0	0	0						

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Matrix elements assignment

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>>	Mz(2,4)=1	olo	2nd row,	4th	column
Mz	=				
0			0	0	
0	0	0	1	0	
0	0	0	0	0	
>>	Mz(3,5)=4	olo	3rd row,	5th	column
Mz	=				
0	0	0	0	0	
0	0	0	1	0	
0		0	0	4	
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Alternative way to assign a matrix

• comma separates column elements

• semicolon separates row elements

>>	Mz=	= [
Ο,	Ο,	Ο,	Ο,	0;						
Ο,	Ο,	Ο,	1,	0;						
Ο,	Ο,	Ο,	Ο,	4]						
Mz	=									
0		0		0	0	0				
0		0		0	1	0				
0		0		0	0	4				

Notice $\cdots\,$ mark, which means that input continues on the next line

		< = > < 6		200
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Strength of Matlat	כ			

Native matrix operations

Mz =						
0 0 0 0 0	>> Mz-	+5				
0 0 0 1 0	ans =					
0 0 0 0 4	5	5	5	5	5	
	5	5	5	6	5	
	5	5	5	5	9	

		(=) < () > < 2 > < 2 > < 2 > < 2 < 2 < 2 < 2 < 2	୬୯୯
M)	Practical Computing	Lecture 02	11 / 26
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Strength of Matlab

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Native matrix operations

Μz	<u>z</u> =	=			
0	0	0	0	0	
0	0	0	1	0	
0	0	0	0	4	

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1121	5			
ans =				
5	5	5	5	5
	5	5	6	5
5	5	5	5	9
>> Mz*	2			
ans =				
0	0	0	0	0
0	0	0	2	0
0	0	0	0	8

0

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More example on matrices operations

>> Mz+5

Mz =	>> Mz·	+Mz			
0 0 0 0 0	ans =				
0 0 0 1 0	0	0	0	0	0
0 0 0 0 4	0	0	0	2	0
	0	0	0	0	8

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More example on matrices operations

Mz =	>> M	z+Mz				
0 0 0 0 0	ans	=				
0 0 0 1 0	0	0	0	0	0	
0 0 0 0 4	0	0	0	2	0	
	0	0	0	0	8	
		ra rules	3			
	aigeb	la luie:	5			
	ans					
	0	0 1	0 0			
	0	0	16			
			(i, j) = M		sposed m	natrix
					12112	∃ •20

Matrix as a function argument

A function can take a matrix as the function argument, it will evaluate the value of the function for each matrix element

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Mz =	>> sin(Mz)			
0 0 0 0 0	ans =				
0 0 0 1 0	0	0	0	0	0
0 0 0 0 4	0	0	0	0.8415	0
	0	0	0	0	-0.7568

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Vectors and column vector

A special case of the matrix is it has only one dimension. Such matrices generally called vectors

• $m \times 1$ column vector

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• $1 \times m$ just a vector

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Vectors and column vector

A special case of the matrix is it has only one dimension. Such matrices generally called vectors

- m × 1 column vector
- $1 \times m$ just a vector
- To create a vector

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>> % use comma to separate column elements >> v=[1, 2, 3, 4, 5, 6, 7, 8] v = 1 2 3 4 5 6 7 8 >> % alternatively you can use spaces >> v=[1 2 3 4 5 6 7 8]; >> % or mix of these two notations (NOT RECOMMENDED) >> v=[1 2 3, 4, 5, 6 7 8] v 3 4 5 6 7 1 2 8 $\partial \rightarrow$ Eugeniy Mikhailov (W&M) Lecture 02 14 / 26

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2

3

1

2

3

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1

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3

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Construction of column vector

>> vc=[1; 2; 3]		
% use semicolon	to separate	row elements
VC =		
ve		
T		
2		
3		

				• • • • • • • • • • • • • • • • • • •	8) - E	n 9 9
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Yet	one more way	to creat	te matrix			
lf yo	ou have prearrange	d vectors c	or column vect	ors you can us	e ther	n
>>	vc=[1; 2; 3];					
>>	% note that ;	after a	statement	suppresses	outp	out
>>	Mc=[vc, vc, vc	2]				
Mc	=					

 <u> </u>	 	 	÷
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Yet one more way to create matrix

If you have prearranged vectors or column vectors you can use them

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>>	vc=[1;	2; 3]	;						
>>	% note	that	; after	a sta	tement	suppr	esses	output	
>>	Mc=[vc,	, vc,	vc]						
Мс	=								
1	1	1							
2	2	2							
3	3	3							
v =	=								
1	2	3	4	5	6	7	8		
>>	Mv=[v;	2*v;	3*v]						
Mv	=								
1	2	3	4	5	6	7	8		
2	4	6	8	10	12	14	16		
3	6	9	12	15	18	21	24		
						< = > < @	*****	।> ⊇ • ० ०(ð
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Colon (:) operator

The : operator is extremely useful to create vectors or matrix indexes It usually take form start:increment:stop and creates a vector with following values

[start, start+increment, ... , start+m*increment]

where

 $\texttt{min(start,stop)} \leq \texttt{m} \star \texttt{increment} \leq \texttt{max(start,stop)}$

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Colon (:) operator

The : operator is extremely useful to create vectors or matrix indexes It usually take form start:increment:stop and creates a vector with following values

r.

[start,	<pre>start+increment,</pre>	 ,	<pre>start+m*increment]</pre>
wh	ere			

min(start,stop) ≤ m*increment ≤ max(start,stop) >> v=5:2:11

v = 5 7 9 11

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Colon (:) operator		Lecture 02 17726
•	mely useful to create ver art:increment:stop th following values	ctors or matrix indexes
[start, start+ir	ncrement, , s	tart+m*increment]
where		
min(start,stop) \leq	$m \star increment \leq ma$	x(start,stop)
>> v=5:2:11		
5 7	9 11	
It is also possible to have	ve negative increment	
>> v2=12:-3:1		
v2 = 12 9	6 3	
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Colon (:) operator	continued	
	top in this case incre	ment = 1
>> v1=1:5		

v1	=	

1 2 3 4 5

Colon (:) operator continued

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Another form start:stop in this case increment = 1								
v1=1:5								
=								
1	2	3	4	5				
ice that								
v3=5:1								
=								
Empty ma	atrix:	1-by-0)					
	ewhat un	expecte	d result,					
ugeniv Mikhailov ((W&M)	F	ractical Comp					
	v1=1:5 = 1 ice that v3=5:1 = Empty m. duce some	v1=1:5 = 1 2 ice that v3=5:1 = Empty matrix: duce somewhat un	v1=1:5 = 1 2 3 ice that v3=5:1 = Empty matrix: 1-by-0 duce somewhat unexpected	v1=1:5 = 1 2 3 4 ice that v3=5:1 = Empty matrix: 1-by-0 duce somewhat unexpected result, itive	v1=1:5 = 1 2 3 4 5 ice that v3=5:1 = Empty matrix: 1-by-0 duce somewhat unexpected result, since defa itive	v1=1:5 = 1 2 3 4 5 ice that v3=5:1 = Empty matrix: 1-by-0 duce somewhat unexpected result, since default increment is itive		

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Slicing matrices

It is handy to choose a subset (block) from the matrix We have a matrix Mv with size 3×8 and we want to choose all elements from columns 2,5,6

>> 1	٩v							
Mv =	=							
1	2	3	4	5	6	7	8	
2	4	6	8	10	12	14	16	
3	6	9	12	15	18	21	24	
>> 1	4v(:,[2,5,6])					
ans	=							
2	5	6						
4	10	12						
6	15	18						

The meaning of the : now is choose all. Notice also that we use vector to specify desired columns < 🔊 >

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Suppose you have a vector with values of x coordinates and we want to plot sin(x).

```
>> x=linspace(0,2*pi,10)
```

X =				
0 0.6981	1.3963	2.0944	2.7925	3.4907
4.1888 4.8869	5.5851	6.2832		
>> y=sin(x)				
у =				
0 0.6428	0.9848	0.8660	0.3420	-0.3420
-0.8660 -0.9	848 -0.6	428 -0.0	000	
>> plot(x,y,'o	') % alte	rnatively	plot(x,si	ln(x),'o')
>> % every plo	t MUST hav	e title, x	and y la	abels
>> xlabel('x (radians)')			
<pre>>> ylabel('sin</pre>	(x)')			
>> title('Plot	of sin(x)	')		

For 3D plots, please see help files for plot3, mesh, surf = Practical Computing

Saving plots

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Now we want to save the figure, use print

>> print('-dpdf', 'sin_of_x')

This will generate file *sin_of_x.pdf* notice automatic file extension addition.

Saving plots

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Now we want to save the figure, use print

>> print('-dpdf', 'sin_of_x')

This will generate file *sin_of_x.pdf* notice automatic file extension addition.

The '-d' switch stands for output format ('pdf', 'ps', 'eps', 'png"...)

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-02 -					
-14					
-					
4					

Now we want to save the figure, use print

>> print('-dpdf', 'sin_of_x')

This will generate file *sin_of_x.pdf* notice automatic file extension addition.

The '-d' switch stands for output format ('pdf', 'ps', 'eps', 'png"...) Note matlab **still** generates *pdf* with a lot of empty space. It is better to save into *eps* format and then convert it to a desired one.

>> print('-deps', 'sin_of_x')

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Saving plots continued

To generate a 'png' file

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• . *

>> print('-dpng', '-r100', 'sin_of_x')

By default figure size is 8 \times 6 inches, the '-r' switch tells the figure resolution in dpi (dots per inch). In this case it is 100 dpi so resulting image will be 800 \times 600 pixels.

	Pet d'anco	
	•	
	•	
1.4		
12		
ş,	•	
-4.2		
-0.4	•	
-1.5	•	
-12	•	
-1	1 2 3 4 6 6 1 1 2 3 4 6 6	

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Special array arithmetic operators

There are special arithmetic operators which applied to the elements of matrices (disregard linear algebra rules), they start with .

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```
• .*

>> x=1:3

x = 1 2 3

>> x*x % will generate an error

>> x.*x % equivalent to x.^2 (see below)

ans = 1 4 9
```

Special array arithmetic operators

There are special arithmetic operators which applied to the elements of matrices (disregard linear algebra rules), they start with .

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>> x=1:3					
x = 1	2 3				
>> x*x *	% will ger	nerate	an error		
>> x.*x	% equivale	ent to	x.^2 (see	below)	
ans = 1	4	9			
•					
>> x.^2					
ans = 1	4	9			

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Special array arithmetic operators

There are special arithmetic operators which applied to the elements of matrices (disregard linear algebra rules), they start with $\ .$

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					< • • • • #		<i>-</i> ୬ ବ	
	ans = 1	1	1					
	>> x./x							
۹	./							
	ans = 1	4	9					
	>> x.^2							
•	•							
	ans = 1	4	9					
	>> x.*x % ans = 1	equiva 4	9	5 x."Z	(see bel	_OW)		
	>> x*x %	-				>		
	x = 1		3					
	>> x=1:3							
•	•*							

>> 1	m=[1	,2,3;	4,5,6;7,8,9]			
m =						
1	2	2 :	3			
4	5	5	б			
7	8	3	9			
Lin	near a	algebra	rules	Elemer	nt wise o	operation
>>	m*r	n		>> m.	*m	
an	s =			ans =		
30		36	42	1	4	9
66		81	96	16	25	36
10	2	126	150	49	64	81

Special array arithmetic operator . ^

>> m 1 4 7

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>> m=[1,2,3;4,5,6;7,8,9]								
m =								
1 2 3								
4 5 6								
7 8 9								
Linear algebra rules	Element wise o	peration						
>> m^m % undefined	>> m.^m							
	ans =							
	1	4	27					
	256	3125	46656					
	823543	16777216	387420489					

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Special array arithmetic operator ./

>> m=[1,2,3;	4,5,	6;7,8,9]					
m =								
1	2	3						
4	5	6						
7	8	9						
Linear algebra rules			Element wise operation					
>> m/	/m % ur	nity	matrix	>>	m./m	%matrix	of	ones
ans =	=			ans	=			
1	0	0		1	1	1		
0	1	0		1	1	1		
0	0	1		1	1	1		

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