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Scientific Computer Software

(MatLab)

Topic 3. Class hierarchy in MatLab.

Классы Double, Char, String, Cell

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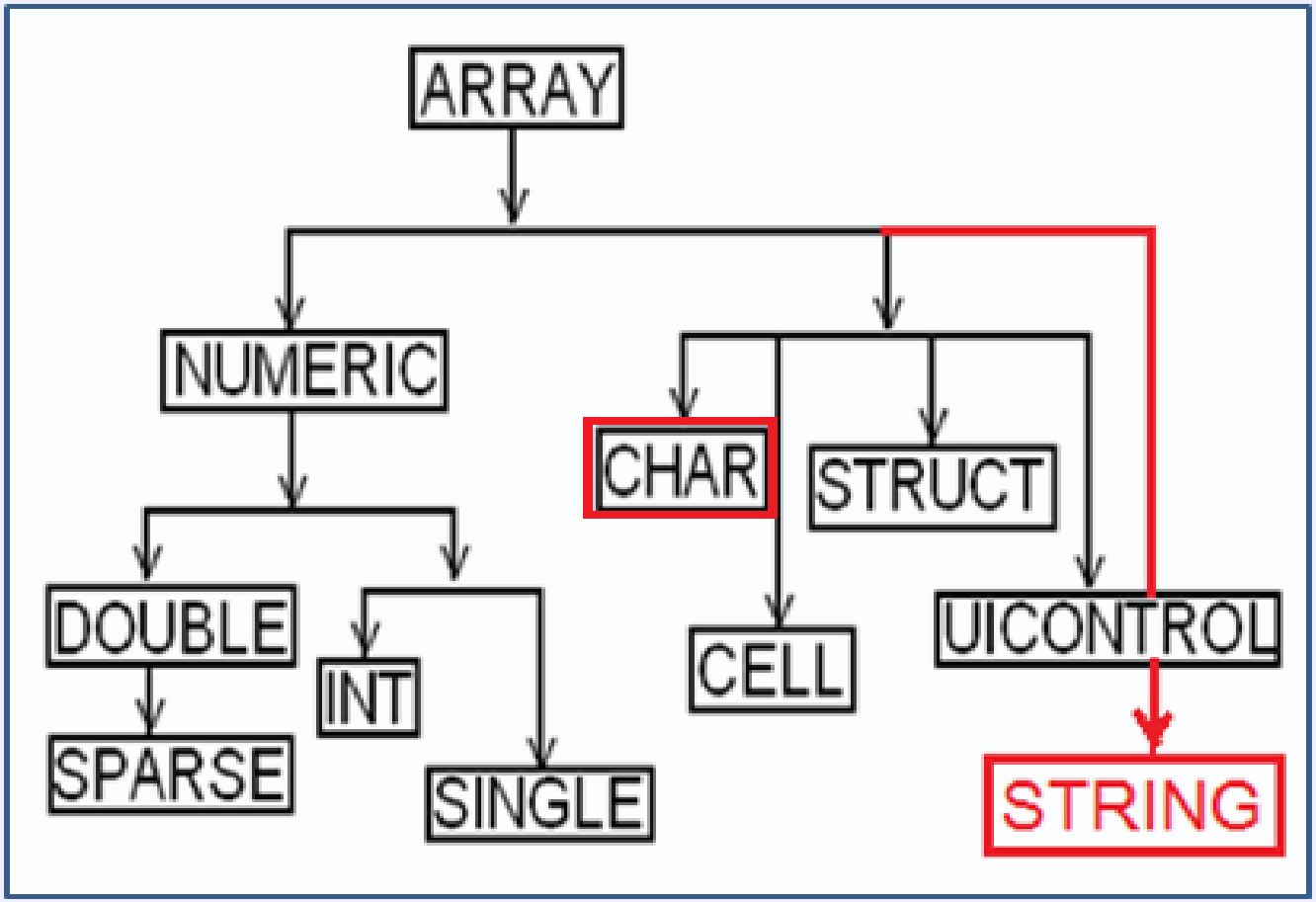
Class hierarchy



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Contents:

Array – <u>all native objects are Array!</u>

- ndims , size, length , numel
- display

Numeric, Double

- Matrix constructors
- Functions and properties(eig, det, rank, cond…)
- SLAE. Gauss Method.
- Construction of the simplest graphs
- I/O operations

String, Char, Cell

- Constructors
- Basic class functions

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Array

The main functions inherited by descendants

N=ndims(a) – dimensions number

[m, p] = size(a) – number of row and column

numel (a) – total elements number (= **m*p**)

length(a) – default: rows number

length(a,2) – column number (length along row)

display (a); – the semicolon does not suppress the output for display

inherited[ɪnˈherɪtɪd]

descendants [dɪˈsendənts]

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Numeric. Double

Matrix Constructors:

- **zeros** – the zero matrix
- **eye** – the unit matrix
- **ones** – all elements are equal to 1
- **rand**, **randi**, **randn** – random matrix
- **magic(n)** – a matrix with the properties of a magic square, the sums of any row and column are equal (does not exist for any order)
- **blkdiag** – constructor of a block-diagonal matrix, f.e.:

```
C={ones(3),randi(20,2,4),rand(3), triu(ones(2))}; % C∈Cell
blkdiag(C{:}) % C∈Cell
```

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Constructors of:

- **triu** – the upper triangular matrix

  triu(A); triu(A,-k); triu(A,k);

- **tril** – the lower triangular matrix

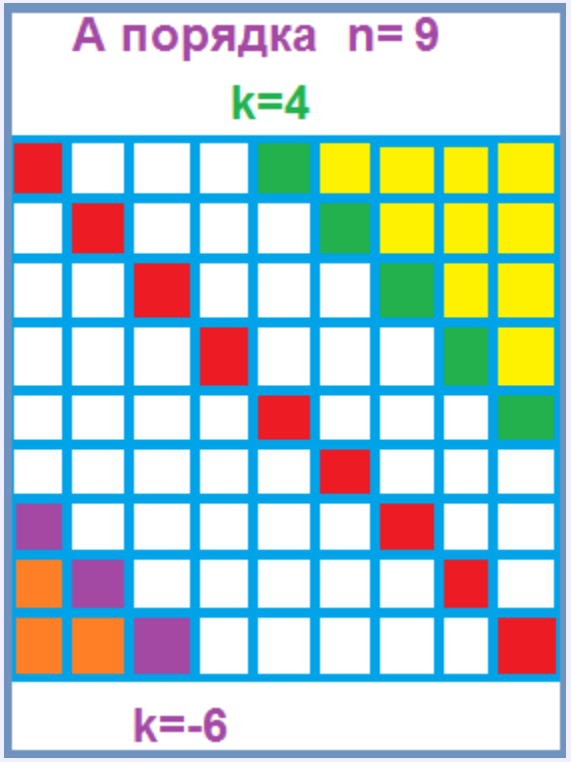
  tril(A); tril(A,-k); tril(A,k);

- **diag** – the diagonal matrix

  a=diag(A); a=diag(A,k); a=diag(A,-k);

  A=diag(a); A=diag(a,k); A=diag(a,-k);

k>0, integer, A – matrix, a – vector



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Vector editing of matrices by condition

Syntactic form of searching for elements by condition:

- LogicalMatrix=**A** *RelationOperation* **B**

RelationOperation: **>, <,==,… A** - **matrix, B** – constant value or**matrix** …

Syntactic [sɪnˈtæktɪk] **form of editing elements by condition:**

- **A(A** *RelationOperation* **B)=const –** assigning new values to matrix elements that meet the condition (*RelationOperation ==, >= ,>,<=,~=)*

Example

A=[0,0,-2; 0,-1,-1; -2,-2,0]

LogicalMatrix=A<-1 LogicalMatrix – ?

A(A<-1)=3 A -?

```
A =
     0     0    -2
     0    -1    -1
    -2    -2     0
```

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Analysis of matrix elements: function: **find**

- **index=find(A)** % finding indexes for elements A~=0

A(index) or A(index(:)) **contains nonzero elements**;

- **[i,j]=find(AnyCondition)** % i,j indexes of elements, satisfying the condition, f.e., AnyCondition={A>value или A<value или A==value,…};

A (i,j) **the same as** Acond

Brain Storm!

index=find(A) % need to detemine indexes!
[i,j]=find(A==-2) % - i,j ?

```
A =
     0     0    -2
     0    -1    -1
    -2    -2     0
```

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Logical analysis of matrix elements: functions: **all, any**

Analysis of matrix relation operations :

- ∀ relation, f.e. **C=A==B**, the result is logical matrix C;
  0 – equality is not true, 1 - true

- TrueFalse=**all**(**all**(**C**)); TrueFalse=1, all elements of C equal to **1** (**true**), matricies **A**,**B**,**C=A==B have the same dimension**

- TrueFalse=**any**(**any**(**C**)); TrueFalse=1, if there is at least one element in A that is equal to the corresponding element in B

Check for an arbitrary matrix a, is the matrix a'*a – symmetric?

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Examples

Поиск элементов с заданным условием:

% Генерируем целочисленную матрицу
% размера 2×3, величина элементов
% принадлежит отрезку [-9,9]:

```
a=randi([-9,9],2,3);  n=nnz(a)
```

% Находим nnz *- ненулевые элементы*
% и их индексы i,j, такие, что a(i(k),j(k)) =anz(k), k=1:n

```
[i,j,anz]=find(a);
[i,j,anz] % упорядочены, см. ans в CommandWindow
 for k=1:n,anz (k)=a(i(k),j(k)),end % testing
```

And what will be the result? Explain it!!

```
[k]=find(a)
a(k(:))    % см. Рис.
```

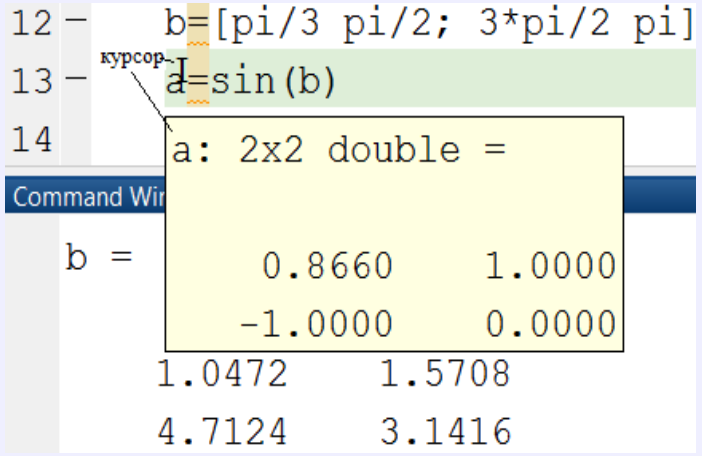
```
>> [i,    j,   anz]
ans =
     1     1    -7
     1     2     9
     2     2    -3
     1     3     2
     2     3    -5

>> a
   a =
  -7     9     2
   0    -3    -5
```

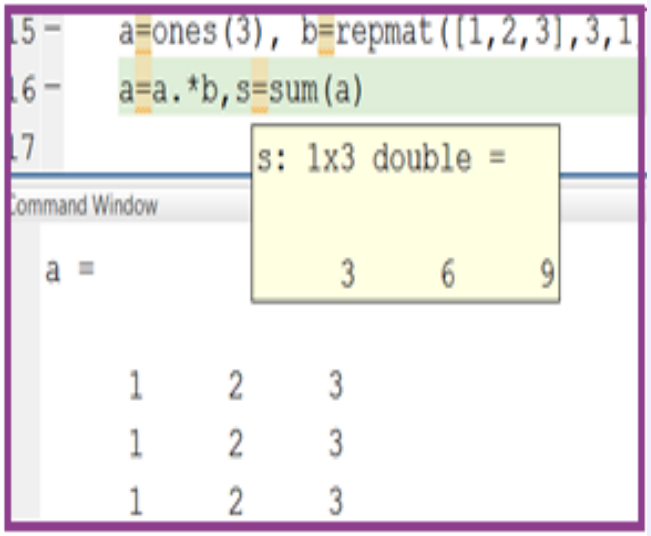
Рис.

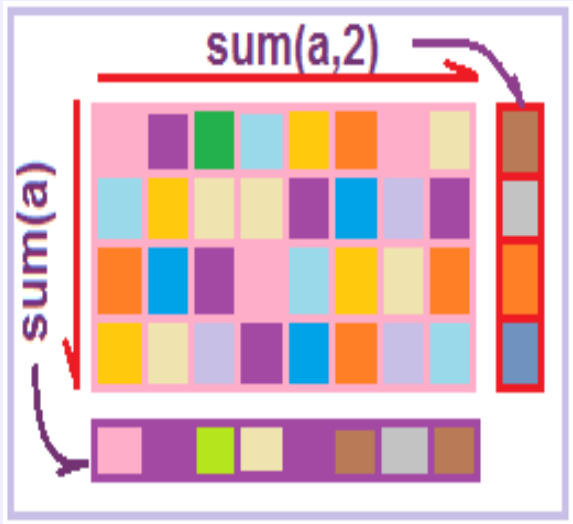
Functions on the of the matrices

- ✓ **sin(a), cos(a), tan(a) – a** (in radians)
- ✓ **sind(b), cosd(b), tand(b) – b** (degrees)
- ✓ **atan, asin, acos –** as usual
- ✓ **log(x)~ln(x); log10 –** clear!
- ✓ **imag, real –** (imaginary and parts)



sum, prod, abs, min, max, sort – the functions perform the operation on the columns, along the rows – default, f.e. **sum(a)~sum(a,1)**;





sum(a,2); line by line, along all columns

sum(sum(a)) ?

Functions defining the properties of matrices

- **s=det (a) –** the value of the determinant is calculated
- **[v,D]=eig (a) – v** – a matrix of eigenvectors-columns, **D** – diagonal matrix, D(i,i) – eigenvalues
- **cond (a)** the number of conditionality; characterizes the stability of the solution
- **issymmetric** (ishermitian for comlex), **isfull**, **issparse**, **isequal**
- **rank(a) –** clear
- **inv(a)** or **a^(-1)** inverse matrix☹
- **norm(a,p)** →

Decomposition svd:

[U,S,V] = svd(X);
X = U*S*V‘
U,V- unitary matrices,
(U*U’)=I, (U’*U)=I,
’ - transposition and complex conjugation

Виды норм:

p	Matrix	Vector
1	max(sum(abs(X)))	sum(abs(X))
2	max(svd(X))	sum(abs(X).^2)^(1/2)
real value p	-	sum(abs(X).^p)^(1/p)
Inf	max(sum(abs(X')))	max(abs(X))
-Inf	-	min(abs(X))

Where is the Euclidean norm? We are looking for!

SLAE. The Gauss method

Ax=b

$$\begin{cases} 3x + y + z = 5 \\ -x + y = 1 \\ x + 2y - z = 5 \end{cases} \qquad A=\begin{bmatrix} 3 & 1 & 1 \\ -1 & 1 & 0 \\ 1 & 2 & -1 \end{bmatrix} \qquad b=\begin{bmatrix} 5 \\ 1 \\ 5 \end{bmatrix}$$

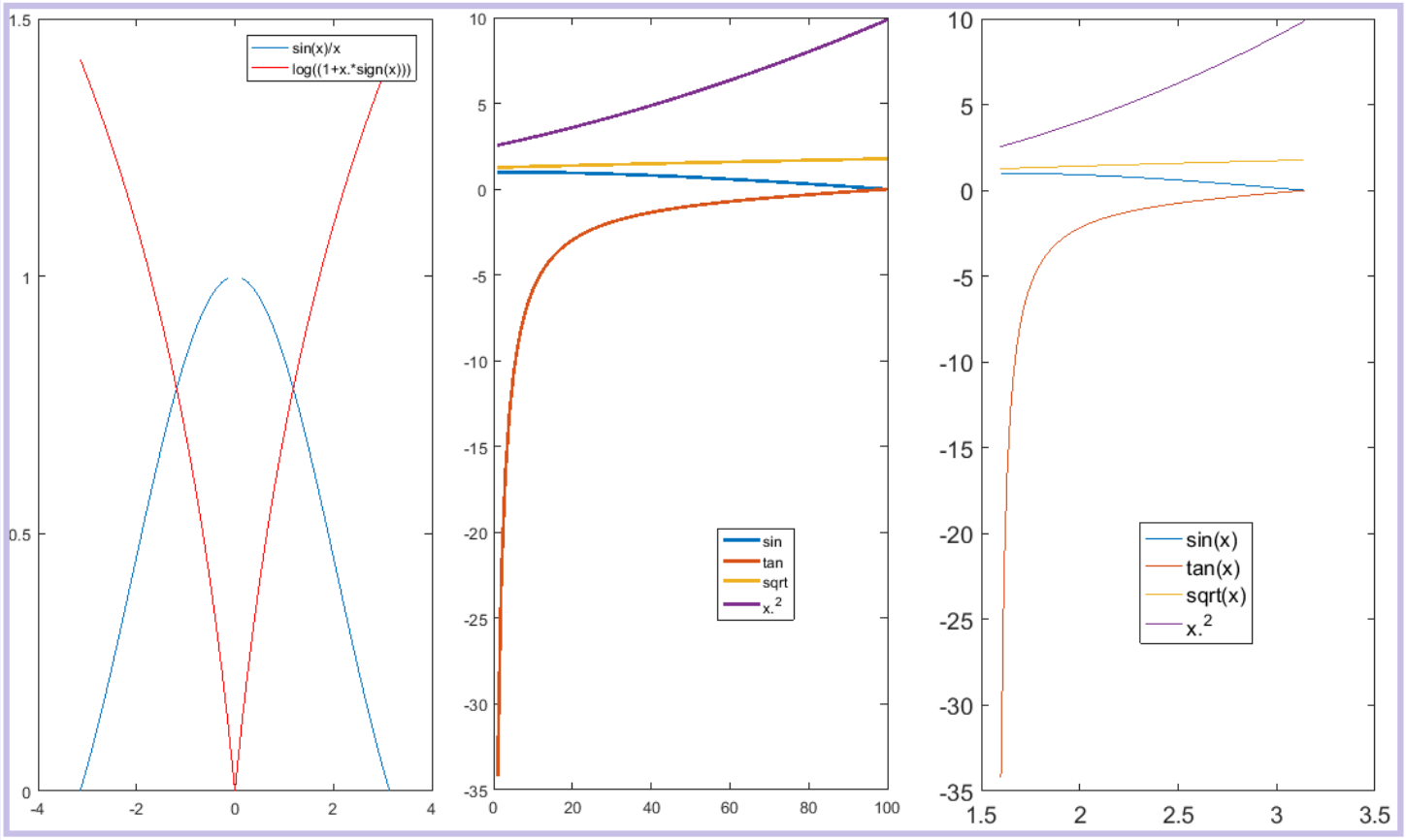
B ML:

```
>>A=[3,1,1; -1 1 0; 1, 2, -1]
>>b =[5 1 5]'
>>x=A\b   % The Gauss method or inverse division
```

Simple plots. Class Double

Graph.m

```
clear
x=-pi:pi/24:pi;
y= sin(x)./x; % element by
element (vector operation)
z=log((1+x.*sign(x)));
   subplot(1,3,1);
    plot(x,y);  hold on;
    plot(x,z,'r-');
    legend('sin(x)/x',…
       'log((1+x.*sign(x)))');
subplot(1,3,2);
% clear x % (if it needs)
x=linspace(1.6,3.1415,100); %
z=[sin(x)', tan(x)', sqrt(x)' x.^2'];
r=plot(z);
legend({'sin','tan','sqrt','x.^2'});
      subplot(1,3,3)
      plot(x,z);
      legend({'sin(x)','tan(x)',…
                'sqrt(x)','x.^2'});
      set(r(:),'linewidth',2);
      set(gca,'fontsize',14);
```



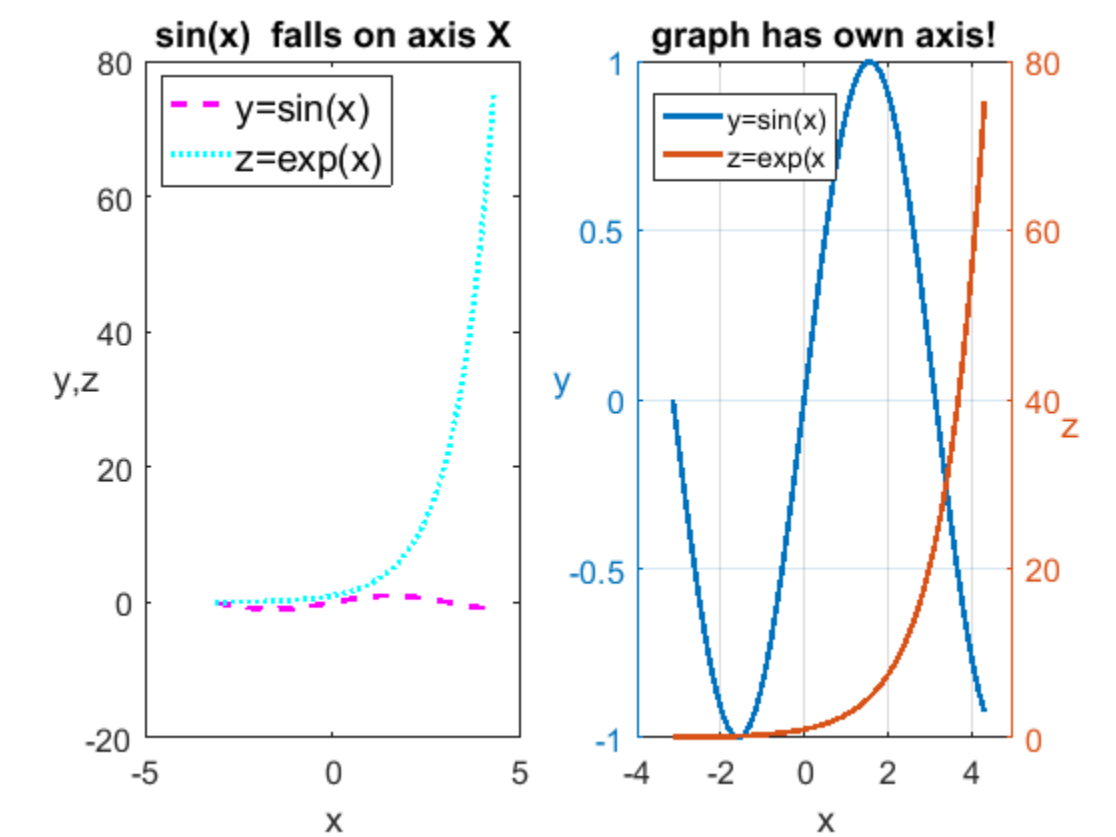
subplot(m,n,k) **%** m×n windows, k-an active;
hold on change **NextPlot** of **Figure:**
Before - **replace** (default) **; after - add**;
What is the risk?
x=linspace(a,b,n) % vector n – n points on [a,b];
gca (graphic **c**urrent **a**xes) **- an active axes**

Graphs of functions of different growth. plotyy -> yyaxis (for last versions)

DifferentIncrease.m

```
x=-pi:pi/24:1.4*pi; y= sin(x); z=exp(x);
   subplot(1,2,1);
   title('sin(x) {\it falis} on axis X')
   plot(x,y,'m--','linewidth',2);  hold on
   plot(x,z,'c:','linewidth',2);
   lg1=legend('y=sin(x)','z=exp(x)');
   lg1.FontSize=14;
   xlabel('x'),
   yl=ylabel('y,z','rotation',0),
   yl.FontSize=14
   set(gca,'fontsize',14)
subplot(1,2,2);
title('Each graph has its own vertical axis!')
[haxes,line1,line2]=plotyy(x,y,x,z);
line1.LineWidth=2;
line2.LineWidth=2;
xlabel('x');  grid on;
ylabel(haxes(1),'y','rotation',0);
ylabel(haxes(2),'z','rotation',0);
    legend('y=sin(x)','z=exp(x');
set(haxes(1),'fontsize',14);
set(haxes(2),'fontsize',14)
```

PLOT **PLOTYY**



When using the **set** and **get** commands, the *case is not specified* in the *names* of the structural fields!
In the notation ObjectPropertyName = PropertyValue, *case is important*!

String array

String Constructor – double quotes (" ")

```
1   clear
2   %% STRING Array
3   %% Creation
4   S="MEXMAT FOREVER!"
5   Sl=isletter(S);
```

```
S: 1x1 string =

    "MEXMAT FOREVER!"
```

S - СКАЛЯР!

Control of letters in a string: ISLETTER

```
5   Sl=isletter(S);
6
```

```
Sl: 1×15 logical array =

  1  1  1  1  1  1  0  1  1  1  1  1  1  1  0
```

```
S2: 2x1 string =

"MEXMAT "
"FOREVER!"
```

```
1   clear
2   %% STRING Array
3   %% Creation
4   S="MEXMAT FOREVER!"
5   Sl=isletter(S);
6   S2=split(S)    %split(S,delimiter,dim)
7   length(S2)
8   %% Edition
9   S3=S2(1)+" .SFEDU" % concatenation
10  s3=lower(S3) % S3=upper(S3) %register
11  erase(S3,' ') % S3=erase(S3,' ')
12  S3
```

Command Window

New to MATLAB? See resources

```
S3 =

    "MEXMAT .SFEDU"

s3 =

    "mexmat .sfedu"

ans =

    "MEXMAT.SFEDU"
```

SPLIT - dividing a string into elements (words), the result is a column vector of string (words); space is the default separator (see S2)

UNIQUE(STRING) - the choice of non-repeating characteristics in string

ERASE – deleting a specified element in a row (см.S3)

LOWER, UPPER – преобразование к соответствующему регистру (см.S3)

What is the result of the line number 12?

Char - character array

Char elements Constructor – single quotes (' ')

```
Command Window
>> whos
  Name      Size    Bytes  Class

  a         1x6        12  char
  b         1x1         8  double
```

Workspace

Name	Value
a	'letter'
b	1

```
2 -    a=upper('letter') % as for string
3      l=length(a);
4 -    it=a(4:end) % Total Expense Ratio
5 -    res=imag(it)
6 -    b='тот потоп'; % almost Palindrom
7 -    b1=fliplr(b)
```

```
Command Window
K>> b1
b1 = потоп тот

K>> whos b res
  Name      Size    Bytes  Class

  b         1x9        18  char
  res       1x3        24  double
```

An element of the Double class takes up 8 bytes!

What are the differences between STRING and Char?

Why does a take 12 bytes and res takes 24 bytes?

It is true for Char and String:

upper, lower – converting a string to uppercase or string (case selection)

fliplr – (flip) inversion from left to right (compare b, b1!)

A *Уверен и не реву* - palindrome[ˈpælɪndrəʊm]?

length(CHAR) ; strlength(STRING) - Number of characteristics;

>>length(**b**) % = 9;

>>strlength('TRUE') % = 4

How does **flipud** work? (Brainstorming)

It is true for Char:

eval('clc, format long, r=pi/180, phi=pi/180*30, sin(phi)')

Char , String. Editing

Conversion Cell to String and vice versa :

Help Center — mathworks.com/help/matlab/ref/string.html

Documentation | Examples | Functions | Apps | Videos | Answers

```
A = {'Mercury','Gemini','Apollo';...
     'Skylab','Skylab B','ISS'}

A = 2x3 cell
    {'Mercury'}    {'Gemini'  }    {'Apollo'}
    {'Skylab' }    {'Skylab B'}    {'ISS'   }

str = string(A),  str(1,2)

str = 2x3 string
    "Mercury"    "Gemini"      "Apollo"
    "Skylab"     "Skylab B"    "ISS"

ans =
"Gemini"
```

```
K>> A = ['Mercury','Gemini','Apollo';...
     'Skylab','Skylab B','ISS']
Dimensions of matrices being concatenated are not
consistent.
```

MercuryGeminiAppolo
SkyLab SkyLab B ISS

StrArr=string(CellChar) – StrArr has the same size as CellChar and consists of Elements of String

Str2mat (A) – Conversion Cell of Char to String (as vector column)

```
10    B=str2mat(A);
      str                    2x3 string
            B =
            Mercury
            Skylab
            Gemini
            Skylab B
            Apollo
            ISS
```

<----------What's wrong? How can we fix it?

Let's formulate a rule!

Array of Cell and Char

Combining objects of different types into a container

- C=**cell**(size) – an object of the given size is being reserved
- C={A,B,D,…} – A,B,D,… - ∀ MatLab objects

```
Command Window

C =
  2×1 cell array

  'my mind is strong'
  'my mind is resting'

TF =
  logical
   0

ans =
  logical
   1
```

```
Editor - F:\Nata\2017\Matlab 2017\2023\Лекции Work Folder\MyPresentation\L
KurbatovaStart.m | ForLecture2.m | StringChar.m

1  clear
2  %% comparisen
3  C={'my mind is strong';...
4     'my mind is resting'}
5  TF=strcmpi(C{1},C{2}) % C(1),C(2)
6  strncmp(C{1},C{2},10)
```

```
ommand Window

ind =
     4

S =

my mind is strongmy mind is restinc

ans =
  1×12 logical array

1  1  1  1  1  1  1  1  1  1  1  1
```

```
[ind]=findstr(C{1},'mind')
S=[C{1},C{2}];  CS=string(C) % Размер CS?
[Ced,ind1]=unique(S);
S(ind1)==Ced %
[Ced,ind1]=unique(CS);
```

Comparison :

- ScalarTrueOrFalse = **strcmp**(S1,S2) – comparison of characteristics in general
- **[LogicalVector]=S1==S2**; or eq(S1,S2);
- TF=s**trncmp**(S1,S2,n); % - for the first n elements
- TF=**strcmpi**(S1,S2) % full comparisen

Class CELL

cell2mat – cell to matrix

num2cell – numeric to cell

```
% Cell  Creation:
%% I)
c=cell(1,7)
[c{1:end}]=3l('O, ', ' Небо,', ' Небо,', ...
     'ты', 'мне', 'будешь', 'сниться?')
%   Compare
disp(c') ; celldisp(c) %
c{:} % each element - ans;
%% II) Assign:
c1={eye(3),'Be healthy',1:8',num2cell(2:6)}
disp(c1) % this is not good idea!
%% III) Celldisp, visualization of the cell contents
celldisp(c1)
c1{1}, c1{2}(3:end), c1{3}(5), c1{4}{3}
%% Conversion :
nc=num2cell([2 3 4;5 6 7])
nm=cell2mat(nc)
```

Examples:

```
mat =
we are
studing
MatLab
ans =
     3     7
ans = char
ans = 1
```

C:\MATLAB6p1\work\ex2.m

File Edit View Text Debug Breakpoints Web Windo

```
1 - a='we are', b='studing', c='MatLab'
2 - mat=str2mat(a,b,c), size(mat)
3 - mat2str(mat), class(mat)
4 - strcmp(mat(3,7),' ')
```

```
>> num2cell('mat')
ans =  'm'    'a'    't'
>> num2cell(mat)
ans =  'w'    'e'    ' '    'a'    'r'    'e'    ' '
       's'    't'    'u'    'd'    'i'    'n'    'g'
       'M'    'a'    't'    'L'    'a'    'b'    ' '
```

cell2mat taking into account the size of the submatrices

Ex. Пусть c – **Cell, point III**

r=cell2mat(c), % c = {[1] [2 3 4]; [5; 9] [6 7 8; 10 11 12]}

$$\begin{pmatrix} 1 & 2 & 3 & 4 \\ 5 & 6 & 7 & 8 \\ 9 & 10 & 11 & 12 \end{pmatrix}$$

String ↔Char ↔ Double ↔Cell

Charact=char(Str);

- **String new class in MatLab!**
- **Double quotes ('') is only in last versions!**
- **The CHAR class is much better** (although it depends on your goal)

CS=strsplit(S,dlm) – conversion of each word **S**, between delimiters **dlm** in S, S ∈**Char** to **CS**∈Cell; **dlm** is space default

strsplit('Диван незаразен на вид - Palindrome!'); →

```
res=double('xyz') % ASCII code
 % res=120 121 122
str2double('pi/2'); % calculate!
Charac=num2str(ClassDouble) % ∈Char
 legend(Charac)
str2double('5+0.17i')  %   5.0000 + 0.1700i
str2num(['1 2';'3 4']) %   ans =
                                1    2
                                3    4
num2str(pi,3) % ans =3.14
```

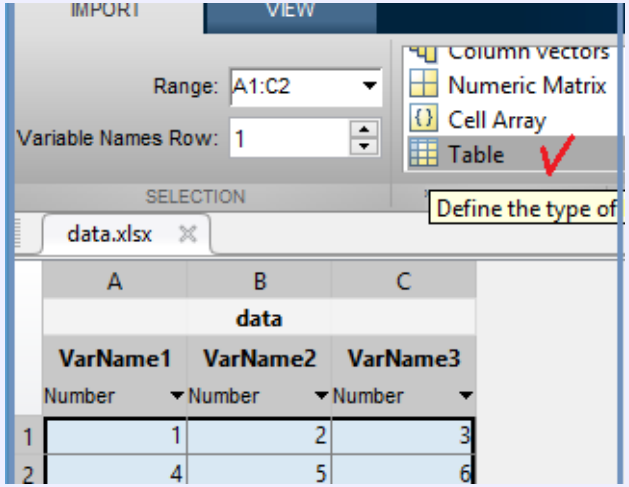
Str=string(Charact);

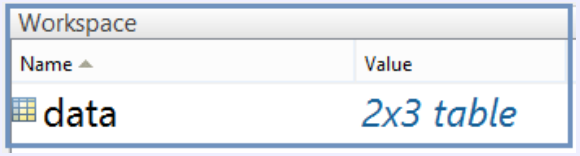
If there is not enough functionality in the CHAR class, then we convert it to the String class and vice versa!

```
ans =
        1×6 cell array
        Columns 1 through 6
'Диван' 'незаразен' 'на' 'вид'  '-' 'ПАЛИНДРОМ!'
```

I/O~ load/save

Import





Home →Import Data

Interactive download

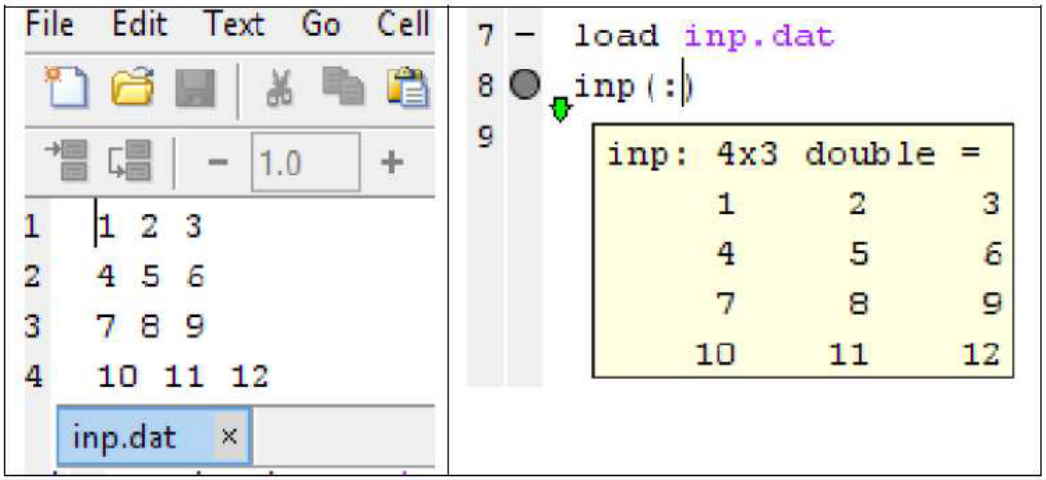
load, save:

Binary file: Nfile.mat

load Nfile Vars; **load** Nfile

Text files (saved before)

load file.txt % inp.dat



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xlsread , xlswrite (Excel)

inex.xls

	A	B
1	0,1869	0,7547
2	0,4898	0,276
3	0,6463	0,7655
4	0,7094	0,7952
5	0,7547	0,1869
6	0,6797	0,4456

Sheet1

- Here (example) without Path, file *xls (*.xlsx) in the current folder
- SheetName – name much better in English
- [STATUS,MESSAGE] =xlswrite(file,array,sheet,range), file, array – required parameters

```
10 - exmatr=xlsread('inex.xls')
11    d
12
```

```
exmatr: 6x2 double =
    0.1869    0.7547
    0.4898    0.2760
    0.6463    0.7655
    0.7094    0.7952
    0.7547    0.1869
    0.6797    0.4456
```

Download Excel table. Example

[a,b,c]=xlsread('data1.xlsx')

a – real part of input data

b – Cell array, containing untypical data

c – Cell array, combining a и b.

data1.xlsx - Microsoft Excel

	A	B	C	D
1	01.01.2023	2	3	1
2	04.01.2023	5	6	4
3	07.01.2023	7	12	0,3
4		1	2	2
5	13.01.2023	2	7	3

```
a =

    2.0000    3.0000    1.0000
    5.0000    6.0000    4.0000
    7.0000   12.0000    0.3000
    1.0000    2.0000    2.0000
    2.0000    7.0000    3.0000
```

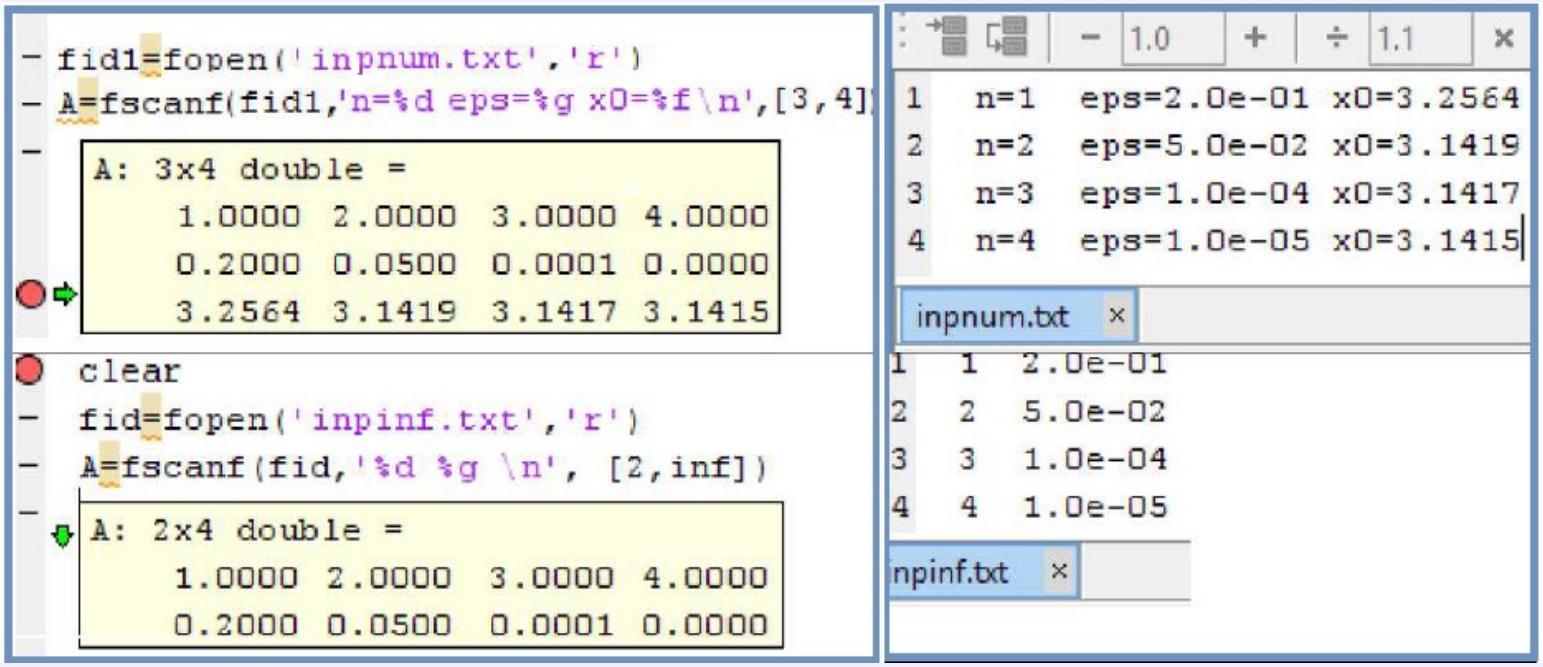
```
b =
  5×1 cell array
    '01.01.2023'
    '04.01.2023'
    '07.01.2023'
    ''
    '13.01.2023'
```

```
c =
  5×4 cell array

    '01.01.2023'    [2]    [ 3]    [     1]
    '04.01.2023'    [5]    [ 6]    [     4]
    '07.01.2023'    [7]    [12]    [0.3000]
    [       NaN]    [1]    [ 2]    [     2]
    '13.01.2023'    [2]    [ 7]    [     3]
```

fscanf, fprintf (formatted text)

Fid=fopen(name, opts)
A=fscanf(Fid, format, [m,n]) % [m,n] – size A
fclose(fid);
if n=inf, then read into m row until the columns are exhausted



Опции форматированного I/O

\n	Переход на новую строку
\t	Горизонтальная табуляция
\b	Возврат назад на один символ
пробелы в строке формата записываются как пробелы	

%c	Последовательность символов
%d	Десятичные числа
%e,%f,%g	Числа с плавающей запятой
%i	Целое число со знаком
%o	Восьмеричное целое число со знаком
%s	Ряд символов без пробелов
%u	Десятичное целое число со знаком
%x	Шестнадцатеричное целое число со знаком

Topics Help:

https://www.mathworks.com/help/matlab/matlab_prog/formatting-strings.html

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Thanks for your attention!

“Как бы медленно ты ни шёл, не останавливайся!”
孔子 *(Конфуций)*

No matter how slow you walk, don't stop!