Matlab, Introduction

Resources:

1. Matlab Guide D.J.Higan,N.J.Higan, SIAM, 2000.
Intro to Matlab 6.0.
2. Matlab Primer, See web page of course18.354: old Matlab 3, but short and clear introduction.
3. Matlab on Athena (MIT computer services web page).
4. www.mathworks.com, Matlab online documentation: answers most of the questions.
5. Mastering Matlab 6, D.Hanselman, B.Littlefield, Prentice Hall 2001, comprehensive tutorial & reference, good after one of 1, 2, 3.
6. Lecture notes: 10.001 web page.

Main Features of Matlab

- Matlab = matrix laboratory, matrix oriented.
- Any variable is an array by default, thus almost no declarations. All variables are by default double.
- High level language: (i) quick and easy coding

  (ii) lots of tools (Spectral Analysis, Image Processing, Signal Processing, Financial, Symbolic Math etc.)

  (iii) relatively slow
- All Matlab functions are precompiled.
- One may add extra functions by creating M-files.

Main Features of Matlab

¥ Translator - interpreter: line after line, no `exe` files, does not reevaluate old variables (example)

```
>> a = 2
a =
     2
>> b = 3 * a
b =
     6
```

```
>> a = 4
a =
     4
>> b
b =
     6
```

`a` has been changed, but `b` has not been reevaluated!

Comparison with C.

- Syntax is similar
- Language structure is similar to C:
  - MATLAB supports variables, arrays, structures, subroutines, files
  - MATLAB does NOT support pointers and does not require variable declarations

Matlab, Getting Started

1. Accessing Matlab on Athena:

```
add matlab
matlab &
```

2. Log out: `quit` or `exit`

Useful hints and commands:

¥ input: `variable_name` ->
  output: `variable_value`

¥ semicolon atthe end will suppress the output

Useful Hints & Commands

- command history: upper & lower arrows,

  also command name guess:

  (i) type `abc`

  (ii) hit "upper arrow" key -> get the last command starting from `abc`

- `format compact` - no blank lines in the output

  `format loose` - back to default

- `help commandname` - info on `commmandname`

Workspace Maintenance

- `clear all` - clears all the memory (workspace)
  `clear xyz` - removes `xyz` from the memory
- `who` - lists all the variables from the workspace
- `whos` - also gives the details

```
>> who
Your variables are:
ans         c1          c2
>> whos
Name  Size     Bytes   Class
ans    1x1      8      double array
c1     1x1     16      double array(complex)
c2     2x2     64      double array(complex)
```

Workspace Maintenance

- `save` saves all workspace variables on disk in file `matlab.mat`
- `save filename x y z` - x, y, z are saved in file filename.mat
- `load filename` - loads contents of the filename.mat to the workspace
- `load filename x y z` - loads only x, y, z from filename.mat to the workspace
- Each array requires a continuous chunk of memory; use `pack` for memory defragmentation.

Dealing with Matrices

Entering matrices by explicit list of elements:

```
A =[1 2 3]
A=
     1   2   3
```

```
A = [1; 2; 3]
A=
     1
     2
     3
```

```
A = [1 2 3; 4 5 6; 7 8 9]
or
A=[1 2 3
     4 5 6
     7 8 9]
```

Spaces separate the elements, semicolons and Ònew lineÓ symbols separate the rows.

Dealing with Matrices

Complex matrices:

```
either A=[1 2; 3 4]+i*[5 6; 7 8]
or      A=[1+5i 2+6i; 3+7i 4+8i]
```

No blank spaces, i or j stands for Òimaginary oneÓ.

Matrix and array operations.

`+` `-` } element-wise (array operations)

`*` `^` } array or matrix operations

Ô conjugate transpose
\ left division
/ right division
} only matrix operations

Dealing with Matrices, Examples

```
>> C = A + B;
C(k,l) = A(k,l) + B(k,l)

>> C = A*B;
C(k,l) = A(k,m) * B(m,l)

>> C = A.*B
C(k,l) = A(k,l)*B(k,l)

>> C = A^alpha;
>> C = A.^alpha;
C(k,l) = A(k,l)^alpha
```

Matrix multiplication, summation over the repeating index is implied.

Element-wise (array) operation

Dealing with Matrices

Conjugate transpose: swaps the indices and changes the sign of imaginary part of each element.

C = AÕ

C(i,j) = real(A(j,i)) - i * imag(A(j,i))

x = A \ b (left) A * x = b A-square matrix, b -column vector
x = b / A (right) x * A = b

Colon notation: used to construct vectors of equally spaced elements:

```
>> a = 1:6
a =
    1  2  3  4  5  6
```

```
>> b = 1:2:7
b =
    1  3  5  7
```

Dealing with Matrices

Submatrices:
`A(1:4,3)` - column vector, first 4 elements of the 3-d column of A.
`A(:,3)` - the 3-d column of A
`A(:,[2 4])` - 2 columns of A: 2-d & 4-th.

Standard math. functions of matrices operate in array sense:
exp(A), sin(A), sqrt(A) = A.^0.5

>> B = exp(A)
B(i,j) = exp(A(i,j))

Relational & Logical Operators & Functions

True: non-zero, false: zero.

Relational: <, <=, >, >=, ==, ~=.

Operate on matrices in elementwise fashion:

```
>> A = 1:9, B = 9 - A
A = 1 2 3 4 5 6 7 8 9
B = 8 7 6 5 4 3 2 1 0
>> tf = A > 4
tf = 0 0 0 0 1 1 1 1 1
>> tf = (A==B)
0 0 0 0 0 0 0 0 0
```

Relational & Logical Operators & Functions

Logical: & AND; | OR; ~ NOT.

```
>> tf = ~(A>4)
tf  = 1 1 1 1 0 0 0 0 0
>> tf = (A>2) & (A<6)
tf = 0 0 1 1 1 0 0 0 0
```

Functions: `xor(x,y)` - exclusive OR, true if either x or y is non-zero, false of both are true or false.

`isempty` - true for empty matrix

`isreal, isequal, isfinite,...`

Flow of Control

For loops. Syntax:

```
for x = array
    (commands)
end
```

Example:

```
>> for n = 1:10
        x(n) = sin(n*pi/10);
   end
```

Flow of Control

Nested loops, decrement loop.

```
>> for n = 1:5
       for m = 5:-1:1
           A(n,m) = n^2 + m^2;
       end
   end
```

Alternative: *vectorized* solution, much faster: assigns memory for x only once.

```
>> n = 1:10;
>> x = sin(n*pi/10)
```

Flow of Control

While loops. Syntax:

```
while expression
    (commands)
end
```

`(commands)` will be executed as long as all the elements of `expression` are true.

Example: search for the smallest number EPS which if added to 1 will give the result greater than 1.

Flow of Control

```
>> num = 0; EPS = 1;
>> while (1+EPS)>1
       EPS = EPS/2;
       num = num+1;
    end
>> num
num = 53
>> EPS = 2*EPS
EPS = 2.2204e-16
```

Flow of Control

If-Else-End constructions. Syntax:

```
if expression1
    (commands1: if expr-n1 is true)
elseif expression2
    (commands2: if expr-n2 is true)
elseif expression3
    (commands3: if expr-n3 is true)
  . . . . . .
else
    (commands: if 1,2,..,n are false)
end
```

Flow of Control

Breaking out of the loop:

```
>> EPS = 1;
>> for num = 1:1000
       EPS = EPS/2;
       if (1+EPS)<+1
       EPS = EPS*2
       break
    end
EPS = 2.2204e-16
```

M-files

Script files & Function files

Script files: contain a set of Matlab commands - programs.
To execute the file: enter the file name.

```
% script M-file example.m
erasers = 4; pads = 6; tape = 2;
items = erasers + pads + tape
cost = erasers*25 + pads*52 + tape*99
average_cost = cost/items

>>example
items =  12
cost = 610
average_cost = 50.833
```

M-files

Interpreter actions while processing `example` statement:

1. Is `example` a current Matlab variable?
2. Is `example` a built-in Matlab command?
3. Is Example an M-file?
4. Opens the file and evaluates commands as if they were entered from the command line.

Thus: (i) all workspace variables are accessible to the commands form the M-file.
(ii) all variables created by M-file become a part of the work space.

M-files

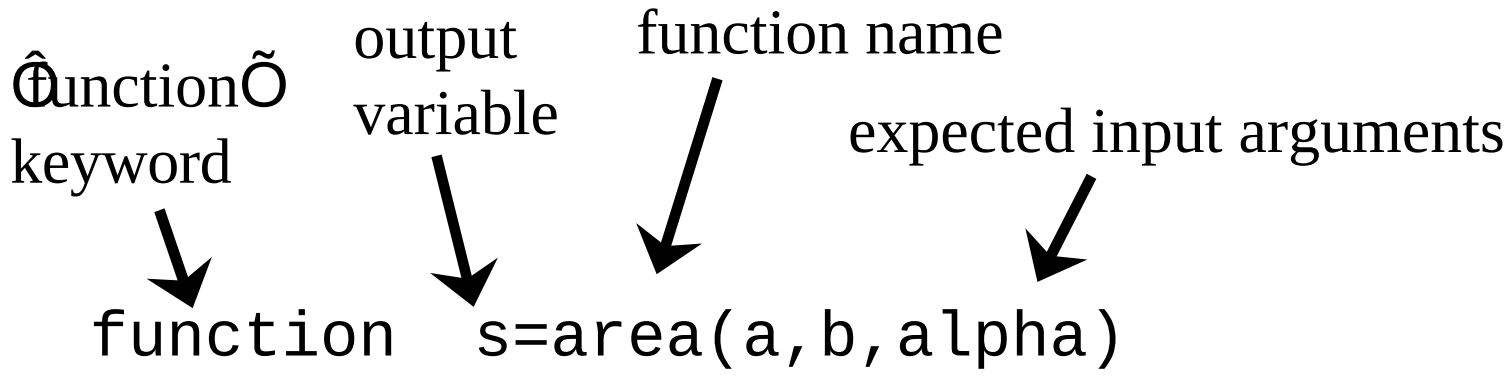
Function files

¥ Analogous to functions in C.

¥ Communicate with the workspace only through variables passed to it and the output variables it creates. All internal variables are invisible to the workspace.

¥ M-file's name = function's name.

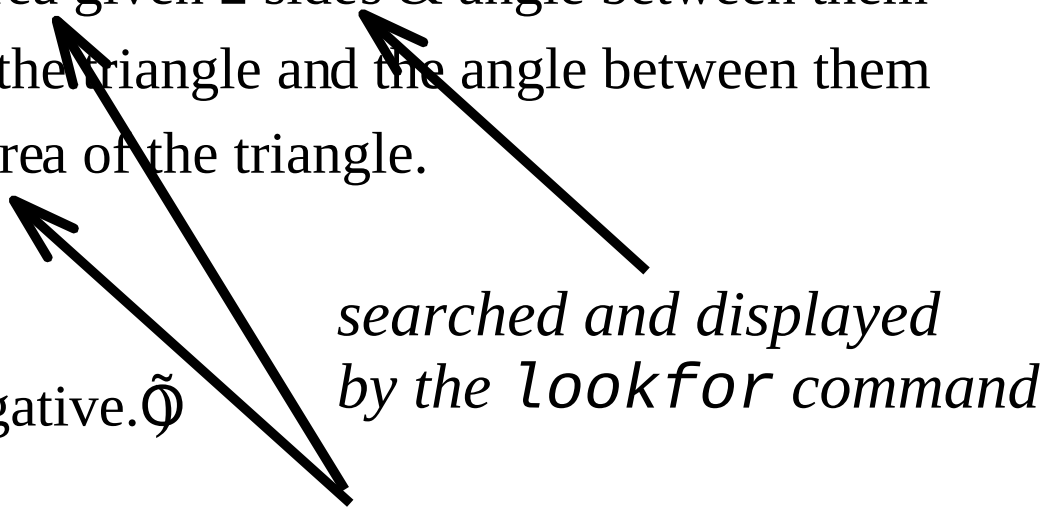
¥ The first line - ***function-declaration line***



Function M-files

```
function s=area(a,b,alpha)
%AREA calculates triangle's area given 2 sides & angle between them
% AREA reads in two sides of the triangle and the angle between them
% (in radians) and returns the area of the triangle.


if a < 0 | b<0
    error('a and b can not be negative.')
end
s = a*b*sin(alpha)/2;
```



searched and displayed by the `lookfor` command

searched and displayed by the `help` command

Function M-files

- Function M-files may call script files, the script file being evaluated in the workspace.
- F. M-files can have zero input and output arguments.
- Functions may share variables. The variable must be declared as `global` in each desired workspace.
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