Introduction in MATLAB (TSRT04)

2020

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`www.commsys.isy.liu.se/en/student/kurser/TSRT04`

MATLAB Basics

Vectors and Matrices

Using Built-In Functions

Scripts and Functions

Visualization

Control Structures

Summary

What is MATLAB?

MATrix LABoratory (MATLAB)

- Advanced calculator for technical computing
- Simple but powerful programming language
- Numerical calculations (not symbolic as Mathematica)
- Available for Windows, Mac, Linux
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- Pros: Many examples and toolboxes for various topics (e.g., math, statistics, optimization, telecom, control, biology, finance)
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- **GNU Octave:** Open source option — MATLAB compatible

My research: 5G Wireless Communications

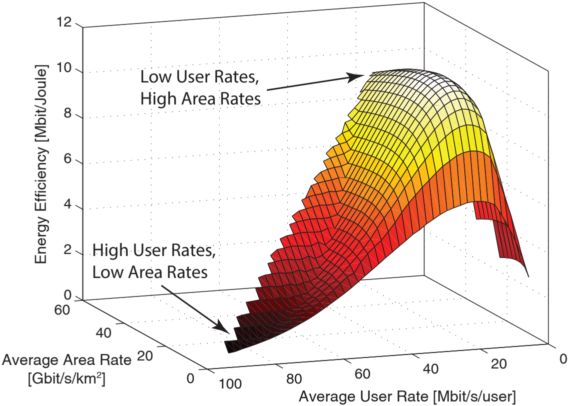
Goal: Develop design principles for the next generation cellular networks.

Understand interplay between

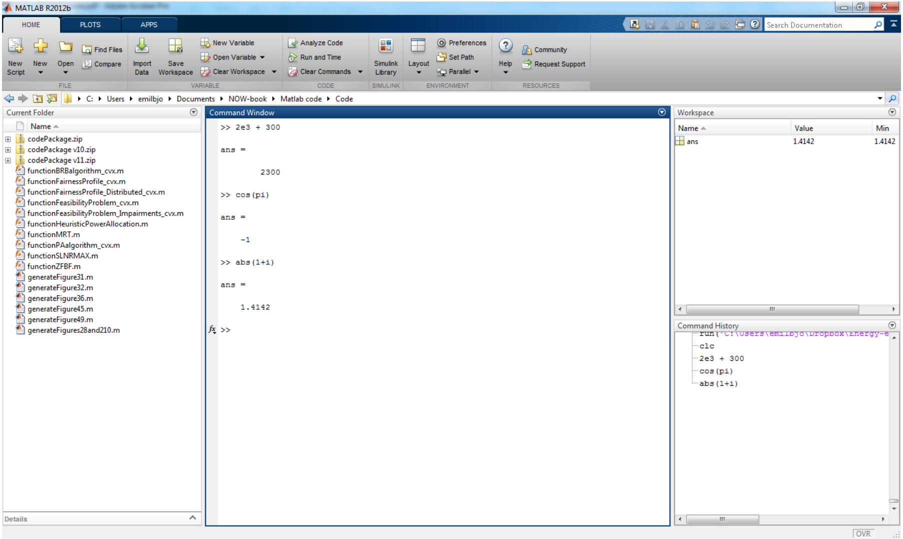
- Data rate per user (bit/s/user)
- Area data rate (bit/s/km^2)
- Energy efficiency (bit/Joule)

Role of MATLAB:

- Test models
- Develop algorithms
- Visualize tradeoffs



MATLAB Interface



Current Folder

- Name
- codePackage.zip
- codePackage v10.zip
- codePackage v11.zip
- functionBRBalgorithm_cvx.m
- functionFairnessProfile_cvx.m
- functionFairnessProfile_Distributed_cvx.m
- functionFeasibilityProblem_cvx.m
- functionFeasibilityProblem_Impairments_cvx.m
- functionHeuristicPowerAllocation.m
- functionMRT.m
- functionPAalgorithm_cvx.m
- functionSLNRMAX.m
- functionZFBF.m
- generateFigure31.m
- generateFigure32.m
- generateFigure36.m
- generateFigure45.m
- generateFigure49.m
- generateFigures28and210.m

Command Window

```
>> 2e3 + 300

ans =

        2300

>> cos(pi)

ans =

    -1

>> abs(1+i)

ans =

    1.4142

>>
```

Workspace

Name	Value	Min
ans	1.4142	1.4142

Command History

```
run('C:\Users\emilbjo\Dropbox\Energy-e
clc
2e3 + 300
cos(pi)
abs(1+i)
```

MATLAB as Pocket Calculator

Use *Command Window* as a scientific pocket calculator

- Simple numbers: `30`, `pi` (π), `1e2` ($1 \cdot 10^2$)
- Simple operators: `+ - / *`
- Simple functions: cosine ($\cos()$), absolute value ($\text{abs}(\cdot)$)

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- A “container” to save values in.
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(That to the right of $=$ is computed first, and the result stored in `b`.)

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What is the result of:

```
>> a = a + 2
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What is the result of:

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a = 7
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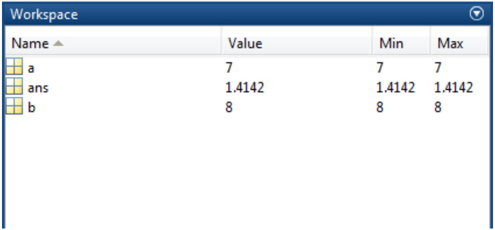
Workspace

Variables are stored in the “Workspace”, cf., a filing cabinet.



Workspace

Name	Value	Min	Max
a	7	7	7
ans	1.4142	1.4142	1.4142
b	8	8	8

Investigate your workspace

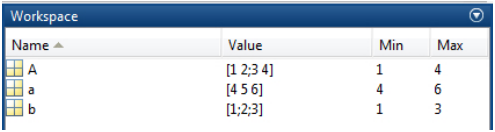
- If you don’t give a variable name: Result is stored in `ans`
- You can click on variables in workspace to find out more.
- You can list all available variables with `>>whos`.

Vectors and Matrices

Vectors and matrices are a fundamental to MATLAB.

- $a = \begin{bmatrix} 4 & 5 & 6 \end{bmatrix}$ is written as `>>a = [4 5 6]` (or `[4, 5, 6]`)

These are stored in Workspace — just as any variable:



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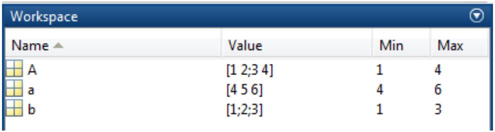

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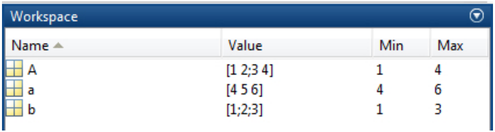

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- `>>C = eye(2)` yields $C = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$.

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- `>>y = 2:3:11` yields $y = \begin{bmatrix} 2 & 5 & 8 & 11 \end{bmatrix}$.

Matrix Operations

Original purpose of MATLAB: Matrix operations

- Define matrices:

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>> A = [1 2; 3 4];
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>> A*B
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- Similar: `^2` vs. `.^2`, and `/` vs. `./`

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>> A(1,2)

ans =  5
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$$A = \begin{bmatrix} 3 & 5 & 2 \\ 7 & 8 & 6 \end{bmatrix}$$

How to find a function?

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General documentation:

- “doc” opens up the MATLAB documentation
- “help” gives a list of “toolboxes” (collections of commands organized by usage)

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Strong recommendation:

- Always use scripts!
- Easy to reproduce result and write documentation.
- Easy to make small changes and rerun everything.

Example: Script

Lina has run 5 km in 23 min and 15 s.

- She wants to compute the time per km.
- She wants to do the same thing next week.

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m-file computeRunPace.m

```
distance = 5; % Distance in km
minutes = 23; % Total time expressed in
seconds = 15; % minutes and seconds

% Compute time per km in minutes:
totalminutes = minutes + seconds/60;
minperkm = totalminutes/distance
```

Scripts vs. Functions

Nature of scripts

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Nature of functions

- Another concept: Have their own local Workspaces.
- Works just like MATLAB's own functions.
- Excellent way to reusing the same code multiple times.

Example: Function

m-file computeRunPace.m

```
function minperkm = computeRunPace(dist, min, s)
% Computes the time per km in minutes, given
% the distance and the total time expressed
% in minutes and seconds.

  totalMinutes = min + s/60;
  minperkm = totalMinutes/dist;
end
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- `function` — indicates the beginning of a function

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- *function name* — should be the same as the m-file name

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- *input* — data needed by the function

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```matlab
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% Computes the time per km in minutes, given
% the distance and the total time expressed
% in minutes and seconds.

  totalMinutes = min + s/60;
  minperkm = totalMinutes/dist;
end
```

- *output* — result delivered by the function

Example: Function Execution

```
>>
```

Workspace:
MATLAB

m-file computeRunPace.m

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Combine Scripts and Functions

Functions

- Create functions whenever a certain “algorithm” or multi-row computation takes place more than once
- Built-in MATLAB functions are written in this way (write `type functionName` to see)

Scripts

- Define input values
- Call different functions
- Process and visualize output from functions

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This is how I work

- Check out my MATLAB code: https://github.com/emilbjornson/
- I publish research code online — simple reproducibility

Visualization

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figure; % Open a new figure ready for plotting
plot(x,y) % Plot y as a function of x
xlabel('x') % Give a name to the horizontal axis
ylabel('y = sin(x)') % Give a name to the vertical axis
title('My first plot') % Give a name to the whole figure
```

Visualization: Many types

Many functions for plotting data:

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Use `help` to read more!

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Use `help` to read more!

Adapt plots:

- Almost everything can be tailored.
- Use the “Property Editor” in menu “View” of a figure

Control Structures

Some “behaviors” depend strongly on the input:

- Does your bank account have enough money or not?

Some pieces of code is repeated:

- Do you need to run the same lines of code multiple times?
- Do you know how many times in advance?

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MATLAB has several *control structures*:

- if statements
- while loops
- for loops

These are similar to other programming languages.

if Clauses

General syntax:

```
if condition
  % statements/commands if condition is true
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Writing conditions using logics

- Use operators such as: `>` `>=` `==` `&&` `||` `~=` `<` `<=`
- Suppose `savings` is a variable with the amount on your bank account.
- Examples: `savings >= 0`, `(savings >= 0) || (salary > 35000)`

Example: if Clauses

Example

A bank account has 2% interest on savings and charges 14% interest for credits. Write a function to compute the interest given an amount.

Example: if Clauses

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A bank account has 2% interest on savings and charges 14% interest for credits. Write a function to compute the interest given an amount.

m-file computeBankInterest.m

```
function interest = computeBankInterest(amount)
% Computes annual interest for a given amount

if amount >= 0
  interest = 0.02*amount;
else
  interest = 0.14*amount;
end

end
```

Guard Towards Errors

If statements can be used to avoid unexpected behaviors

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if imag(amount) ~= 0
  error('There is no imaginary money!');
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Guard Towards Errors

If statements can be used to avoid unexpected behaviors

- Example: `computeBankInterest(amount)` cannot handle complex numbers
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if imag(amount) ~= 0
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```

- `imag()` gives the imaginary part of a scalar/vector/matrix
- `error()` displays an error message
- Text strings are written as `'message'`
- Alternative: `disp()` displays a non-error-related message

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- Repeat similar computations *while* a condition is fulfilled
  - Condition is checked only at beginning of each loop
  - Be sure that the condition will eventually be false — otherwise the loop runs forever!

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Example: while Loops

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Suppose you have borrowed 1 million kr from the bank. The bank charges 0.25% interest per month. You amortize 5,000 kr per month. How many months will it take to repay the loan?

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m-file predictLoan.m

```
currentLoan = 1e6; % The initial loan is 1,000,000 kr
monthlyPayment = 5000; % You pay 5000 kr each month
montlyInterest = 0.0025; % The bank charges 0.25% per month
monthNumber = 0; % Keep track of month number

while currentLoan >= 0
  currentLoan = currentLoan + currentLoan*montlyInterest; %Apply interest rate
  currentLoan = currentLoan - monthlyPayment; %Reduce loan by monthly payment
  monthNumber = monthNumber + 1;
end

% monthNumber will now contain the month when you have repaid your loan
% Be sure that monthlyPayment > currentLoan*montlyInterest, otherwise it never stops!
```

for Loops

- If you know how many time to repeat commands
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  - More compact to use `for`-loops instead of `while`
- General syntax:

```
for var = vector with values
  % statement/commands to be repeated
end
```

Example: for Loops

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Suppose you start saving 500 kr per month when your kid is born. The monthly interest is 0.17% (2% per year). How much will the kid have at the age of 18?

Example: for Loops

Example

Suppose you start saving 500 kr per month when your kid is born. The monthly interest is 0.17% (2% per year). How much will the kid have at the age of 18?

m-file predictSavings.m

```
currentSaving = 0; % Bank account is empty in advance
monthlySaving = 500; % You save 500 kr per month
montlyInterest = 0.0017; % The bank interest is 0.17% per month

numberOfMonths = 12*18; % Compute number of months before turning 18

for index = 1:numberOfMonths
  currentSaving = currentSaving + currentSaving*montlyInterest; %Apply interest rate
  currentSaving = currentSaving + monthlySaving; % Add monthly saving
end

% currentSaving will now contain the savings at the age of 18
```

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- MATLAB is useful in many different computations
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- Choose variable names carefully — and write comments
- Use scripts and functions, it *will save you time*
- Control statements:
  - `if` statements — do different things depending on a condition
  - `for` loops — repeat computations for a predetermined set of values
  - `while` loops — repeat computations until a condition is no longer fulfilled
- Make use of the help system to extend your knowledge!!!

Good luck with the course!

Have fun with MATLAB!

Learn by exploration!