Introduction to MATLAB/Octave programming: Fundamentals

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Outline of Topics

What is it?

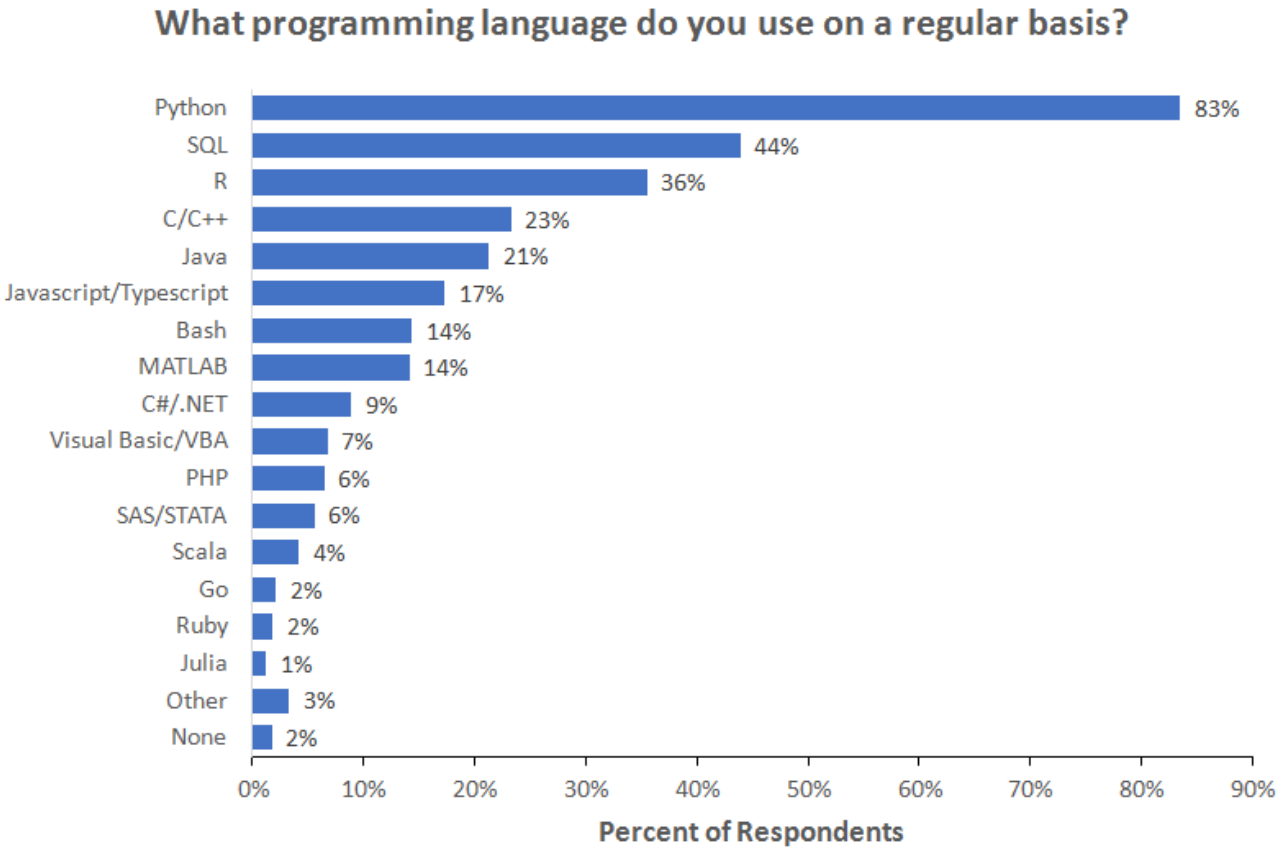
- A humble origin: an interactive matrix calculator for students.
- Now more than 1 million users
- Used in engineering, science, and economics, etc.
- "*A high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numerical computation.*" – Matworks

Why Matalb?

- Faster algorithm development than other languages
- Concise matrix notation and great matrix manipulation.
- Easy visualisation, debugging and code optimisation.
- Many core mathematical, engineering, and scientific functions
- Widely used in science, engineering and education and good community support. Example: Stanford's Machine learning module used Matlab/Octave

Why Matalb?

Widely used in data science



Note: Data are from the 2018 Kaggle Machine Learning and Data Science Survey. You can learn more about the study here: http://www.kaggle.com/kaggle/kaggle-survey-2018. A total of 18827 respondents answered the question.

Free Matlab and GNU Octave

- Problem of Matlab: expensive commercial software
  - Solution 1: Use UoB's Matlab site license
  - Solution 2: **GNU Octave**, an opensource alternative to Matlab, download it from here

The most useful command in MATLAB

```
>> help
```

or Google

The heart of MATLAB: matrices

- MATLAB stands for "matrix laboratory".
- The basic data type is matrix (including vectors).
- Matrix operations: create, access, modify and manipulate matrices
- Matrix operation is very fast in MATLAB – try to avoid for-loops

Creating Matrices

- Create an empty matrix:
```
>> A = []
```
- Enter data directly:
```
>> A = [1 1; 2 3; 4 5]
```
- If you know the pattern of your matrix:
```
>> A =[1:2:100]
```
- A lot of functions to create specific matrices: `zeros()`, `ones()`, `rand()`, `eye()`
- Let's try code examples (Matrix creation)

Transposing and concatenating matrices

- To transpose matrix A, use the transpose operator '

```
>> B = A'
```

- To concatenate matrix, enclose them inside of square brackets.

```
>> C = [A; 6 7]
```

Indexing

- To extract individual entries from a matrix, use indices inside round brackets:

```
>> A(1,2)
```

- Use the ':' operator to extract all entries along a certain dimension:

```
>> A(1,:)
```

- Use 'end' statement to get the last index of a dimension:

```
>> A(end,1)
```

- Use logical indexing to find specific entries:

```
>> A(A>2)
```

- We can also use `find()` function to find specific entries:

```
>> A(find(A>2))
```

- Let's try code examples (Matrix operations)

Assignment and deletion

- To change entries in the matrix, using indexing to specify the entries and assign new values:

```
>> A(1,2) = 100
```

```
>> A(:,1:3:end) = 100
```

- To delete entries, assign '[]' :

```
>> A(1,:)  = []
```

- For a matrix, you can only delete column(s) or row(s)
- For array (1D matrix), you can delete any entries.

```
>> A(3) = []
```

- Let's try code examples (Matrix assignment and deletion)

Sorting

- We can also sort the elements in a matrix, by default in an ascending order
- For example, to sort an array:
```
>> A = [9 0 -7 5 3 8 -10 4 2]
>> B = sort(A)
```
- For example, to sort a matrix by row, i.e., to sort each of its rows in ascending order:
```
>> A = [3 6 5; 7 -2 4; 1 0 -9]
>> B = sort(A,2)
```
- You can also get the arrangement of the elements of A into B along the sorted dimension, i.e., the index of the sorted element of the previous unsorted matrix:
```
>> A = [9 0 -7 5 3 8 -10 4 2]
>> [B, idx] = sort(A)
```
- Let's try code examples (Matrix assignment and deletion)

Matrix manipulations

- We can perform matrix addition, subtraction, multiplication, exponentiation, etc.
- For example, matrix multiplication of an m-by-n matrix and an n-by-p matrix yielding an m-by-p matrix:

```
>> C = A*B
```

- We can do element-wise matrix arithmetic by using '.' precede the arithmetic operator

```
>> A = rand(3,3)
>> B = rand(3,3)
>> D = A.*B
```

- For element-wise arithmetic operation, both matrices must be the same size.
- Let's try code examples (Matrix manipulation)

Flow of Control

MATLAB only has the following statements:

- `if, else, elseif`
- `switch statements`
- `for loops`
- `while loops`
- `try/catch statements`

Scripts and functions

- We can use MATLAB editor to edit/save/load/exceute your programs.
- Two types of MATLAB programs: scripts and functions.
- A script is a collection of Matlab commands.
- The commands in the script are executed exactly as at the command prompt.
- However, scripts:
  - No lexical scoping, that is, the variables in scripts are global. We cannot reuse the same variable name multiple times.
  - Cannot be parameterize to be called multiple times with different inputs.
  - Difficult to read and understand.
  - Slow.

Creating functions

- Open a new file in MATLAB editor, or type: `edit filename.m` at the command prompt.
- In you m file, begin by creating the function header:
  `function [output1 ,output2, output3...] = myfunction(input1, input2...)`
- We can use the inputs as local variables.
- All variables are local in a function.
- We must assign values to each of the outputs before the function terminates.
- Although optional, it is better to end the function with the "`end`" keyword
- Let's try code examples (MATLAB function example).

Functions: other issues

- The functions must located in the directories of the command path, or under the current working directory.
- Use "%" for comments
- We can have multiple functions in a .m file
- We can pass functions as inputs to other functions by creating handle to the function and then pass the handle as a variable.

```
>> x = fminbnd(@humps, 0.3, 1)
```

- We can create anonymous functions without having to store your function to a file each time:

```
>> fhandle = @(arglist) expr
```

```
>> sqr = @(x) x.*x;
```

1D/2D plots

- To plot 1D and 2D data, we use `plot(y)`.
- If y is a vector: a piecewise linear graph of the elements of y versus the index of the elements of y
- If y is a matrix: `plot(y)` will automatically cycle through a predefined (but customizable) list of colors to allow discrimination among sets of data
- If we specify two vectors as arguments, plot(x,y) produces a graph of y versus x.
- Use `hold on` command to superimpose all the plots onto the same figure. Use `hold off` to disable.

3D plots

- To plot 3D lines: `plot3(X1,Y1,Z1)`
- To plot 3D shaded surface: `surf(X,Y,Z)`
- You can also specified shading property: shading flat/faceted/interp
- To plot 3D mesh: `mesh(X,Y,Z)`
- To plot contour lines: `contourf(X,Y,Z)`

Customise plots

- Multiple subfigures: `subplot(nr,nc,i)`
- Title: `title('you title')`
- Axis labels: `xlabel('x'); ylabel('y'); zlabel('z')`
- We need to get handle of a figure
  - Handle of the current figure: `gcf()`
  - Handle of the current set of axes: `gca()`
- To access specific properties: `get(handle,'property')`
- To change specific properties: `set(handle,'property1', value1, 'property2', value2, ...)`
- Let's try code examples (Plot example).

Now let's complete the exercises