Ulster University

Introduction to MATLAB

M M Manjurul Islam

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Aim

- **To understand and manipulate introductory features and functions for programming in MATLAB.**
- **Simulating a simple neuron model using the Leaky Integrate-and-Fire (LIF) model.**

What is Matlab?

Why do I need to learn ‘it’?

Because the course leader said so…

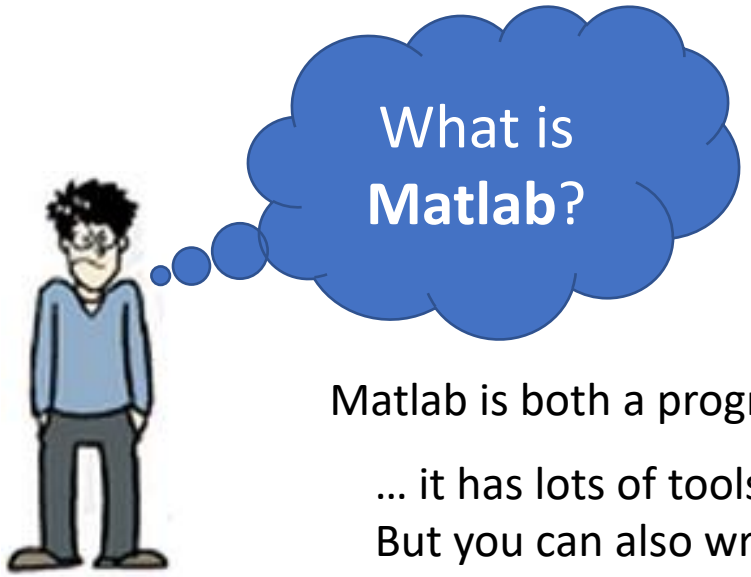
What is MATLAB?

- MATrix LABoratory program (MATLAB), a high-level programming language and environment, initially written for scientists and engineers (in industry and academia) with interactive access to numerical computation libraries, and use matrix based techniques to solve problems without having to write programs in traditional languages e.g. C and Fortran.

- Now, MATLAB is a commercial (needs license) software package that operates as an interactive programming environment with graphical output, including creation of user interfaces. Used in Windows, UNIX, OSX, etc environments, and interfacing with C, C++, C#, Fortran, Java, Python, etc.

- MATLAB is primarily for numerical computing, and assumes almost every data object to be an array (ie. a matrix). But MuPAD allows symbolic computing, and Simulink allows graphical multi-domain simulation and model-based design for dynamic and embedded systems.

https://uk.mathworks.com/
https://en.wikipedia.org/wiki/MATLAB

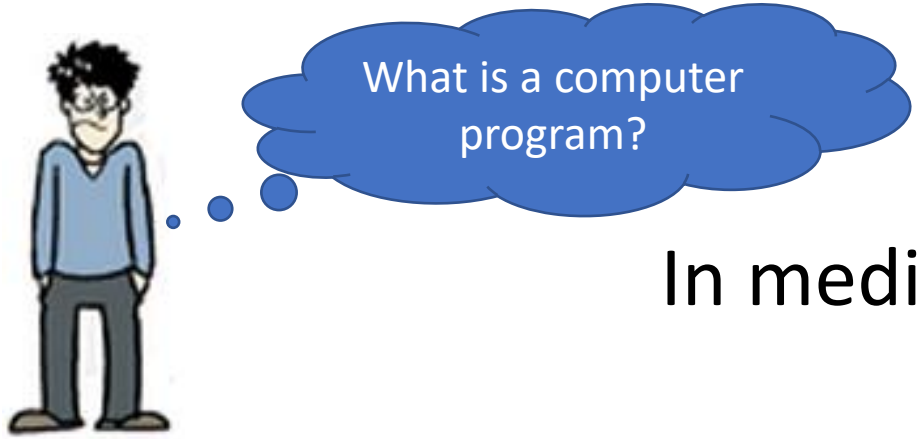


Matlab is both a program and a programming language ...

… it has lots of tools you can just use to analyse data and images. But you can also write code to extend it to do any analysis you like (although unlike a 'pure' language, it will only work if the Matlab program is installed on the computer).

Excel + Photoshop + Using other people's code + Writing your own code

= A really powerful tool for imaging research!



In medical imaging…

DATA

Image(s)

Lab results

Patient data

PROGRAM

Do something clever…

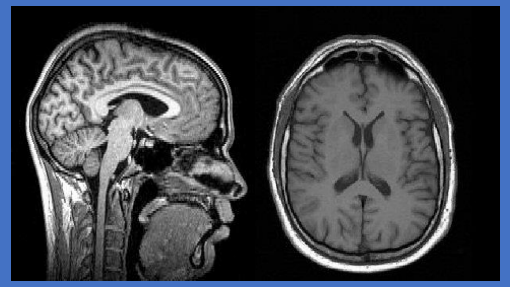
RESULT

Hopefully clinically useful!

What is a computer program?

In medical imaging…

DATA



MR images of the brain

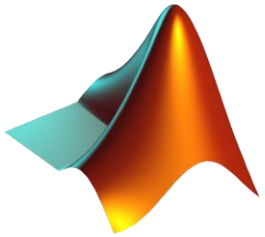
PROGRAM

Measure volume of grey/white matter…

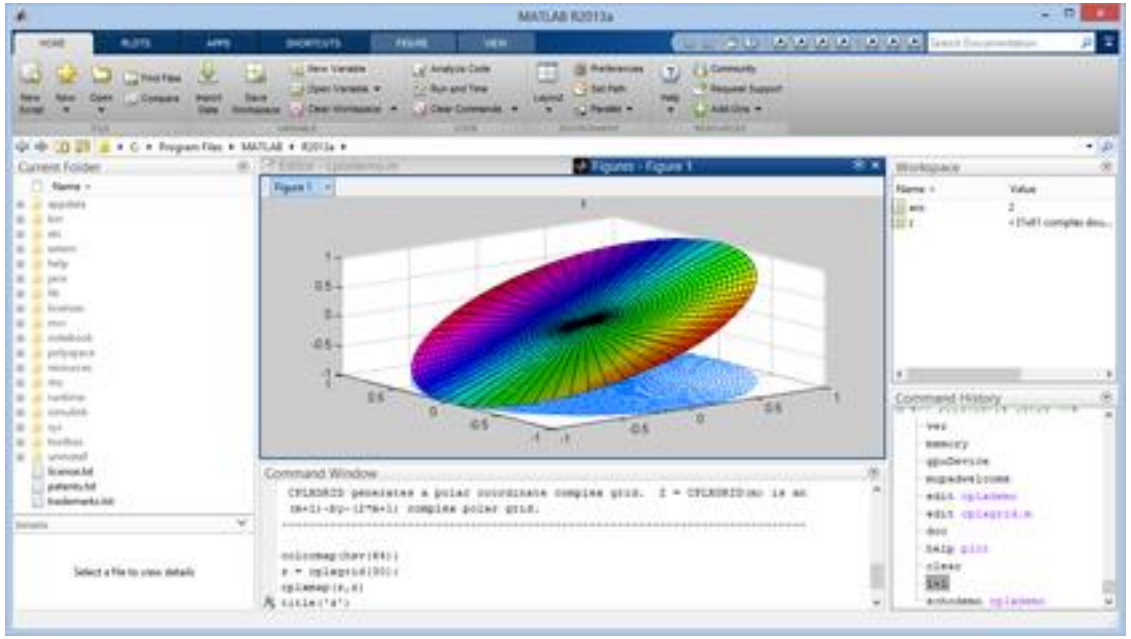
RESULT

Predict whether the patient has Alzheimer's Disease

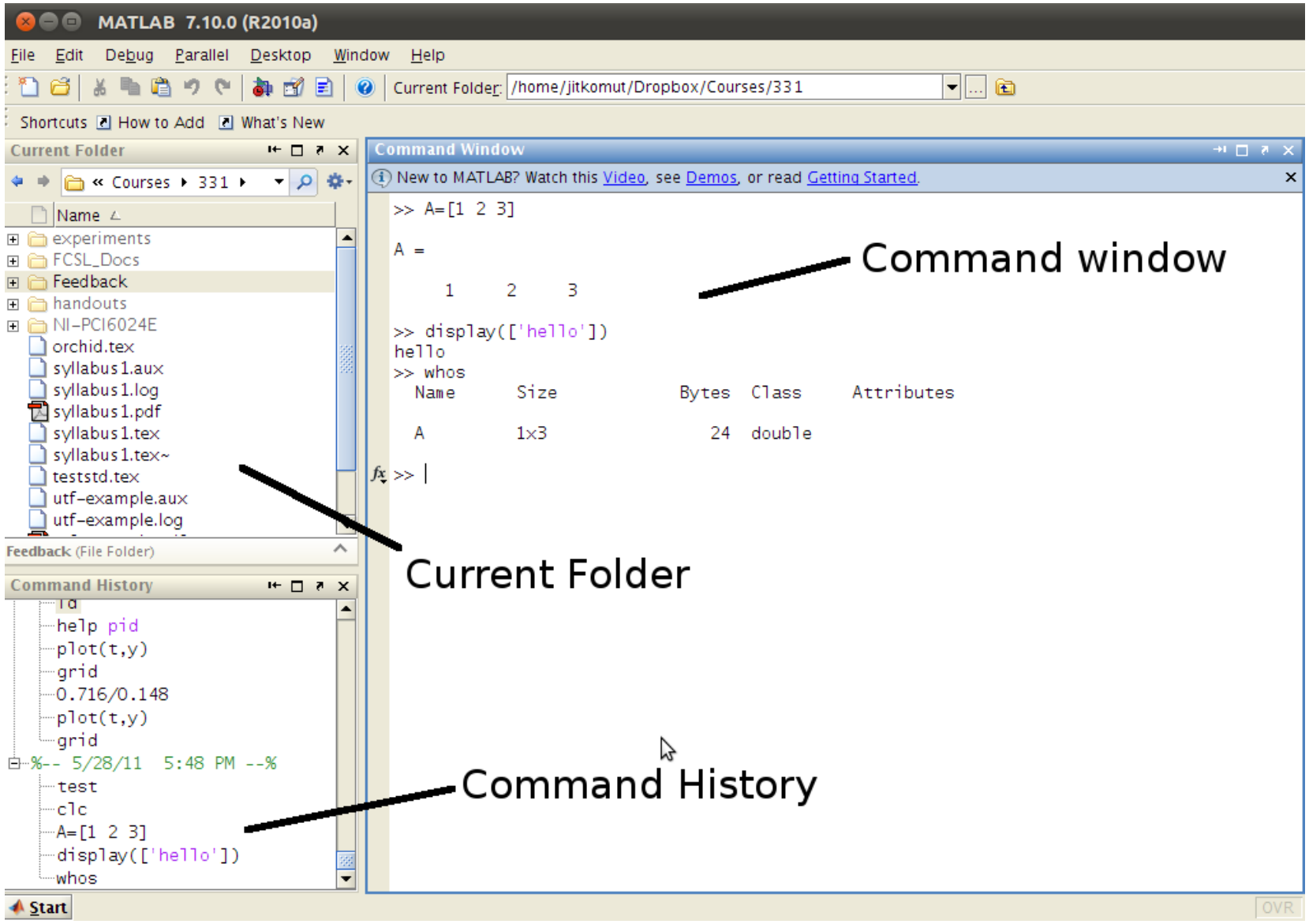
Why?



- Built-in operations to handle arrays/matrices. E.g. 2 arrays together needs only 1 command cf. a for or while loop (as in C)
- Easy to prototype! Much lesser lines of codes!
- Graphical output optimized for interaction – very user friendly
- Additional toolboxes could be included e.g. Statistics Toolbox for more specialized statistical manipulation of data (Anova, data fitting, etc)



MATLAB environment



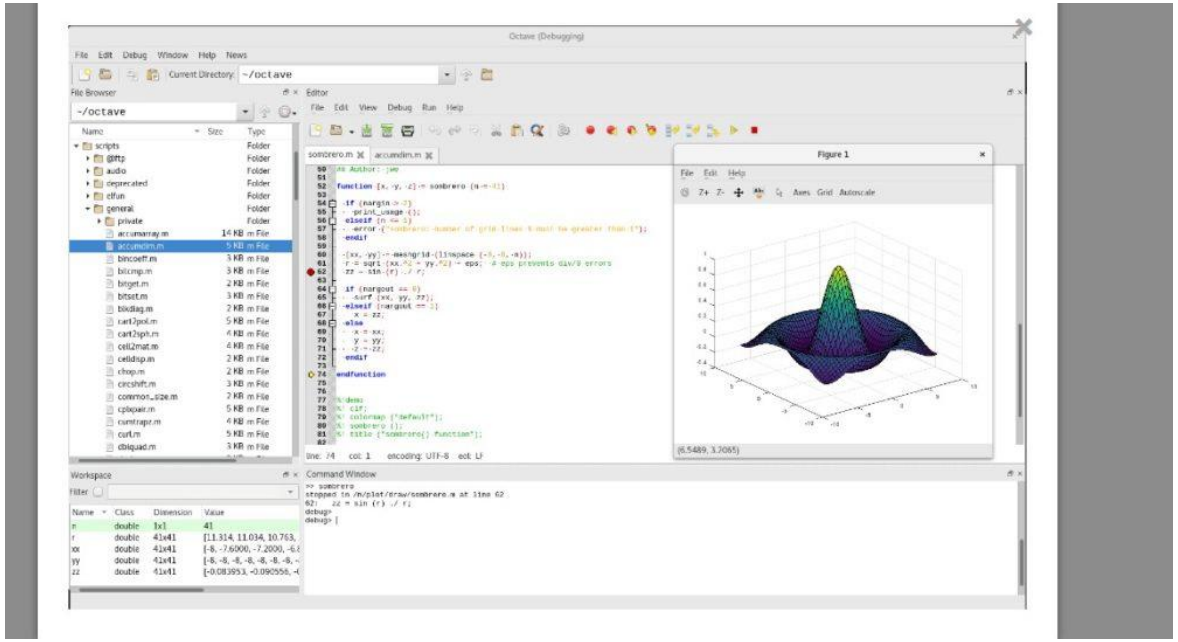
Advantages

- **User-Friendly Interface**: Simplifies complex computations and tasks.
- **Extensive Mathematical Functions**: Supports a wide range of engineering and scientific applications.
- **Robust Visualization Capabilities**: Ideal for data analysis and presentation.
- **Versatile Usage**: Perfect for developing algorithms, analyzing data, and simulating complex systems.
- **Preferred by Engineers, Scientists, Researchers, and Educators**: A reliable tool for academic and professional use.

Disadvantages or Limitations

- Uses lots of memory and hard to use with slow computers
- Real-time computing an issue
- Expensive license

A free alternative, compatible with MATLAB – Octave
https://www.gnu.org/software/octave/



Introduction to MATLAB programming

- In MATLAB, the scripts are written in *.m or .mlx (cf. e.g. *.c in C programming)

- These are scripts, not programs, and read by an interpreter (unlike in e.g. C where they are compiled). But documentation in MATLAB refers to scripts as programs. So we'll follow that.

- To create a script, click File, then New, then M-file. A new window will appear called the Editor. To create a new script, simply type the sequence of statements and click Run (or F5).

- Save the file using File → Save. Make sure the extension is in *.m format. Rules for filenames are the same as for variable (must start with a letter, and after that there can be letters, digits or underscore, etc). Once saved and closed, the file can be reopened by clicking File → Open and then select the name of the file.

Code Snippet

```
% Four basic opperation:
a = 20
b = 10;

% addition
addition = a + b

% subtraction
subtraction = a - b

% multiplication
multiplication = a *b

% division
division1 = a / b
division2 = a \ b
```

Run

```
a = 20

addition = 30

subtraction = 10

multiplication = 200

division1 = 2
division2 = 0.5000
```

Code Snippet

Creating Matrix:

```
m1 = [1, 2, 3; 4, 5, 6]
m2 = [1, 2, 3
      4, 5, 6
      7, 8, 9]

m1 (1, 2)
m2(1:2, 2:3)
```

Run

```
m1 = 2×3
     1     2     3
     4     5     6

m2 = 3×3
     1     2     3
     4     5     6
     7     8     9
```

```
ans = 2
```

```
ans = 2×2
     2     3
     5     6
```

Vector and matrix modification:

```
m4 = ones(1, 5)
m4(1:3) = -1

m5 = zeros(2, 3)
m5(1, 3) = 5
```

Run

```
m4 = 1×5
     1     1     1     1     1

m4 = 1×5
    -1    -1    -1     1     1

m5 = 2×3
     0     0     0
     0     0     0

m5 = 2×3
     0     0     5
     0     0     0
```

Download the lab tutorial file

https://tinyurl.com/basic-matlab

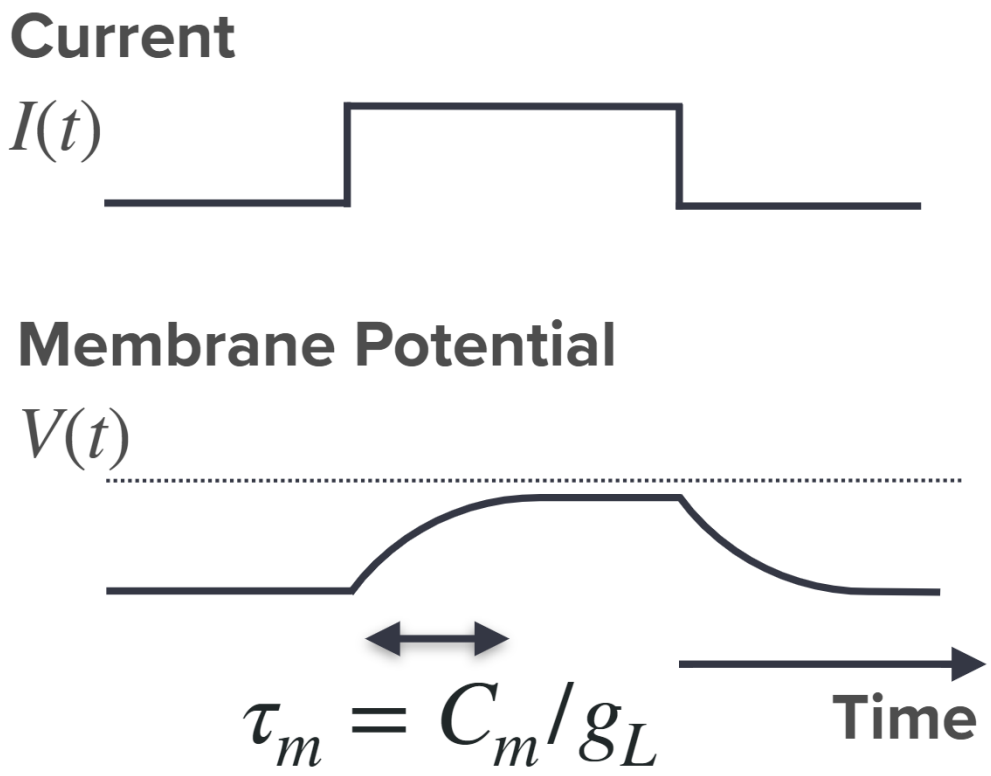
Leaky Integrate-and-Fire (LIF)

$$C_m \frac{dV}{dt} = -g_L(V - E_L) + I$$

If $V(t) = V_{th}$ then $V(t + \Delta) = E_L$

Subthreshold current step: Exponential relaxation to a steady-state.

$$V(t) = (\frac{I}{g_L} + E_L)\left[1 - e^{-t/\tau_m}\right]$$



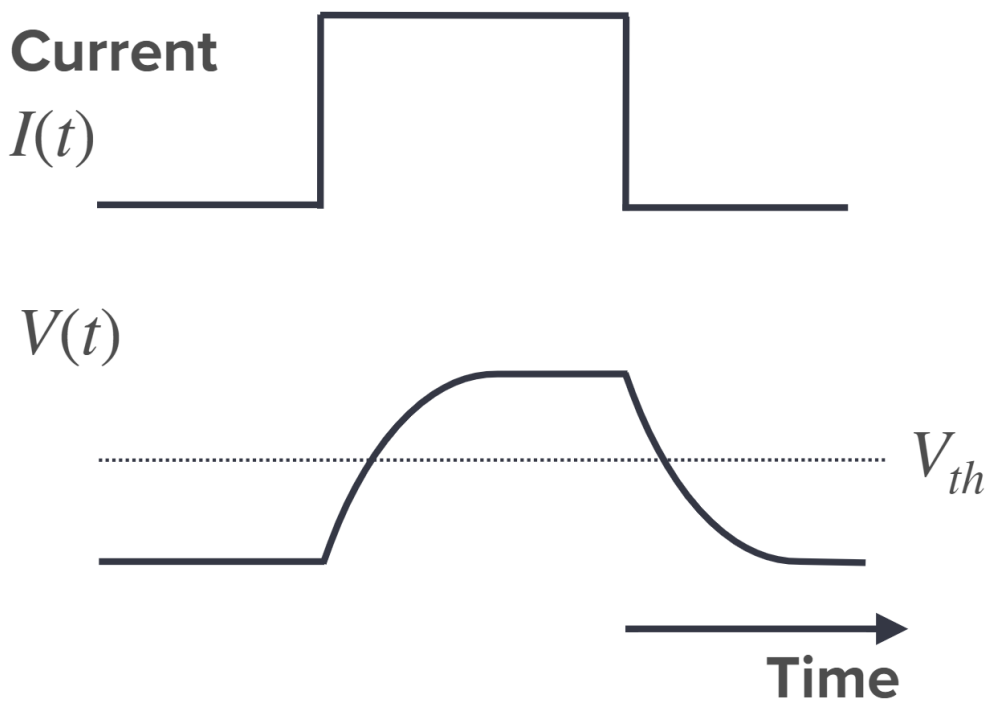
https://compneuro.neuromatch.io/

Leaky Integrate-and-Fire (LIF)

$$C_m \frac{dV}{dt} = -g_L(V - E_L) + I$$

If $V = V_{th}$ then $V(t + \Delta) = E_L$

Suprathreshold current step:



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Exercise (Write a MATLAB code for simulation of LIF model)

Hint:

- tau = 0.010; % Membrane time constant (tau) in seconds
- E_L = -0.070; % Leak potential (also known as resting potential) in volts
- Vth = -0.050; % Threshold potential in volts (the potential at which a spike is generated)
- Vreset = -0.080; % Reset potential in volts (the potential after a spike)
- Cm = 100e-12; % Total membrane capacitance in farads
- G_L = Cm / tau; % Total membrane conductance (leak conductance) in siemens
- Iapp = 210e-12; % Value of applied current steps in amperes

```
V(i) = V(i-1) + dt * (I(i) + G_L * (E_L - V(i-1))) / Cm; % Update membrane potential using Forward Euler method
```

If $V = V_{th}$ then $V(t + \Delta) = E_L$

Thank you!