Task1 – Basic Pulse Sequence Simulator on Digital Phantom

Part 1. Digital phantom:

Digital phantom is a handy medical imaging tool used to simulate the tissue properties upon which the imaging effect can be simulated to produce how the expected image may look like. One of the famous phantoms is the Shepp–Logan phantom. Please, do your readings and research for the underlined words.

In this task, you need to implement a 2D MR digital phantom that resembles the contents of the Shepp-Logan phantom. i.e. an array/matrix of pixel where each pixel resembles specific tissue properties: Proton Density (PD), T1, T2. The user should be able to change/control the below features:

- **Phantom size:** The user can set the phantom size to be 16, 32 or 64 through a combobox in your GUI.
- **Displayed tissue property:** Another combobox should help the user to determine which tissue property (e.g. PD, T1, T2) is displayed in the image (note that your image can display only one property at a time).
- **Explore any pixel values:** Upon clicking any pixel in the phantom, the pixel should be highlighted (some colored frame/rectangle around it), and a tooltip should appear with the PD, T1, and T2 of this pixel.
- **Brightness/Contrast:** The user can change the brightness/contrast of the displayed phantom through mouse dragging on the image (such effect is very common in any image viewer application).

Part 2. Pulse Sequence Simulator:

MRI Pulse Sequence is a sequence of RF pulses and gradient switches that help to excite the body spins, encode their position in the body and readout their Free Induction Decay (FID) signals.

In this task, you need to implement a basic simulation for the pulse sequence where the user can perform the following tasks:

- **Schematic viewer**: Open a pulse sequence file where such file consists of the time sequence and values of a collection of RF, Gz, Gy, Gx, RO. The format of such file is completely up to you. Just be alert, we will continue using this format in the next tasks so try to make it as standard and clear as possible. Upon opening the file, the UI should visualize it to the user.
- **Simulate the phantom:** Based on the opened digital phantom, prepare a matrix of simulated spin vectors. Each vector should have Mx, My, Mz components. The size of the matrix is the chosen size of the digital phantom.
- **Simulate the sequence**: Upon pressing the “Start” button, the simulation should go through all the simulated spin vectors, apply the RF or Gradients effect on all of them, take their summation and place it properly in the k-Space matrix. This process is repeated N×N times until the k-Space is filled. K-space should be visualized dynamically while being prepared.
- **Reconstruct the image**: After the completion of k-Space, an inverse FFT should be applied to generate the image and visualize it. i.e. three images will be shown to the user: original phantom image, k-Space, and reconstructed image.
- **Control Flip Angle, TE and TR**: Two edit/spin boxes should be available to enter TE and TR in ms, and another one for entering the Flip angle (FA). Two vertical columns representing the TE and TR times should be plotted on the sequence schematic. Note that this feature is just for visualization in this task. It will be effective from in the next tasks.

General Note: The next tasks will be built on top of this one. So, please try to make your implementation as general, modular and object-oriented as possible.