dMRI: Desktop MRI

dMRI is the first simulator built with a goal to make an open-source simulator to the help in teaching the concepts of MR physics.

Layout of dMRI

dMRI's graphical user interface is organized into five panels.

A. User Input Panel:

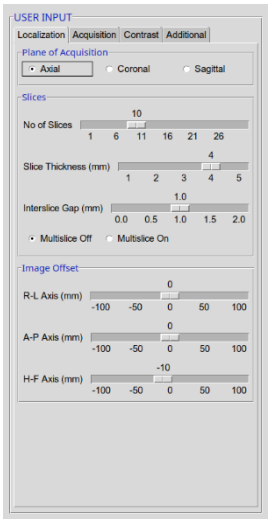
Displays all the important user adjustable parameters that are available on a clinical MR scanner. The parameters are organized into four tabs:

a. Localization parameters: Parameters that determine the location and dimensions of the reconstructed slices

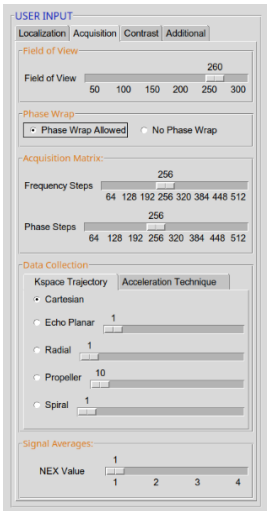
b. Acquisition parameters: Parameters that determine the location and dimensions of the voxels constituting the reconstructed slices, k-Space trajectory employed for data collection and number of signal averages

c. Contrast parameters: Parameters that determine the voxel signal intensities in reconstructed slices. These include the pulse sequence and parameters such as Flip angle, TR, TE, Inversion time and Bandwidth

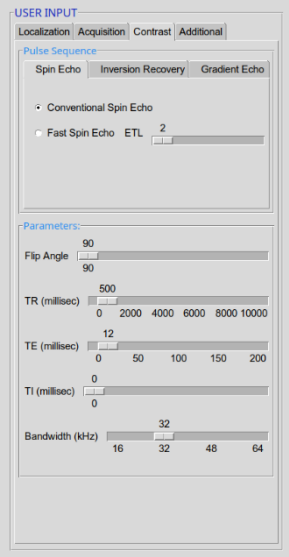
d. Additional parameters: Additional k-Space strategy related parameters, choice of artifacts and image filters that can be introduced into the reconstructed image are listed in this tab. It also contains sliders to control the magnitude or location of some of these parameters



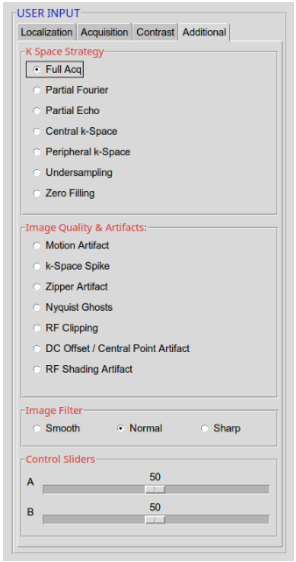
Tab 1: Localization



Tab 2: Acquisition



Tab 3: Contrast



Tab 4: Additional

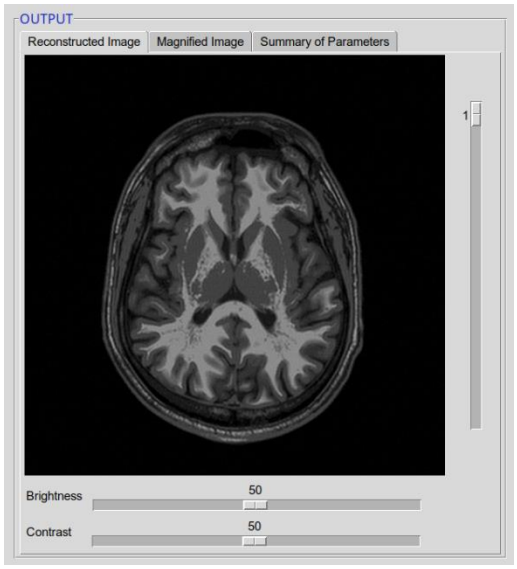
B. Output Panel

Displays the images output and numerical results of the simulation. It has three tabs:

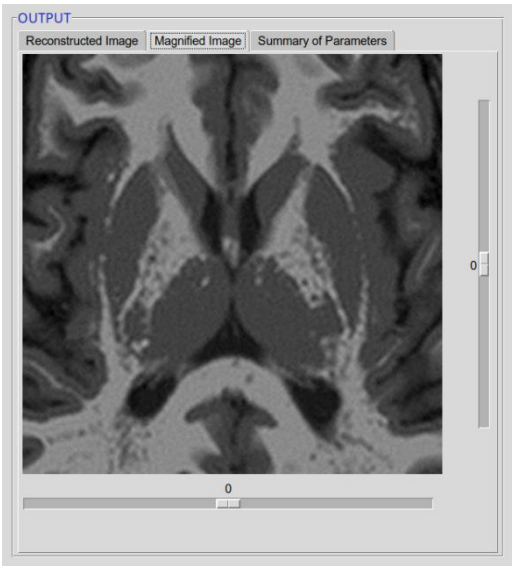
a. Reconstructed Image: Sliders are available to scroll through the reconstructed images and to adjust the brightness and contrast in the images

b. Magnified Image: Centre of the reconstructed image is magnified and displayed so as to demonstrate finer details such as spatial resolution, partial volume artifacts, truncation artifacts, etc

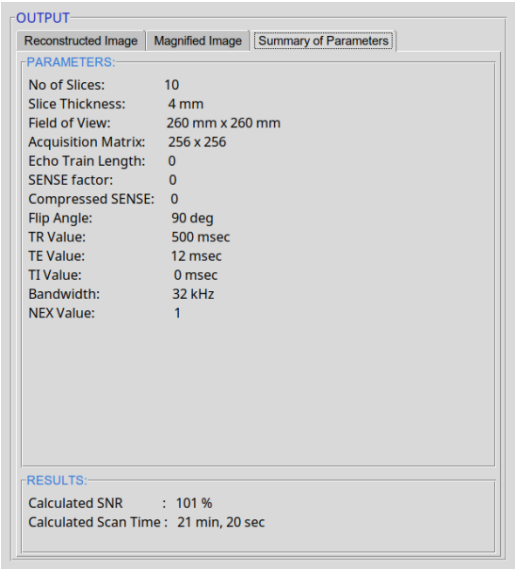
c. Summary of Parameters: The user-defined parameters utilized during the simulation, the calculated signal-to-noise ratio and the calculated scan time are displayed.



Tab 1: Reconstructed Image



Tab 2: Magnified Image



Tab 3: Summary of parameters

C. Control Panel

Contains three buttons.

a. Run button: To run the simulation employing the user defined parameters
b. Reset button: To reset the user defined parameters to default values
c. Quit button

Control panel

D. Physics Panel

Displays the MR physics concepts behind the simulation. It has four tabs:

a. Pulse Sequence Diagram: Displays the pulse sequence diagram, depicting the radiofrequency pulses, slice selection, phase encoding, frequency encoding gradients and signal output
b. Relaxation Curves: Displays the T1 and T2 relaxation curves for the four major tissues (CSF, grey matter, white matter and fat) and explains the T1 and T2 contributions to the signal generated by the current user defined parameters
c. k-Space Trajectory: Displays the k-Space filling trajectory for the employed data collection mechanism
d. k-Space Display: Displays the k-Space representation of the image generated by the current user defined parameters and additional k-Space strategie

E. Message Panel

Displays relevant messages on use of sliders when applicable (acts as an inbult help window)

Functional Overview of dMRI

Steps of dMRI image reconstruction:

1. A 3D anatomical array of T1, T2 and proton density maps is loaded. This array has been computed from a 3D T1 MR acquisition from a single subject.
2. Slices are sampled and voxel data is computed from the 3D anatomical array, using user defined parameters such as 'plane of acquisition', 'slice parameters', 'image offset', 'field of view' and 'acquisition matrix'

   The parameters that can be adjusted are

   i. Plane of Acquistion
      a. Axial
      b. Coronal
      c. Sagittal
   ii. Slice Parameters
      a. Number of slices: 1 - 30 slices
      b. Slice thickness: 1 - 5mm (in 1mm increments)
      c. Interslice gaps: 0 - 2mm (in 0.5mm increments)
   iii. Image offset
      a. A-P Axis: Shifts the centre of field of view along the antero - posterior axis
      b. R-L Axis: Shifts the centre of field of view along the right - left axis
      c. H-F Axis: Shifts the centre of field of view along the head - foot axis
   iv. Field of View: 50 - 300mm (in 10mm increments)
   v. Acquisition matrix
   vi. Frequency encoding steps: 64 - 512 (in 8 step increments)
   vii. Phase encoding steps: 64 - 512 (in 8 step increments)
3. Signal intensity is calculated for each voxel, using signal equations depending on user selected 'pulse sequence' and user selected 'parameters'

   The parameters that can be adjusted are

   i. Pulse Sequence
      a. Spin Echo
      b. Inversion Recovery
         - Magnitude inversion recovery
         - Phase sensitive inversion recovery
      c. Gradient echo
         - Spoiled gradient echo
   ii. Parameters

   a. Flip angle: 1 - 90 degrees (in 1 degree increments - adjustable for gradient echo sequence only)
   b. TR (Repetition time): 1 - 10000 milliseconds (in 10 millisecond intervals)
   c. TE (Echo time): 1 - 200 milliseconds (in 1 millisecond intervals)
   d. TI (Inversion time): 1 - 3000 milliseconds (in 1 millisecond intervals - adjustable for inversion recovery sequences only)

4. k-Space is generated by Fourier transform of the reconstructed voxel data
5. k-Space strategies and artifacts originating in the k-Space are encoded into the k-Space data
6. Image is constructed by inverse Fourier transform of the modified k-Space data
7. Pulse sequence diagram is generated using the parameters supplied
8. Tissue T1 and T2 relaxation curves are generated using the parameters supplied
9. k-Space trajectory is generated using the parameters supplied
10. Scan time is calculated based on
    i. Number of slices
    ii. Multislice Acquisition mode: On / Off
    iii. Phase encoding steps
    iv. TR (Repetition time)
    v. TI (Inversion time - for IR Acquisitions only)
    vi. Echo Train Length (For Fast Spin Echo and Fast IR Acquisitions)
    vii. NEX (Number of Excitations)
    viii. Acceleration technique (None / SENSE / Compressed SENSE)
11. Signal to noise ratio is calculated based on
    i. Pulse sequence
    ii. Slice thickness
    iii. Voxel dimension in phase axis
    iv. Voxel dimension in frequency axis
    v. NEX (Number of Excitations)
    vi. Bandwidth
    vii. Acceleration technique (None / SENSE / Compressed SENSE)
12. Noise is added to the image based on the calculated SNR a precalculated 3D array of noise data is added to the image
13. Image filter (Smooth / Normal / Sharp) is added.
14. Reconstructed Image and magnified image, generated Pulse sequence diagram, Tissue relaxation curves, k-Space trajectory and Modified k-Space are displayed