VIP ANR-09-COSI-03
Virtual Imaging Platform

D3.3.4 - Simulated images of the inflamed artery and brain

Fang Cao[1], Olivier Commowick[1], Elise Bannier[1], Alessandro Crimi[1], Christian Barillot[1]
[1] VISAGES : Vision Action et Gestion d'Informations en Santé (VISAGES) ; INSERM : U746 CNRS : UMR6074 INRIA Université de Rennes 1

Hugues Benoit-Cattin[2]
[2] Université de Lyon, CREATIS; CNRS UMR5220; Inserm U1044; INSA- Lyon; Univ. Lyon 1

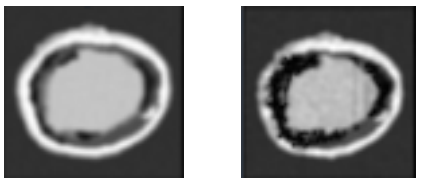
Abstract

This report describes simulated MRIs of the inflamed artery (section 1) and brain (section 2). These images were obtained with simulators SIMRI and SimuBloch that are available in VIP. The corresponding models were described in M3.3.1 (artery) and M3.3.2 (brain), and built from data acquired in D3.3.2 (artery) and D3.3.1 (brain).

1 Simulated images of the arterial model with USPIO

This section briefly describes simulated images of the inflamed artery marked with USPIO. From the 3 2D artery models defined in the project, among which 2 correspond to inflamed artery models marked with USPIOs (see project milestone M3.3.1), we can simulate MRI images with different characteristics using the SIMRI simulator available in VIP.

In SIMRI, the defect of electromagnetic field introduced by USPIOs can be taken into account or ignored (Figure 1(a) vs Figure 1(b)) in order to better understand the effects induced by this type of markers on the images.

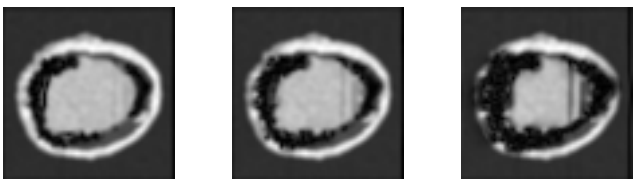


(a) Ignoring the field defect

(b) Taking the field defect into account

Figure 1: Simulated images (64×64) from a 256×256 artery model and a gradient echo sequence (TR=400ms, TE=10ms, θ=90°, Tacq=8ms).

In addition, it is also interesting to study by simulation the effect of this field defect w.r.t the static magnetic field B0 (Figure 2).



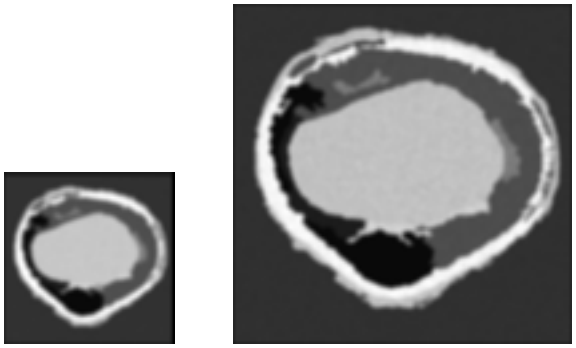
(a) B0=0.2T (b) B0=0.6T (c) B0=1T

Figure 2: Simulated images (64×64) from a 256×256 artery model and a gradient echo sequence (TR=400ms, TE=10ms, θ=90°, Tacq=8ms) and different B0 values.

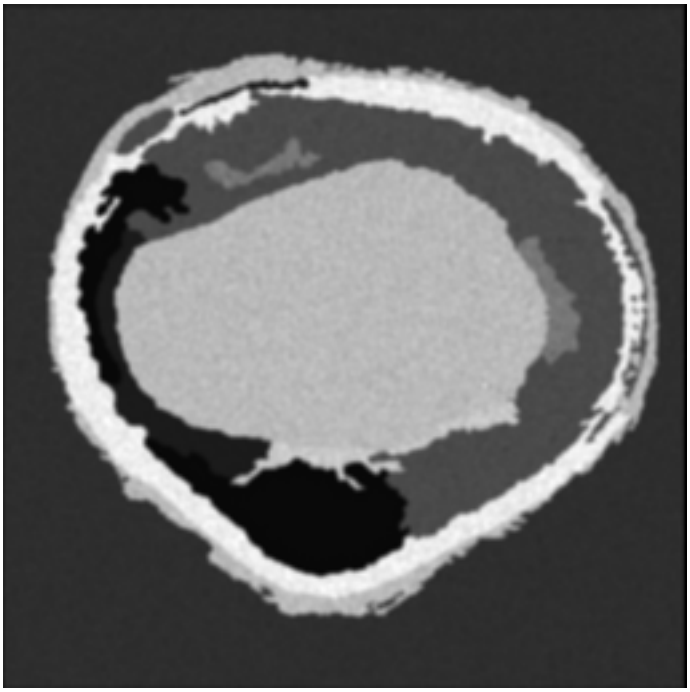
Finally, note that simulated images can be obtained at different resolutions to study partial volume effects (Figure 3). Tuning the size of the simulated image and the resolution of the model can also reduce the simulation time for preliminary studies.

Contact for more information about SIMRI and artery simulated images:

Hugues BENOIT-CATTIN
Email: hugues.benoit-cattin@creatis.insa-lyon.fr
Tel: +33 4 72 43 60 61



(a) 64 × 64 (b) 128 × 128



(c) 256 × 256

Figure 3: Simulated images (64x64) from a 512×512 artery model and a gradient echo sequence (TR=400ms, TE=10ms, θ=90°, Tacq=8ms), with different image resolutions.

2 Validation study of the brain model for MS USPIO-enhanced diagnosis

This project addresses one of VIP's major applicative objectives: the modeling of the brain inflammation process from MRI simulation. We have validated the simulation of molecular MR images in the context of neuro-inflamatory pathology. We work in the context of ultra-small iron oxide nanoparticles (named USPIO) that are MRI contrast agents of high interest because they specifically mark macrophages which are involved in the inflammation in Multiple Sclerosis.

The first step is to generate the parameters T_1, T_2, T_2^* and PD of the input object. This can be modeled as an inverse problem with respect to relaxometry protocols. The unknowns to be determined are the parameters T_1, T_2, T_2^* and PD of the object, and the acquisition parameters and relaxometry sequences are fixed for all the objects. In our case, the acquisition protocol USPIO6 includes three relaxometry sequences, which are T_1 relaxometry using 3D spoiled gradient echo sequence, T_2 relaxometry using multi-echo spin-echo seqence, and T_2^* relaxometry using multi-echo gradient echo sequence. Let $(S_1, S_2, \ldots, S_n)$ be the acquired relaxometry sequences with respect to the USPIO–6 protocol, and let n be 2, 7 and 5 corresponding to the numbers of echoes for T_1, T_2 and T_2^* estimation. The T_1, T_2 and T_2^* maps are estimated sequentially through a process of optimization with constraints. The proton density map PD is estimated together with the T_2 map by taking consideration of the effect of longitudinal relaxation time T_1. The flow diagram of the optimization process is presented in Fig. 4.

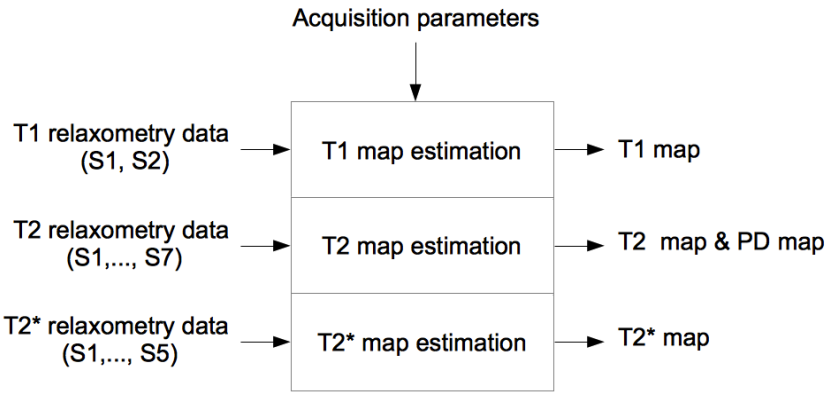
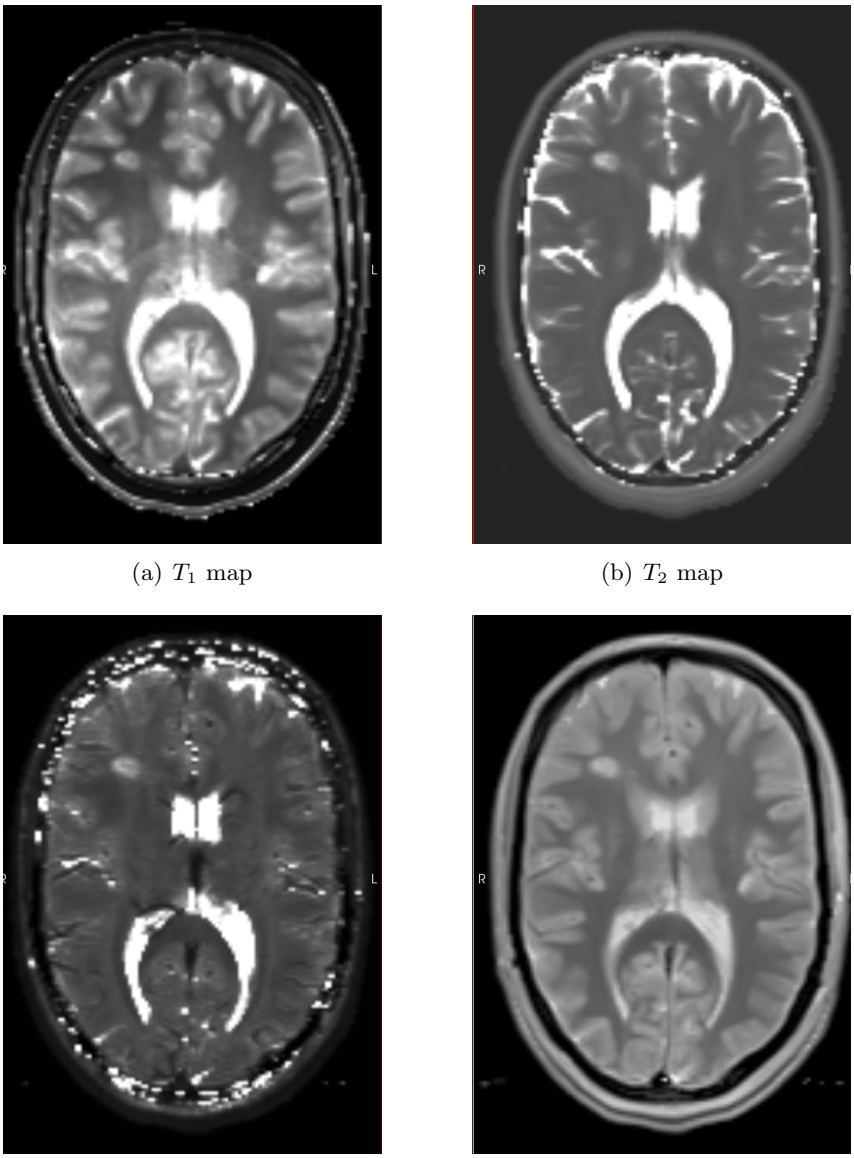


Figure 4: Estimation of physical parameters: T_1, T_2, T_2^* maps and PD image.

The parameter set (T_1, T_2, T_2^*, PD) are the estimations from these relaxometry sequences and acquisition parameters that depend on the MR imaging protocol. One example of the estimated T_1, T_2, T_2^*, PD maps is given in Fig. 5.

The second step is the construction of the input object for the MRI simulator. Each voxel of the object is defined by its physical properties, the 4 parameters T_1, T_2, T_2^* and PD (Fig. 6). In our case, this object represents a brain suffering from multiple sclerosis. Using these 4 physical parameters, we can simulate the weighted images of T_1-w, T_2-w, PD-w, FLAIR, etc., such as the sequences implemented in real measurement, whose acquisition parameters are known. In this project, we specifically work on the design of a virtual model to simulate MR images with different acquisition protocols. We focus on an inflamed brain



(a) T_1 map (b) T_2 map

(c) T_2^* map (d) PD map

Figure 5: The estimated T_1, T_2, T_2^*, PD maps. The results are registered to the baseline of the object.

model as encountered in Multiple Sclerosis before and after the injection of USPIO contrast agents. The model is used to simulate MR images of the neuro-inflammation process and validated from real MR relaxometry parameters as obtained on 3T MRI systems. The purpose of such simulated images is the modeling of MRI acquisition sequences in order to estimate high resolution quantitative imaging parameters able to exhibit the actual neuro-inflammation within Multiple Sclerosis lesions. One example of the simulated T_1-weighted image is given in Fig. 7. We find a good consistency with the image obtained in real measurement.

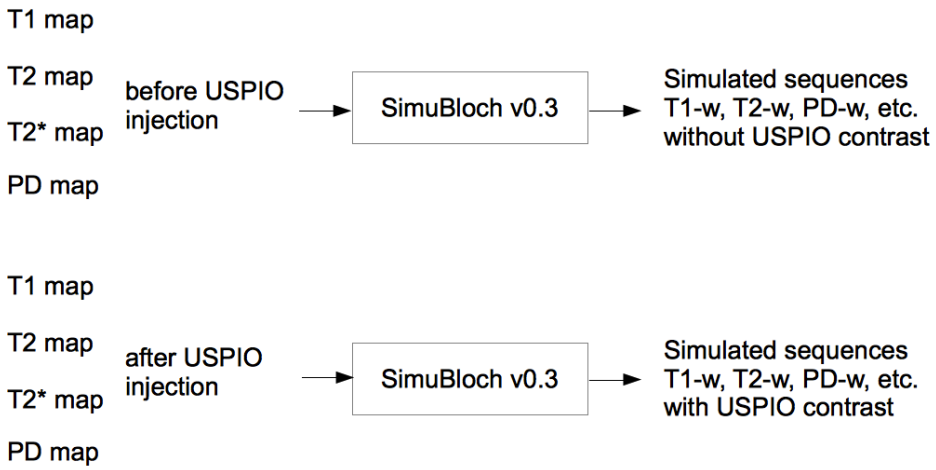
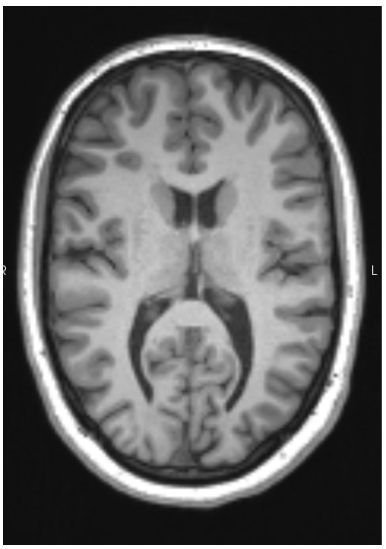
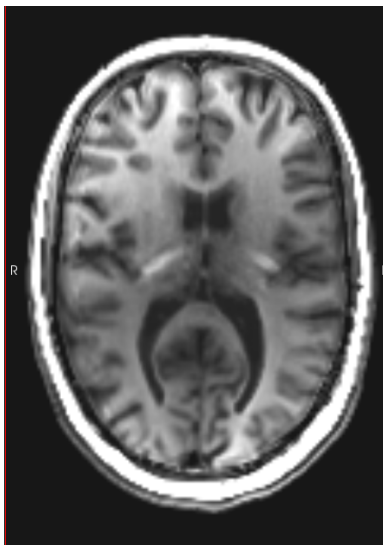


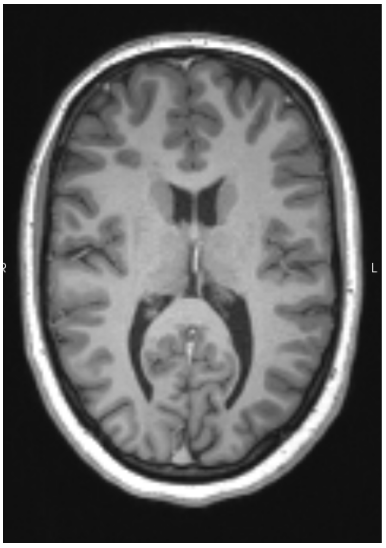
Figure 6: Construction of an input object for MRI simulator: T_1, T_2, T_2^* maps and PD image.



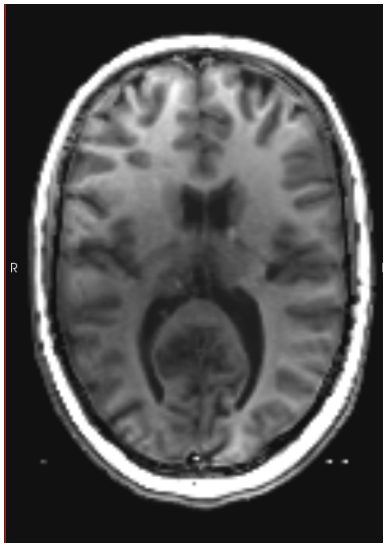
(a) The real measurement
(before USPIO injection)



(b) The simulated T_1-w
(before USPIO injection)



(c) The real measurement
(after USPIO injection)



(d) The simulated T_1-w
(after USPIO injection)

Figure 7: The simulated T_1-weighted images and the real measurements. The real measurement is high resolution 3D MPRAGE sequence. The results are registered to the baseline of the object and are presented in the same gray level.