# Slab registration as a first step towards hippocampus subparts high resolution imaging at 7T

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**Purpose**

Analyzing hippocampal subparts is of major interest, as these have been shown to be affected differently by different pathologies [1,2]. However, imaging these subparts with MRI remains challenging due to their very small size, requiring very high resolution and long acquisition time. High to very high field MRI (3T, 4T or 7T) has made it possible to study the hippocampus subparts in vivo using T2- or T2*-weighted sequences with high resolution ranging from about 0.4*0.4mm² coronal in plane resolution with 2mm slice thickness [2] at 4T, to about 0.25*0.25mm² coronal in plane resolution with 1.2mm slice thickness [3] at 7T. In order to reduce acquisition time per sequence and thus avoid as much as possible subject's movements, multi-slab acquisitions can be used [3]. Furthermore, T2-weighted acquisitions require interleaved slabs in order to increase signal to noise ratio and reduce artifacts. Nevertheless, this approach requires a robust registration method that makes it possible to correctly combine the information coming from the acquisition slabs even in case of between slabs movement. We propose here a robust registration procedure that can be used to register slabs into a single slab image in muti-slab acquisitions. This method was tested for subjects belonging to two datasets acquired in two research centers with 7T systems.

**Methods**

In order to evaluate the robustness of our registration procedure we tested it on 27 subjects acquired in center1 and 7 subjects acquired in center2 [3] with different acquisition protocols. All acquisitions were performed for projects aiming to study the hippocampus subparts at very high fields.

***Acquisition*** **-** Data were acquired in both centers on a 7T MRI system. The acquisition parameters are described in table 1 below. The acquisitions included high resolution (HR) slabs and a low resolution (LR) single slab reference volume. Acquisition time was about 5 min for all sequences.

***Table 1: acquisition protocol for each database***

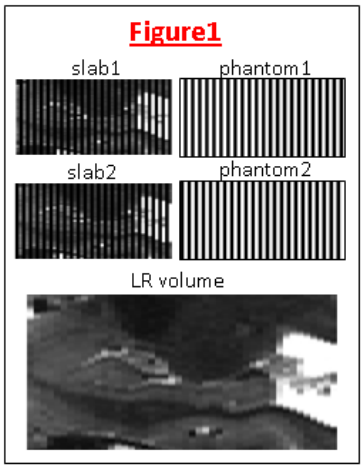
| | center 1: Magnetom 7T (Siemens, Erlangen, Germany) and 32 channel coil | center 2: 7T magnet(Magnex, Oxford, England) operated from a console(Siemens, Erlangen, Germany) and a 16 channel coil |
|---|---|---|
| **T2-weighted high resolution (HR) slabs** | **Fast Spin Echo sequence:** 2 "interleaved" slabs with coronal in plane resolution of 0.3*0.3mm², slice thickness of 1.2mm with 1.2mm gap; slabs were acquired twice for averaging. TR=5000ms, TE=82ms, flip-angle=60°, Nex=1, acquisition matrix=576x576. | **Fast Spin Echo sequence:** 2 or 3 "interleaved" slabs with coronal in plane resolution 0.25x0.25mm² and slices of 1.2mm with 1.2mm gap; slabs were acquired three times for averaging. TR=5830ms, TE=77ms, flip-angle=60°, Nex=1, acquisition matrix=512 × 412 |
| **T2-weighted low resolution (LR) single slab** | **Fast Spin Echo sequence:** coronal in plane resolution of 0.6*0.3mm², slice thickness of 1.2mm with no gap, TR=8000ms, TE=80ms, flip-angle=60°, Nex=1, acquisition matrix=576x576 | **Fast Spin Echo sequence:** coronal in plane resolution of 0.5x0.25mm3, slice thickness of 1.2mm with no gap, TR=5830ms, TE=77ms, flip-angle=60°, Nex=1, acquisition matrix=512 × 412 |

***Preprocessing*** **-** The LR volumes were upsampled to the resolution of the HR slabs. Voxels corresponding to the gap for each (HR) slab were set to zero. For each slab, a synthetic phantom was created, which aims at homogenizing intensity values after the registration. Each phantom is in fact a duplicate of the slab with a value equal to 1.0 in each voxel with slab signal and 0.0 in each voxel corresponding to slab gap.

***Registration*** **-** Each HR slab was registered to the LR volume using the SPM8 (www.fil.ion.ucl.ac.uk/spm/software/spm8/) coregistration module. For each slab registration, the phantom associated to the slab was registered simultaneously to the LR volume with the same transformation matrix.. The final full HR volume was obtained by dividing the sum of the registered slabs by the sum of the registered phantoms.

**Results and discussion**

The registration procedure was applied to the 34 test subjects. An example of result of the preprocessing step is shown in figure 1 for a test subject acquired in center1. The validation of the registration was done by visually checking the coherence of the final image of the hippocampi for each subject on sagittal slices. Figure 2 shows the result of the registration for two subjects acquired in center1 and 2. Figure 2(a) shows the sum of unregistered slabs and highlights the between-slab movement of the subjects. The registration of the interleaved slabs to the reference LR volume using SPM removes the inter-slabs movement but leads to non-homogeneous gray levels between slices as shown in Figure 2(b). This non-homogeneity is corrected by the normalization of the registered slabs by the registered phantom as shown in Figure2(c). The registration procedure allowed a robust registration of the slabs of all the 34 subjects to their corresponding LR reference despite their acquisition protocol differences.



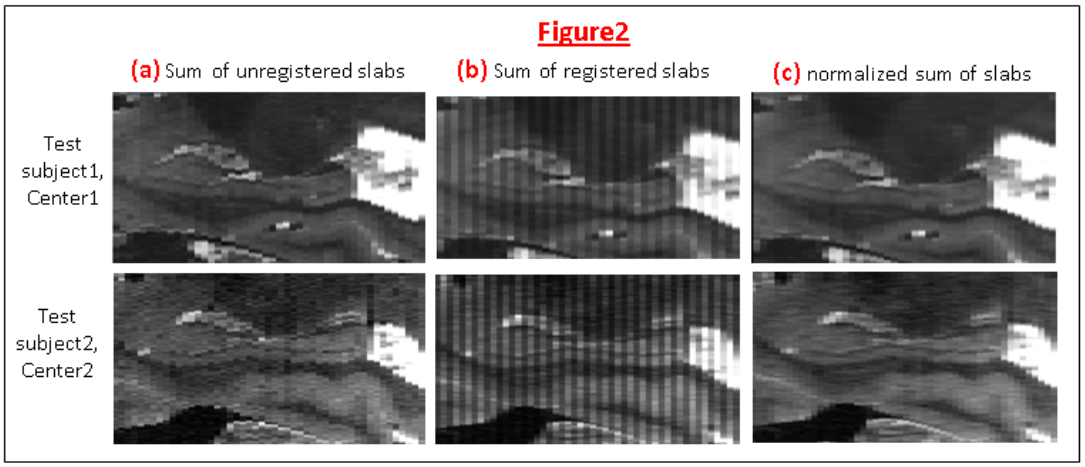




***Figure 1: slabs, phantoms and LR volume resulting from the preprocessing. Figure 2: registration results of two test subjects acquired in center 1 and 2 respectively***

**Conclusion**

We presented a registration procedure that overcomes the problem of movement between slabs in interleaved slab acquisition design. We evaluated this procedure for two datasets acquired in two different centers for HR imaging of the hippocampus but such procedure should be efficient for other multi-slab acquisition designs.

**References**

[1]Eriksson et al, Epilepsia 2008, 49(1) :33-39 [2]Mueller et al, Epilepsia 2009, 50(6) :1474-1483 [3] Henry et al, Radiology 2011, 261(1) :199-209