A rigid Registration Method for automated Scan Planning in Follow-up Examinations: Retrospective Analysis from Volunteer and Patient Neuro Scans

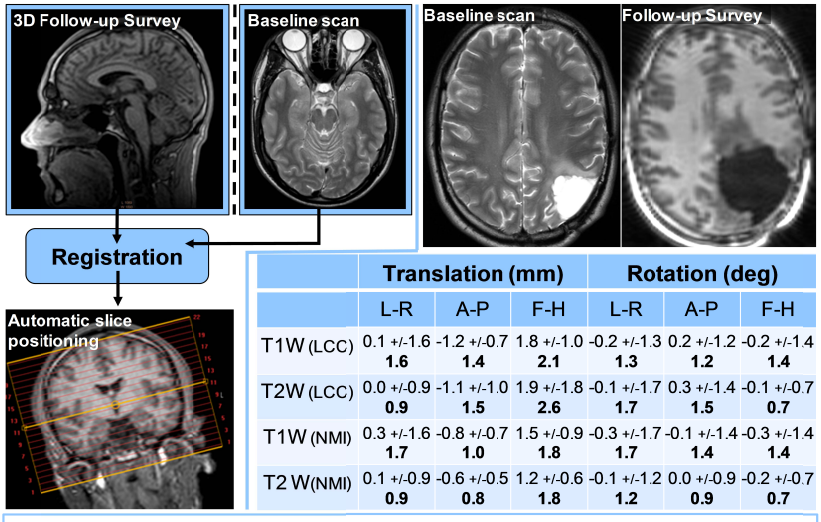
Julien Sénégas[1], Torbjoern Vik[1], Jens von Berg[1], Peter Koken[1], Juergen Gieseke[2,3], Vincent Denolin[4], Roy König[3], and Stefan Sunaert[5]
[1]*Philips Research Laboratories, Hamburg, Germany,* [2]*Philips Healthcare, Best, Netherlands,* [3]*Radiology, University of Bonn, Bonn, Germany,* [4]*Philips Healthcare, Brussels, Belgium,* [5]*Medical Imaging Center, Radiology, Catholic University of Leuven, UZ Leuven, Leuven, Belgium*

INTRODUCTION – MRI based monitoring of cerebral diseases such as brain tumors and multiple-sclerosis requires a precise comparison of the signal intensity and structure between baseline and follow-up exams. To minimize visual changes due to variations in patient positioning and scan planning, an accurate replication of the baseline acquisition geometry is desired. If done manually by visual inspection of the baseline images, this is a very tedious, time-consuming procedure with limited accuracy. Previously, automated scan planning techniques [1, 2] were applied to improve planning consistency between baseline and follow-up exams [3]. However, in clinical practice, requiring that the same planning engine is applied for all exams may be a too severe constraint, since baseline and follow-up exams can be acquired on different MR scanners running different software versions. Another method relying on the registration of baseline and follow-up survey scans was proposed and evaluated in volunteers [4]. This approach in turn requires the survey scans to be consistently stored with the diagnostic images. In this work, we propose an alternative, general approach for automated scan planning in follow-up exams that only requires the baseline diagnostic images as input, with no further restrictions on the baseline exam as far as types of MR sequences, of MR scanner (vendor, field strength) or of planning (automated or manual) are concerned. Results from a preliminary study based on a retrospective analysis of volunteer and patient scans are presented.

METHODS – It is proposed to compute the acquisition geometry of the follow-up scans by applying a rigid registration algorithm between each baseline scan to be repeated and a 3D survey scan acquired at the beginning of the follow-up exam (Fig. 1, *left*). In our work, a 3D T1W gradient echo sequence (TR / TE: 3.8 / 1.7 ms, flip angle: 8°, voxel size: 2.2x2.2x2.2 mm) was used as a survey scan.
Seven volunteers were scanned each 2 to 3 times on a 1.5T scanner (Achieva, Philips Healthcare), with repositioning on the scanner table before each exam start. This resulted in a total of 31 pairs of "baseline / follow-up" exams. A routine brain protocol consisting of the proposed 3D survey scan and three diagnostic scans in transverse orientation - T2W fast spin echo (TR / TE: 4452 /100 ms, voxel size: 0.6x0.8x5 mm), T1W spin echo (TR / TE: 596 /15 ms, voxel size: 0.9x1.1x5 mm), and FLAIR (TR / TI / TE: 11000 / 2800 / 140 ms, voxel size: 0.9x1.1x5 mm) - was used. For each exam, the three diagnostic scans were registered separately to the 3D survey of the other exams of the same volunteer using either local cross-correlation (LCC) or normalized mutual information (NMI) as similarity measure [5, 6]. The resulting translation and rotation parameters were compared to those obtained through rigid registration of the 3D surveys using cross-correlation. The latter transform was considered as reference, as baseline and follow-up survey images were isotropic and had identical contrast. Differences between LCC and NMI results were assessed using a paired Student's t-test.
To test the performance of the registration algorithm in the presence of pathologies and anatomical changes, 20 anonymized clinical MR neuro exams with baseline and follow-up scans of varying MR sequence types (T1W, T2W and FLAIR spin echo; T1W gradient echo with or without contrast agent) were analyzed retrospectively. These exams were performed at two different clinical institutions on 3T MR systems and covered different clinical conditions (15 pre- and postoperative cases of brain tumors, 5 remaining cases: brain tumors and brain metastasis, acute migraine, multiple sclerosis). Rigid registration based on NMI between each of the 74 available baseline scans and the 3D survey of the related follow-up exam was performed. The performance of the registration was qualitatively assessed by two clinical experts who were asked to rank the alignment as accurate, reasonably accurate, or insufficiently accurate.

RESULTS – In the volunteer study, rigid registration based on NMI achieved higher accuracy and precision than LCC ($p < 0.005$), especially concerning the T2W fast spin echo sequence (Fig1, *table*). Translation errors were largest on average in the F-H direction, while rotation errors were slightly higher around the L-R axis than around the A-P and F-H axis. In the retrospective patient study (Fig 1, *top right*), slice positioning on the 3D survey was found accurate in 59 cases (80%), reasonably accurate in 12 cases (16%), and insufficiently accurate in 3 cases (4%).

DISCUSSION and CONCLUSION – Translation and rotation errors in the volunteer study were due to both registration inaccuracy and bulk patient motion during examination. In neuro scans, natural motion such as nodding is found mainly around the L-R axis, which may explain the higher rotation values found around this axis as argued in [7]. The larger translation errors found in the F-H direction were likely due to the high slice thickness compared to the in-plane resolution. In the retrospective patient study, the registration algorithm proved robust enough to achieve reasonable to good alignment in the vast majority of cases (> 95%), despite strong local anatomical changes observed in some datasets (Fig. 1, *top right*). Using NMI as similarity measure, it was possible to register baseline scans of various contrast types to the same survey scan, demonstrating that the method can be applied in a wide range of cases. These results suggest that automated planning of follow-up exams can be performed in a clinical context using the proposed methodology, which has the advantage that only baseline images are required as input. Implementation of the method on a clinical scanner and its evaluation in volunteers are described in a separate study [8].



	Translation (mm)			Rotation (deg)		
	L-R	A-P	F-H	L-R	A-P	F-H
T1W (LCC)	0.1 +/-1.6 **1.6**	-1.2 +/-0.7 **1.4**	1.8 +/-1.0 **2.1**	-0.2 +/-1.3 **1.3**	0.2 +/-1.2 **1.2**	-0.2 +/-1.4 **1.4**
T2W (LCC)	0.0 +/-0.9 **0.9**	-1.1 +/-1.0 **1.5**	1.9 +/-1.8 **2.6**	-0.1 +/-1.7 **1.7**	0.3 +/-1.4 **1.5**	-0.1 +/-0.7 **0.7**
T1W (NMI)	0.3 +/-1.6 **1.7**	-0.8 +/-0.7 **1.0**	1.5 +/-0.9 **1.8**	-0.3 +/-1.7 **1.7**	-0.1 +/-1.4 **1.4**	-0.3 +/-1.4 **1.4**
T2 W(NMI)	0.1 +/-0.9 **0.9**	-0.6 +/-0.5 **0.8**	1.2 +/-0.6 **1.8**	-0.1 +/-1.2 **1.2**	0.0 +/-0.9 **0.9**	-0.2 +/-0.7 **0.7**

Fig. 1: *(Left)* Overview of the proposed planning method. *(Top Right)* Baseline T2W scan and reformatted follow-up survey in a brain glioblastoma case. (*Bottom Right*) Mean and SD of translation and rotation errors in the volunteer study. Root mean squared errors are indicated in bold.

REFERENCES – [1] Young et al, SPIE (2006) [2] Iskurt et al, JMRI (2011) [3] Nelles et al, JMRI (2009) [4] Gedat et al, JMRI (2004) [5] Weese et al, MICCAI (1999) [6] Wells III et al, Med Imag Anal (1996) [7] Petersen et al, ISMRM (2008) [8] Koken et al, ISMRM (2012, submitted)