Robust anatomy recognition for automated MR neuro scan planning

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Introduction: The definition of the precise scan geometry, with respect to the patient's anatomy, is typically performed in an initial planning phase using survey images. Automation of this task allows the operator to focus on other tasks. For example, Lelieveldt [1] proposed a method for automatic scan planning (ASP) for cardiac imaging, based on fitting a 3D surface model to sparse survey slices, from which standard plans (short- and long-axis) are derived. In this study, a recently proposed approach [2] for automated planning of neuro scans is evaluated using data from a clinical trial, carried out over a 6 month period at the Dept. of Radiology at University of Bonn. The results presented demonstrate the robustness of the method to a range of pathological indications, as well as to imaging artefacts and strong variations of image contrast.

Methods: In current clinical routine, brain MR scans are typically planned using a set of sparse slices with a fixed, orthogonal geometry. In the proposed approach, a dedicated 3D T1-weighted neuro survey encompasing the entire head of the patient is used. The scan planning method consists of two fundamental steps: determining the location of a set of anatomical landmarks in the survey image, then defining the required scan geometries with respect to these landmarks. Firstly, a global correspondence is established to a model image [3] using multi-scale intensity-based image registration. Then, images are reformatted in a set of planes defined with respect to patient anatomy, for example the mid-sagittal plane (MSP), using the transformation parameters established via registration. Shape models, consisting of B-splines representing patient anatomy, are then fitted to image features determined within the reformatted slices. In an iterative approach, further planes are reformatted in other orientations based on landmarks already estimated, and further models fitted to yield landmarks describing the 3D extent of the head. In order to plan the final scan geometry, extracted landmarks are aligned to a set of 'atlas' landmarks, determined from training examples, using a point-based rigid registration algorithm.

Results: The proposed approach was tested using 3D survey scans of 231 clinical patients, acquired on a 3T Philips Achieva scanner during clinical trials at the Dept. of Radiology at University of Bonn. In order to measure the accuracy of the algorithm with respect to anatomy localization, a set of reference annotations were created manually using an offline image viewing tool. The results of a comparison to the corresponding annotations determined by the ASP algorithm are presented in Table 1, showing the results for mid-sagittal plane estimation, and for three important landmarks, located in the MSP at either end of the corpus callosum (L1, L2), and on the medulla oblongata at the level of the bottom of the cerebellum (L3). Figure 1 illustrates these results for a healthy volunteer, and figure 2 shows results for several examples in which pathologies or artefacts are present, including (d) the case for which maximum deviation from manual annotations (21.9 mm) was observed.

	Mean	Std. Dev.	Max.
Midsagittal plane (degrees)	2.33	1.20	7.09
Landmark accuracy - all (mm)	5.06	2.60	21.9
L1 (mm)	4.20	2.32	21.9
L2 (mm)	4.39	1.68	11.8
L3 (mm)	6.62	2.92	17..4

Table 1: Observed accuracy of the algorithm with respect to manually created reference annotations.

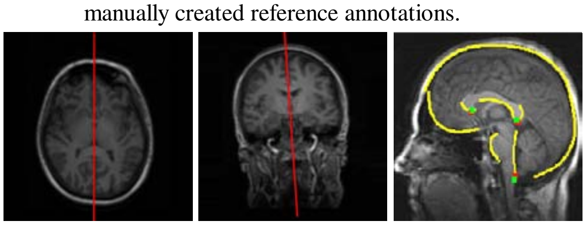

Fig. 1: Mid-sagital plane shown in axial and coronal views (left, middle), and the fitted model (right) with landmarks L1- L3 estimated manually (red) and automatically (green)

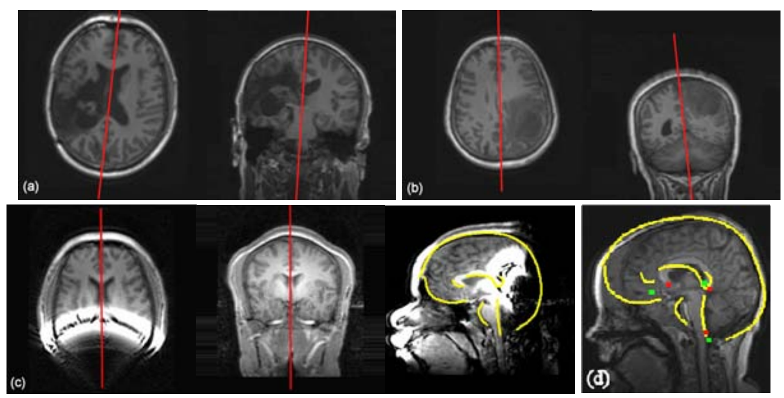

Fig. 2: Examples of MSP estimates, in corresponding axial and coronal views, in presence of severe pathology (a,b), and metal-induced artefacts (c). In (d), an example is seen where the model allows approximate recognition, despite not finding the ventricle boundary well (manual landmarks in red, ASP algorithm in green).

Discussion: The results presented demonstrate the robustness of the approach to the wide range of anatomical variations which are observed in clinical routine, as well as to some artefacts which can occur. The mean accuracy of landmark estimation of 5.1mm, over all observed patients, compares to an image resolution of 1.0x1.0x1.3mm. Even for cases in which anatomy recognition is not ideal, the model-based approach still correctly locates prominent global features, such as skull outline, enabling an approximate plan initalization. It is also noted that the manual (reference) annotations are also subject to operator inconsistencies. No significant outliers were observed within the trial consisting of 231 3D surveys of clinical patients. The proposed method enables complete automation of MR neuro scan planning, releasing the operator from this time-consuming task, and furthermore extends the possibility of robust, repeatable planning for all users.

References:

[1] Lelieveldt *et al*, *Radiology*, 221, 537-542, 2001.

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