

Geometric reconstruction of brain vasculature from small rodents; A comparison of different imaging methods

M. Gaudnek¹, M. Sibli^{1,2}, K. Obermayer^{1,3}, B. Kay⁴, and A. Hess⁵

¹Neural Information Processing Group, Berlin University of Technology, Berlin, Germany, ²Bernstein Centre for Computational Neuroscience, Berlin, NA, Germany, ³Bernstein Centre for Computational Neuroscience, Berlin, NA, Germany, ⁴Doerenkamp Professorship in Innovations in Animal and Consumer Protection, I. f. Experimental Pharmacology, Erlangen, NA, Germany, ⁵Pharmacological Imaging and Image analysis, I. f. Experimental Pharmacology, Erlangen, NA, Germany

Abstract

The exact knowledge of the blood vessel geometry plays an important role, not only in clinical applications (stroke diagnosis, detection of stenosis), but also for deeper analysis of functional data, such as fMRI. Here an exact reconstruction of the vascular system could be used to constrain BOLD models used for the analysis finally aimed at improving the spatio-temporal resolution. Here we provide a framework consisting of different computerized methods for reconstructing the tubular structures of blood vessels. We further compare the results obtained from different image approaches, including Magnetic Resonance Angiography (MRA), both three dimensional (3D Time-of-Flight) and slice wise (2D Time-of-Flight) with and without the usage of paramagnetic contrast agents (Endorem) and Micro Computer Tomography (μ CT) of corrosion casts. The later acts as GOLD standard for vascularization with respect to resolution and geometric distortions.

Materials and Methods

Rat and mice brain angiograms were imaged using a 4.7 T BRUKER Biospec 47/40 MR scanner, equipped with an actively RF-decoupled coil system. For the rat experiments a homogeneous excitation was provided by a whole-body birdcage resonator. A 3 cm surface coil, located directly above the head was used as receiver coil. For the mice experiments a transmit-receive quadrature resonator (3.5 cm) was used. After dedicated shimming to the imaging volume in order to reduce non-linear image distortions, the angiographs are acquired with a 3D Gradient Echo sequence. For the rat experiments a field of view 25 x 25 x 25 mm, for the mouse 18 x 18 x 18 mm, matrix 256 x 256 x 128 pixels, TR = 30 ms, TE_{eff} = 3.5 ms, flip angle = 45 degree, NEX 4) was used. On some experiments different contrast agent concentrations (Endorem 0.2 to 0.6 ml/kg) was applied intravenously just before MRA datasets were recorded. The animals were kept under constant Isoflurane anaesthesia via a nose mask. The depth of anaesthesia was adjusted to keep the respiration rate of the animals around 60. Body temperature was kept constant through heating via a water bath.

Results

All MRA's were preprocessed using a self developed algorithm based on a modified homomorphic unsharp masking method to remove RF bias induced by the head coil. The geometric reconstructions of vessel systems were automatically generated by another self developed software (pat. pending). The overall reconstruction time for a typical dataset is approximately 3 minutes, compared to over 12 hours for manual reconstruction. The quality achieved, using our method is at least comparable to human performance, which shows some variance for multiple segmentations especially for smaller vessel diameters. In cases where multiple MRA's were reconstructed, acquired in different image planes, the reconstructed vessels from individual MR scans were initially affine registered, followed by a nonlinear registration of vessel parts apparent in at least two datasets, using an iterative graph matching method.

Furthermore, we show the gradual increase of reconstructable vessels in dependence of the amount of contrast agent used as well as the integration of different angiograms (slicing directions) obtained from one animal into one, much more complete reconstruction. The robustness of our method is demonstrated by the fact, that reconstructions of μ CT data are possible without any change to the algorithms. We further show the dependence of imaged vessels on saturation gaps used in 2D TOF measurements, enabling us to discriminate between arteries and veins.

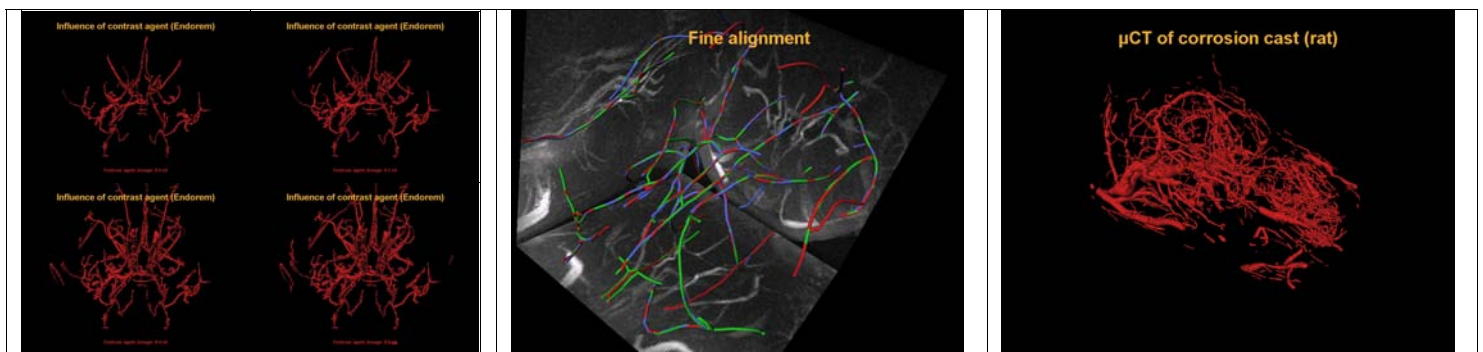


Figure 1: [left] Reconstruction of brain vessels from MRA's of the same rat using 4 different concentrations of endorem (0.0, 0.2, 0.4 and 0.6 ml/kg). [middle] Three aligned reconstructions of MRA's using different orthogonal slicing directions. [right] Reconstruction of brain vessels from a μ CT corrosion cast.

Supported by the BMBF (BCCN Berlin 10025304, DFG FG 661), the Doerenkamp Professorship in Innovations in Animal and Consumer Protection and the IZKF Erlangen Z2.