Quantification of Spinal Cord Atrophy in Magnetic Resonance Images

Quantifying the volume of the spinal cord is of vital interest for studying and understanding diseases of the central nervous system such as multiple sclerosis (MS). In this thesis, which is motivated by MS research, we propose methods for measuring the spinal cord cross-sectional area and volume in magnetic resonance (MR) images. These measurements are used for determining neural atrophy and for performing both longitudinal and cross-sectional comparisons in clinical trials.

We present three evolutionary steps of our approach: In the first step, we use graph cut–based image segmentation on the intensities of T1-weighted MR images. In the second step, we combine a continuous max flow segmentation algorithm with a cross-sectional similarity prior and Hessian-based structural features, which we apply to T1- and T2-weighted images. The prior leverages the fact that the spinal cord is an elongated structure by constraining its cross-sectional shape to vary only slowly along one image axis. In conjunction with the additional features, the segmentation robustness is thus increased. In the third step, we combine continuous max flow with anisotropic total variation regularization, which enables us to direct the regularization of the cross-sectional shape of the spinal cord more flexibly.

We implement the proposed approach as a semi-automatic software toolchain that automatically segments the spinal cord, reconstructs its surface, and acquires the desired measurements. The software employs a user-provided anatomical landmark as well as hints for the location of the spinal cord and its surroundings. It accounts for the bending of the spine, MR-induced image distortions, and noise.

We evaluate the proposed methods in experiments on phantom, healthy subject, and patient data. Our measurement accuracy and precision are on par with the state of the art. At the same time, our measurements on MS patient data are in accordance with the medical literature.