

Automatic Segmentation of T1-MR-Images of the brain

Magnetic Resonance Imaging (MRI) is one of the most important medical imaging techniques, which helps investigating diseases of the human brain and of the central nervous system. For example, MRT is used in the research of multiple sclerosis. By means of MRI, lesions in brain and spinal cord may be detected.

Evaluation of MR-Images by human experts shows very high inter- and intra-observer variability. Besides this, evaluation by human experts is a very time consuming process, because of the enormous amount of data of MR-Images. Therefore it is necessary to assist evaluation by semi-automatic techniques or replace human evaluation completely by automatic methods.

One important task of automatic evaluation is the segmentation of the brain into different tissue classes, mainly white matter, gray matter, cerebrospinal fluid (CSF) and other tissue classes like bone, fat and eyes. After the segmentation direct measure of brain volume or further search for brain lesions, like in multiple sclerosis research, is possible.

To solve this segmentation problem for T1-weighted MR-images, a fully automatic algorithm was developed in cooperation with Trium Analysis Online and the gsf research center. The algorithm consists of an energy function, based on the Potts model, which models the segmentation of an image. The energy function provides a rating for every possible segmentation of the MR-Image. It is constructed in such a way, that it gives a lower value the better the segmentation. To find the optimal segmentation, this energy function is minimized.

The energy function consists of three parts: The first part of the energy function is called the data term. It considers the transition probability of a certain tissue class to a certain intensity in the observed image. Theoretically every tissue class leads to a constant, but unknown, intensity in the observed image, which depends on the imaging modalities. In reality there are some effects degrading the image, like noise and the bias field evoked by inhomogeneities of the magnetic fields. To overcome these problems, the second part of the energy function prefers piecewise constant segmentations and smoothes noise in the image, by giving lower energy to segmentations with bigger connected areas. The last part is a brain atlas, that introduces rough anatomical foreknowledge into the segmentation. Besides advancing the possibility to segment degraded images, this allows to assign the right tissue classes to the observed intensities. The brain atlas used, was developed by the Montreal Neurological Institute (MNI) and is freely available with the program package spm99 (www.fil.ion.ucl.ac.uk/spm/). It is registered to the MR-Images using the program FLIRT from the FSL program package (www.fmrib.ox.ac.uk/fsl).

To find an optimal segmentation the energy function is minimized using a Markov chain Monte Carlo optimization algorithm called simulated annealing. The algorithm is adapted in such a way the unknown intensity of the tissue classes can be determined and foreknowledge about their intensity distributions can be taken into account.

The algorithm was evaluated using 20 MR-Images provided freely by the Internet Brain Segmentation Repository (IBSR, www.cma.mgh.harvard.edu/ibsr). For these images a gold standard segmentation and comparison data with other segmentation algorithms is available. Figure 1 shows a rating for the segmentation of gray matter, calculated with the different algorithms, for every of the 20 images. Higher values indicate better segmentation. The developed algorithm shows an improvement in nearly all cases.

The original diploma thesis (in German) and some links are available online at www.trium.de -> Research -> Publications

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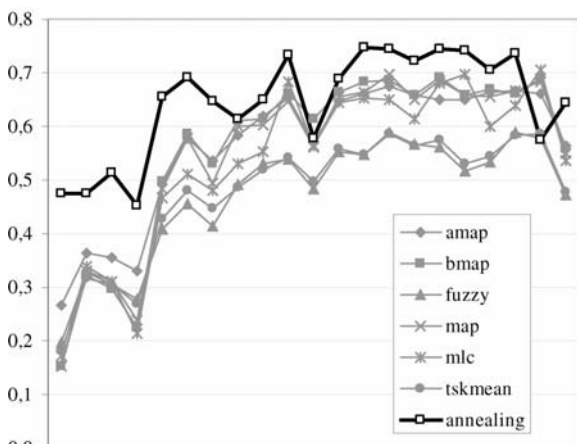


Figure 1: White matter segmentation performance of developed annealing algorithm (dark) compared to reference algorithms provided by the IBSR.

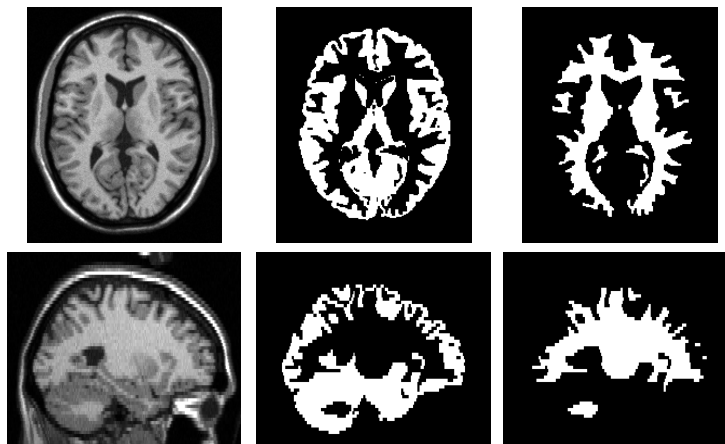


Figure 2: MR-Image (left), segmented white matter (middle) and segmented gray matter (right)