Simultaneous Reconstruction and Segmentation with Class-Specific Priors

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Studying the interior of objects using tomography often require an image segmentation, such that different material properties can be quantified. This can for example be volume or surface area. Segmentation is typically done as an image analysis step after the image has been reconstructed. This thesis investigates computing the reconstruction and segmentation simultaneously. The advantage of this is that because the reconstruction and segmentation are computed jointly, reconstruction errors are not propagated to the segmentation step. Furthermore the segmentation procedure can be used for regularizing the reconstruction process. The thesis provides models and algorithms for simultaneous reconstruction and segmentation and their performance is empirically validated.

Two method of simultaneous reconstruction and segmentation are described in the thesis. Also, a method for parameter selection is given. The reconstruction and segmentation are modeled as two parts: the image that is reconstructed and a so-called Hidden Markov Measure Field Model (HMMFM). Pixel values in the image contain material attenuation coefficients and the HMMFM contains pixelwise probabilities for material classes. The number of material classes and their parameters are assumed known a priori. These parameters are the mean value of the class attenuation coefficients and their standard deviations. Given this input together with projection data, the problem is to find the image and HMMFM. The segmentation is obtained from the HMMFM as the most probable class in each pixel.

The solution for the reconstruction and segmentation problem is found using an algorithm that simultaneously minimizes the reprojection error, deviation of the grey levels of pixels from known mean values and the spatial differences in the class probabilities.

In the first Simultaneous Reconstruction and Segmentation (SRS) method data is assumed Gaussian distributed and the minimization is done using standard optimization techniques in two stages. Experimental validation on both phantom and real data shows that modeling the reconstruction and segmentation simultaneously has superior performance, especially when the problem is underdetermined, i.e. when the number of unknowns in the reconstruction exceeds the number of observations.

The second SRS method assumes Poisson distributed data, which is the case for data originating from discrete events like photon counts. The algorithm is again based on solving a minimization problem. In addition a relaxation strategy is employed in order to avoid being stuck in local minimum. This model is also validated on artificial data.

Selecting appropriate regularization parameters can be difficult, so the last thing that we consider is a parameter selection approach. The most promising approach was a modified L-curve algorithm, which was empirically analyzed.

This thesis contributes with methods for simultaneous reconstruction and segmentation and demonstrates the benefits of this approach in situations where only few projections are available and data is noisy. Here a higher precision image as well as segmentation can be computed.

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