A New Hybrid Algorithm based on Watershed Method, Confidence Connected Thresholding and Region Merging as Preprocessing for Statistical Classification of General Medical Images

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ABSTRACT

Segmentation of morphology in medical image data is a highly context specific and differs from various imaging modalities, necessitating the use of sophisticated mathematical models and algorithms to achieve good results. In this work an algorithm is presented for pre-segmentation of general medical input data, based on a watershed-segmentation strategy utilizing both, original intensities and derived gradient magnitudes for region growing. The number of resulting pre-classified regions is iteratively reduced to a user-defined threshold using merge metrics, accounting for the similarity of intensity profiles of two neighboring regions to merge, as well as the height of the gradient barriers to overcome and geometric aspects like sphericity and size of the border area with respect to the total region size. Based on such a context-independent pre-segmentation, the resulting manageable number of regions can be further merged and classified, utilizing texture features and a priori statistical models. Results are presented from brainweb database.

Keywords: Medical Image Data, Pre-segmentation, Statistical Image Classification, Texture Features, Watershed-Segmentation

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1. INTRODUCTION

Accurate and automated segmentation of medical image data is of high importance in a very broad range of medical applications. The evaluation of geometric properties like position, size and extent of anatomical structures necessitates previously performed image segmentation and is of high relevance in the domain of surgery planning as well as disease progression. Based on such an anatomical classification, e.g. in case of liver tumors, the position of the lesion with respect to the supplying vessel systems as well as the parenchyma size and shape can be assessed prior to liver lobe resection (Zwettler, Backfrieder, Swoboda, & Pfeifer, 2009). When combining data from different imaging modalities like CT/MRI for high anatomical resolution and SPECT/PET from the functional imaging domain, metabolic activity can be quantified utilizing segmentation masks of the corresponding anatomical region (Beyer, Schwenzer, Bisdas, Claussen, & Pichler, 2010). Evaluation of therapy success and disease progression gets feasible in a quantitative way if morphological segmentations of the same patient at different points in time are available (Kuhnigk, Dicken, Bornemann, Bakai, Wormanns, Krass, & Peitgen, 2006). Furthermore, in virtual reality scenarios, patient specific segmentation models based 3D tracking and navigation, true 3D vision and rapid prototyping of haptic patient models (Wulf, Vitt, Gehl, & Busch, 2001; Torres, Staskiewicz, Sniezynski, Drop, & Maciejewski, 2001) are highly applicable for the task of surgical training and planning (Stone, 2011).

To achieve accurate segmentation of particular organs and anatomical structures, semi-automated concepts like region growing (Gonzalez & Wintz, 1987) or live-wire contour definition (Barrett & Mortensen, 1997) can be applied. Due to the high demand for user-interaction these concepts are improper for clinical use. Although requiring rarely no a priori knowledge and thus favoring generic segmentation, utilizing these strategies only rather awkwardly shaped structures with homogenous intensities can be segmented. Although not directly applicable for medical applications, these concepts are of high relevance preparing manual reference segmentations for model-driven segmentation approaches.

Utilizing deformable models (McInerney & Terzopoulos, 1996) and incorporating a priori knowledge, particular structures with low anatomical variability can be precisely segmented. The generic use of deformable models for segmentation of arbitrary anatomical structures is not practicable, because the model parameters need proper adjustment to the target morphology and fine structures showing inhomogeneous intensities remain hard to segment. Statistical Shape Models (Cootes, Taylor, Cooper, & Graham, 1992) can be automatically derived from a set of reference segmentations, allowing for the use of geometric features of the target structures to segment. If trying to model several structures utilizing statistical shape models, the problem of shape overlapping as well as topological changes remain unconsidered. Furthermore, modeling very thin and sparsely connected structures with respect to low imaging resolution or partial volume effects cannot be achieved with geometric shape modeling. Active appearance models (Cootes, Edwards, & Taylor, 1998) introduce statistical properties of the targets structure expected intensity profile besides geometric features, thus being more robust in case of anatomical variability. Segmentation of small, loosely connected structures and changes in topology remain still unaddressed. Utilizing level sets (Osher & Sethian, 1988), topological changes and anatomical variability can be handled, but adapting the steering parameters curvature, propagation and advection, only rather compact structures can be modeled. Furthermore, the level set parameters must be adjusted for each structure to segment, rather than deriving them from a set of reference segmentations.

To facilitate generic segmentation of arbitrary anatomical structures, a context and modality invariant pre-segmentation is required as fundament for texture based merging for classification. Classifiers like fuzzy connectedness (Gammage & Chaudhary, 2006) and confidence
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