Spatio-Temporal Analysis of Contrast Enhanced Ultrasound Perfusion Imaging Data

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I. Introduction

Contrast enhanced ultrasound is used for detection of tumors in different organs, such as liver [1] or brain [2] via perfusion specific imaging. The foundations for this differentiation are the morphologically differences of tumor tissue due to the development of new blood vessels to fulfill the high nutritional needs of the fast growing neoplasia.

The combination of 2D image processing and 1D time course of the contrast agent concentration improves the differentiation between tissue types by interpreting both spatial and temporal information. We aim to quantify and combine those information by computing spatial features and approximating model functions to the concentration and feature time courses. To model the time courses several well known [3] and new models are applied. The model parameters can be used for classification as recently demonstrated [4].

II. Methods

Data: A total of 85 intracranial videos with a resolution of 408×340 pixels in the image plane and 500 frames were acquired in tumor resection surgery of 63 patients after applying a 2 ml bolus of the contrast agent SonoVue.

Feature images: Local changes of gray value distributions in image frames are described via features, e. g. variance or entropy.

Time Courses: The time course in every pixel resulting from unprocessed video frames corresponds to the concentration time course of the contrast agent bolus. In addition to the first pass bolus models a new more flexible 1D-model based on sigmoid functions was developed [5] to fit the concentration time course with increased precision and enable depiction of the influence of recirculation in the wash-out phase of the bolus.

Time courses of features encode 2D spatial and 1D temporal information of the perfusion. They have to be analysed for characteristic behaviour enabling differentiation of tissues types.

III. Results

The feature images show largely increased values of entropy for perfused areas, while variance depicted arterial regions more homogeneous than tumor regions.

Concentration time courses of different tissue types vary in peak concentration, slope and width of the bolus. Tumour tissue demonstrated lower peak concentration while the wash-out phase of the agent was prolonged. The approximation of model function produced sets of parameters to describe time courses. A first step towards automated segmentation is the visualization of these parameters in maps, depicting e. g. arrival time or peak concentrations of contrast agent.

Time courses of spatial feature images are generated to evaluate additional changes in perfusion behaviour.

IV. Discussion

The regional distinction of the feature time course may be a result of the larger number of capillaries in tumor tissues and thus a changed perfusion dynamic. Some parameters of model functions correspond to currently used quantitative measurements and produce rather intuitively interpretable visualizations, other parameters (e. g. slope of the wash-out phase) are abstract, but also carry relevant information about tissue perfusion.

We aim to identify parameters applicable for tissue classification based on the 1D time courses of 2D features and intend to evaluate the utility of a diversity of parameter and feature combinations.

References

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