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Applications of statistical methods for quantitative magnetic resonance imaging

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Abstract
Magnetic resonance imaging, MRI, offers a vast range of imaging methods that can be employed in the characterization of tumors. MRI is generally used in a qualitative way, where radiologists interpret the images for *e.g.* diagnosis, follow ups, or assessment of treatment response. In the past decade, there has been an increasing interest for quantitative imaging, which give repeatable *measurements* of the anatomy. Quantitative imaging allows for objective analysis of the images, which are grounded in physical properties of the underlying tissues. The aim of this thesis was to improve quantitative measurements of Dynamic contrast enhanced MRI (DCE-MRI), and the texture analysis of diffusion weighted MRI (DW-MRI).

DCE-MRI measures perfusion, which is the delivery of blood, oxygen and nutrients to the tissues. The exam involves continuously imaging the region of interest, *e.g.* a tumor, while injecting a contrast agent (CA) in the blood stream. By analyzing how fast and how much CA leaks out into the tissues, the cell density and the permeability of the capillaries can be estimated. Tumors often have an irregular and broken vasculature, and DCE-MRI can aid in tumor grading or treatment assessment. One step is crucial when performing DCE-MRI analysis, the quantification of CA in the tissue. The CA concentration is difficult to measure accurately due to uncertainties in the imaging, properties of the CA, and physiology of the patient. **Paper I**, the possibility of using two aspects of the MRI data, phase and magnitude, for improved CA quantification, is explored. We found that the combination of phase and magnitude information improved the CA quantification in regions with high CA concentration, and was more advantageous for high field strength scanners.

DW-MRI measures the diffusion of water in and between cells, which reflects the cell density and structure of the tissue. The structure of a tumor can give insights into the prognosis of the disease. Tumors are heterogeneous, both genetically and in the distribution of cells, and tumors with high intratumoral heterogeneity have poorer prognosis. This heterogeneity can be measured using texture analysis. In 1973, Haralick *et al.* presented a texture analysis method using a gray level co-occurrence matrix, GLCM, to gauge the spatial distribution of gray levels in the image. This method of assessing texture in images has been successfully applied in many areas of research, from satellite images to medical applications. Texture analysis in treatment outcome assessment is studied in **Paper II**, where we showed that texture can distinguish between groups of patients with different survival times, in images acquired prior to treatment start.

However, this type of texture analysis is not inherently quantitative in the way it is calculated today. This was studied in **Paper III**, where we investigated how texture features were affected by five parameters related to image acquisition and pre-processing. We found that the texture feature values were dependent on the choice of these imaging and preprocessing parameters. In **Paper IV**, a novel method for calculating Haralick texture features was presented, which makes the texture features asymptotically invariant to the size of the GLCM. This method allows for comparison of textures between images that have been analyzed in different ways.

In conclusion, the work in this thesis has been aimed at improving quantitative analysis of tumors using MRI and texture analysis.

Keywords
Quantitative imaging, tumor imaging , dynamic contrast-enhanced MRI, diffusion weighted MRI, texture analysis

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