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Inferring sub-micron sizes using oscillating gradient diffusion weighted magnetic resonance imaging

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We have developed a new method for distinguishing the size of submicron structures using diffusion weighted magnetic resonance imaging (MRI). This method relies on MRI signal changes because water in samples undergoes diffusion. The mean-square displacement of the water molecules depends on the diffusion time. Molecules diffusing in a uniform medium with no barriers experience unrestricted diffusion. In non-uniform media (e.g. porous samples and cellular tissues) barriers hinder or restrict molecular displacements so that the diffusion depends on the time scale of the study, on the size of pores, and on the permeability of the barriers.

The method relies on probing the shortest possible diffusion time scales so that the transition from restricted to hindered diffusion within the smallest structures can be detected. Current state-of-the-art methods cannot distinguish these small structures because current methods use pulse sequences which limit the ability to probe the shortest diffusion times. Our method circumvents those limitations by using oscillating gradients in place of pulsed gradients. The new method has important biological and neuroscience applications; one example is probing axon diameter distributions.

In this talk I will summarize the method and our improvements to other methods for determining axon sizes. I will discuss our Monte Carlo simulations using cosine gradient spin echo sequences and the ability of our method to infer submicron sizes. Improvements to the speed of the simulations were made using GPUs instead of CPUs. I will also show our MRI data collected from micron-sized polystyrene beads on our Bruker 7 T 21 cm scanner using three of the OGSE sequences (sine, double sine, and apodised cosine).

This method has opened a new era of MRI with sensitivity of submicron scale structures. The method can be adapted to other systems, biological or otherwise. Combining our method with other methods sensitive to large scales will allow us to distinguish a large range of restriction sizes from very small to fairly large and give a more complete understanding of the geometry of the sample.

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