Application of Aitchison metrics on magnetic resonance imaging data with multiple contrasts at ultra high field (7 Tesla) to investigate compositional characteristics of brain tissues in living humans

O.F. Gulban[1]
F. De Martino[1]
[1]Maastricht University, Maastricht, Netherlands; *faruk.gulban@maastrichtuniversity.nl*

Abstract

Images of living human brains can be acquired at sub-millimeter spatial resolution using ultra-high field (UHF, ≥7 Tesla) magnetic resonance imaging (MRI) scanners (Ugurbil, 2014). Different scanning parameters weight the image contrast to different tissue properties. A few examples of these differently weighted images are; T1 weighted (T1w) images to maximize the contrast between white matter gray and matter tissues, proton density weighted (PDw) for measuring concentration of hydrogen atoms and $T2^*$ weighted ($T2^*$w) for iron content. In recent years, attempts were made to combine different contrasts by simple ratio images to mitigate image inhomogeneities (T1w/PDw ratio image) (van de Moortele and others 2009) or reveal some tissue properties such as myelination (T1w/$T2^*$w ratio image) (De Martino and others, 2014).

Multi-contrast MR images can be treated as compositional data to combine more than two MRI contrasts at the same time. Voxel-wise Aitchison norm and Aitchison distance (Pawlowsky-Glahn and others, 2015) can be used to create virtual MR contrasts to investigate compositional characteristics of the tissues. In addition, thanks to the scale invariance principle, the otherwise problematic image inhomogeneities (due to signal variations from radio-frequency transmit/receive profiles) are greatly mitigated inside of the simplex. Hence the virtual contrasts are mostly inhomogeneity-free.

The scale invariance of the virtual contrasts has important implications in image segmentation, especially in UHF MRI. Image segmentation methods commonly assume homogeneous contrast, which is a challenging assumption to fulfill at UHF. Using intensity-gradient magnitude 2D histograms of 3D tissue characteristics (Kniss and others, 2005), the virtual contrasts can be exploited for improved tissue classification and segmentation by themselves or in combination with the traditional MR contrasts.

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