Design of An MR Phantom for Comparison of Frequency Based Texture Analysis Techniques

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Introduction

Image analysis frequently examines the intensity of a feature: *e.g.* a tumor may appear on average to be brighter or darker than surrounding tissue. A complementary technique is that of texture analysis, where characteristic patterns of intensity are recognized. Textural features of magnetic resonance (MR) images have been shown to be significantly associated with clinically important genetic differences in some brain tumors[1] as well as other clinical applications[2].

Texture can be quantified in several ways but a simple, intuitive, robust method is through examination of the frequency spectrum[3]. Frequency based texture analysis has traditionally used the Fourier transform (FT) to provide spatial frequency information[3]. The two-dimensional FT is calculated for an area of interest. Since most tissue textures lack a meaningful preferred direction, the spectrum is converted to a polar coordinate system and averaged over the angle axis, producing a one-dimensional function of frequency that is orientation-independent.[3] An alternative transform, the S-transform (ST)[4], provides a local frequency spectrum for every pixel in an image, allowing arbitrarily shaped regions of interest to be analysed.

This abstract reports the design of an MR phantom to investigate the properties of frequency-based texture analysis techniques and compares the characteristics and repeatability of FT- and ST-based frequency analysis of that phantom and a volunteer's head.

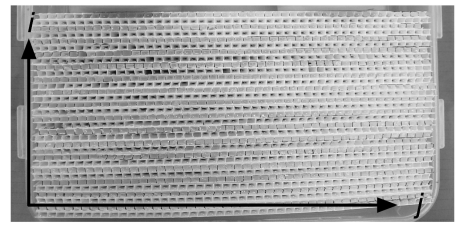

Figure 1: top view of the MR phantom. The coordinate system used to refer to the phantom is illustrated in black, with the i-*axis corresponding to the short axis of the phantom, which is also the short axis of the cells, and the direction of the agar-water or agar-gadolinium contrast. The* j-*axis runs along the long axis of the phantom.*

Methods

An MR phantom was designed and constructed to exhibit several prominent textural features. Corrugated plastic (Coroplast; Granby, Quebec) was cut into 25 cm by 17 cm sheets, with each sheet containing cells in the shape of rectangular prisms, approximately 3 mm by 6 mm by 170 mm, with plastic borders < 0.5 mm thick on the short axis and < 1.0 mm thick on the long axis. These sheets were stacked, and the cells in adjacent sheets were filled with agar or water. To add additional contrast, experiments were repeated with water doped with a 2% solution (10 μM) of contrast agent (Magnevist; Bayer, Wayne, NJ). The phantom (Figure 1) exhibits three main textural features: (1) 5 mm wide bright areas with thin dark borders along the *j*-axis, (2) a similar 3 mm wide pattern along the *i*-axis, and (3) 3 mm wide bright and dark bands produced by the agar-water contrast along the *i*-axis. A mathematical model was constructed to simulate these features and predict the resulting FT and ST texture measurements. A 3 T clinical scanner (Signa; General Electric Healthcare, Waukesha, WI) and quadrature head coil were used to repeatedly image the phantom (fast spin echo, TR = 750 ms, TE = 21 ms, ETL = 4, 24 cm × 24 cm FOV, 256 × 256 acquisition matrix, 2.5 mm slices) and a volunteer's head (para-axial slices, fast spin echo, TR = 2000 ms, TE = 104 ms, ETL = 8, 24 cm × 24 cm FOV, 256 × 256 acquisition matrix, 2.5 mm slices). Both the phantom and volunteer were repositioned between each scan.

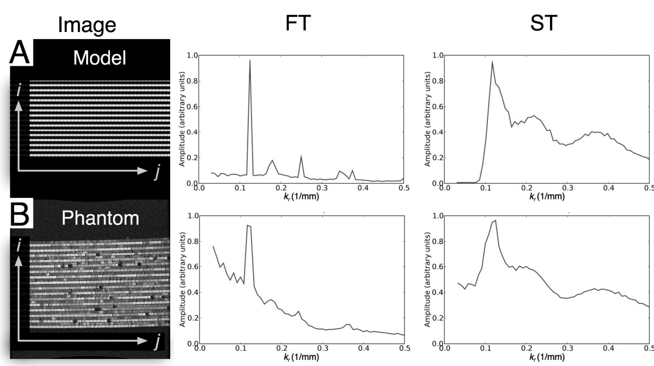

Figure 2: Images with gadolinium from the model (A) and the phantom (B). The resulting FT and ST spectra are shown in column 2 and 3 respectively.

Results

The overall texture is visually similar between the MR images of the phantom and the synthetic images from the mathematical model but the phantom contains features that were not modelled, including air bubbles (Figure 2). The predicted ST spectra are consistent with results from the phantom. The predicted and measured FT spectra also exhibit peaks in the expected locations, but the measured FT spectra contain several other prominent features that are not present in the modeled spectra.

ST spectra calculated from repeated scans of the phantom produced coefficients of variation (COV) that were < 15% for all frequencies, and < 10% for most of the spectrum. COV for the FT technique were similar except for several frequencies with COV > 20%. Spectra from a region of interest placed in white matter produced a similar pattern, with COV in the ST spectra < 8% but with the FT spectra showing COV spikes up to 15%.

Conclusions

The differences between the measured and predicted FT spectra indicate that the FT technique is more sensitive to small changes in texture than the ST technique. However, repeated scans performed in this experiment suggest that the FT spectra are less reproducible. Experiments investigating texture analysis for clinical applications have also shown that the ST technique is better able to identify textural differences in patients[3], likely as a result of the better reproducibility of the ST technique.

References

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