Assessing the Impact of Image Registration on Texture Analysis of MR Images

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Introduction

MRI is a sensitive tool used to visualize lesions in diagnosing multiple sclerosis (MS). However, abnormalities seen on routine clinical MRI lack pathological specificity: it is difficult to determine the severity of tissue destruction, including axonal loss and scarring. Texture analysis is a computerized approach for analyzing changes in the MR image "texture" that result from changes in pathology that are too subtle to detect visually. Recently, a method to quantify image texture using space-frequency transforms, the polar Stockwell transform (PST), has been used in MR studies of brain tumors and MS lesions (Zhu et al.). The PST quantitatively describes the magnitude of each spatial frequency component present in an image. Changes in image texture can then be quantified by measuring the corresponding changes in spatial frequency power. Preliminary results suggest that spatial frequency information is associated with MS lesion pathology and evolution. Because the changes detected are small, it is important to determine how image resampling, a common procedure used during image registration, will impact texture analysis. Image registration transforms multiple data sets into a single coordinate system, and is often used for longitudinal monitoring. When an image is registered and resampled, the original grid is moved and new pixel intensities are computed. The intensities differ depending on the interpolation algorithm. This study investigates the impact of resampling using different image interpolation methods on texture analysis using PST.

Methods

MRI data from 25 patients with definite MS were used in the study. Hypointense regions indicative of MS lesions ("black holes") were identified on the pre-contrast T1-weighted images by an experienced radiologist. A total of 1402 black hole regions of interest (ROIs) were used in the study. The scans, collected from a 3-T Philips scanner, consisted of 50 image slices (Image size: 256x256 pixels; Pixel size: 0.937x0.937 mm²; Slice thickness: 3.00 mm; %FOV: 75.00%; TR: 616.7 ms; TE: 9.0 ms). Using in-house registration software, each of the images was moved by +0.5 pixels in the x, y and z directions to a new location and then resampled back to the original location. Resampling was performed using three separate currently popular interpolation methods: linear, Blackman and B-spline. The different interpolation methods produce different resampled images, with B-spline being the most accurate resampling method. Using parameters based on a previous study by Zhang et al., the PST spectrum of each ROI (32x32 pixels) for the images was computed, generating a 4-D dataset, containing the PST energy at each point (x, y, k_x, k_y), where k_x and k_y represent the spectral frequencies. The mean differences between the computed PST spectra of the original images and the resampled images are computed and compared. Paired Student t-test was also used to compare the PST values in the original images to the resampled images by comparing the changes in the average energies using a spectral frequency resolution of 0.32 cm^{-1}. Because of the multiple comparisons, Bonferroni correction method was used in the T-test analysis of the individual spectral contours.

Results

Figure 1 shows the mean differences between the PST energies at different frequency contours for the three different interpolation methods. Within the low frequency range between 0 and 2.56 cm^{-1}, the maximum energy difference between the linear interpolation PST with the original image PST is 0.092 PST units, compared to the Blackman and B-spline interpolation methods that have maximum energy differences of only 0.020, and 0.016 PST units respectively. At the higher frequency range (between 2.56 cm^{-1} and 5.12 cm^{-1}), the maximum energy difference between the linear, Blackman and B-spline interpolation PST computations compared to the original image PST computation are 0.035, 0.0166, and 0.0127 PST units respectively. T-test analysis results show that for all spectral contours in the lower and higher frequency ranges have t-values > 1.646, which is statistically significant for p=0.5 and d.o.f. = 1400.
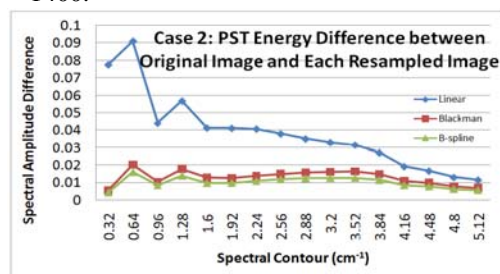

Figure 1. Spectral amplitude difference is greatest at lowest spectral contours for all three interpolation methods. Blackman and B-spline interpolation methods show smaller differences.

Conclusions

Irrespective of the interpolation method used, statistically significant differences between the PST spectrum of the interpolated images and the original images were found. The results also show that the choice of resampling method affects the degree of change in the texture measurements. The degree of change in the texture measurements simply from resampling, is in the range of what has previously been reported by Drabycz et al. as the difference between MS lesion and normal appearing white matter (less than 0.05 PST units). Based on our results, it is clear that linear interpolation should not be used in texture analysis of MS lesions. While Blackman and B-spline interpolation, which are computationally more intensive, are more accurate than linear interpolation, they still lead to significant changes in the PST spectrum, and may mask potential differences between tissues making interpretation of any results difficult. Comparing the PST pre and post-interpolation would be advisable.

References

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