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N-Peaks, a novel method of intensity normalization for magnetic resonance images

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Purpose

Intensity units in magnetic resonance (MR) images have no inherent meaning. Quantitative evaluation of MR images may benefit from an intensity normalization. There exists no consensus about the best intensity normalization method, and most approaches do not consider physiological meaning of image regions or are restricted to specific body regions.

We developed a novel approach for MR intensity normalization, called N-Peaks, which produces intensity units with a physiological connection while being applicable in any body region.

Methods

N-Peaks requires an image from any body region and an arbitrary number (N) of contours describing histologically different tissues. In each contour, it determines the peak of the homogeneous tissue in the intensity histogram and uses those peak intensities as landmarks for normalization to a target intensity scale.

The homogeneous tissue in each contour is isolated by excluding voxels where the magnitude of local intensity change is higher than an automatically determined threshold. The remaining region should contain one or more intensity peaks, corresponding to different sub-regions, of which one peak is chosen. The result can be interpreted by visualizing the found homogeneous region and intensity peak.

Finally, a piecewise linear intensity transformation is applied to the image such that peak intensities are mapped to target intensity values.

We tested N-Peaks on 2308 brain MRI using four sequences (T1, T1c, T2 and FLAIR) from the Brain Tumor Segmentation challenge dataset using cerebrospinal fluid and white matter as contours. For each sequence, the intensity-volume histogram of brain tissue was determined for each image and the Jensen-Shannon distance (JSD) was calculated to the average histogram across all images in that sequence.

Results

The mean JSD (± 1 standard deviation) for T1, T1c, T2 and FLAIR were: without normalization $0.55(\pm 0.05)$, $0.54(\pm 0.06)$, $0.31(\pm 0.13)$ and $0.48(\pm 0.08)$; and with N-Peaks $0.13(\pm 0.03)$, $0.12(\pm 0.04)$, $0.14(\pm 0.03)$ and $0.18(\pm 0.06)$.

Conclusion

N-Peaks is a flexible, physiologically motivated and interpretable MR intensity normalization technique. The improved consistency of the intensities was demonstrated in brain MRI in the form of lowered JSD values between histograms.

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