Testing classical single-shell HARDI techniques

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I. Introduction

The goal of this submission is to provide a set comparitive results using some of the most common HARDI reconstruction techniques having made their mark in the local reconstruction community in the last several years. Namely, we have ran analytical q-ball (a-QBI) and normalized analytical q-ball, also called constant solid angle (CSA-QBI), with different spherical harmonics (SH) orders. We have also ran spherical wavelet tranformation (SWT) of the orientation distribution function (ODF). Finally, we have ran spherical deconvolution (SD) with contrained regularization at different SH orders using two implementations. The first, from the q-ball ODF to obtain the fiber ODF (fODF) and, second, from the raw signal to obtain the fiber orientation distribution (FOD).

II. Single-shell HARDI techniques tested

A. Analytical q-ball imaging (a-QBI)

We used our in-house implementation of [1] with regularization parameter $\lambda = 0.006$ and SH order $L = 4, 6$ and 8. Recall that this QBI solution is actually a smoothed approximation of the ODF, Ψ, since it is derived from the ODF definition without the Jacobian term in the ODF integral, i.e. $\Psi(\theta, \phi) = \int_0^\infty P(r, \theta, \phi)dr$, where P is the diffusion propagator describing the 3D diffusion of water molecules.

B. Constant solid angle q-ball imaging (CSA-QBI)

We used our in-house implementation of the analytical technique presented in [2], [3] using spherical harmonics order $L = 4, 6$ and 8. Recall that this technique finds a solution to the previous equation with the proper r^2 term in the integral, i.e. $\Psi(\theta, \phi) = \int_0^\infty P(r, \theta, \phi)r^2 dr$. A regularization parameter $\lambda = 0.006$ was also used.

C. ODF sharpening with spherical wavelets

We also tested the technique of [7] for SH order $L = 8$. Recall that this is a sharpening transform of the ODF. It decomposes the a-QBI ODF into low and high frequency components using a multi-resolution *à trou* spherical wavelet decomposition. Only the high-frequency ODF part, or sharpened ODF, is used to detect maxima.

D. Spherical deconvolution

Finally, we tested two SD techniques: the one presented in [4] and and the other in [5]. For both techniques, a constrained regularization implementation is used, at orders $L = 6, 8, 10$, and diffusion profile of [17, 3, 3] x10^{-6}mm^2/s is used as single-fiber deconvolution model. We found it the best trade-off and choice from the training data. The techinique [4] is implemented in our in-house tools, whereas the one of [5] uses *mrtrix* [6].

III. Solution for the ISBI contest

To respect clinical-like acquisition time and real data acquisition settings from the literature, we have limited our number of diffusion measurements to 60 directions. On the training data, we have first used the number of peaks detected as our quantitative quality measure of reconstruction. Then, we have varied the number of directions for $N = 30, 35, 40, 45, 50, 55, 60$ diffusion directions, SNR $= 5, 10, 15, 20, 25, 30, 35, 40$ and b-values $= 700, 1000, 1500, 2000, 2500, 3000, 3500$ s/mm^2. Peaks are extracted using finite differences on the ODF 724 mesh points and volume fractions of fiber crossings using a normalized ratio of the ODF peaks. The sum of ratios must equal 1.

Based on these simulations, the optimal configuration, on average, over the different phantoms, SNRs, number of measurements and b-values was $N = 60$ and $b = 3000$s/mm^2. However, none of the techniques outperformed all the others when considering all SNRs and all phantoms. This is not surprising. On the independent voxels (IV), the fODF of order $L = 6$ was the best with success of detecting all peaks at approximately 52%. On the other hand, a success rate of 80% was obtained on the structured field (SF) in 3D; from the FOD of *mrtrix* for SNRs between 10 and 25, and from the CSA-QBI/fODF/FOD/SWT for higher SNRs (almost all equal in terms of success rate). Note that for SNR 5, a-QBI of order 4, which is the technique to the most intrinsic smoothing, was best with approximately 50% sucess rate. Hence, a hybrid technique would have probably best for the datasets presented in this ISBI contest.

IV. Conclusion

Overall, when averaging over both phantoms and all SNRs, CSA-QBI of order 4, fODF of order 6 and FOD of order 8 from *mrtrix* was best at correctly finding peaks. The problem with these SD techniques is that they do not provide a diffusion ODF but a sharp angular profile. We could have generated a synthetic diffusion ODF from the peaks fODF or FOD but, instead, we decided to go with CSA-QBI of order that reconstructs a diffusion ODF close to the ground truth. Therefore, our selected "*best*" technique for the competition is **constant solid angle q-ball imaging with spherical harminics order 4**. Nonetheles, we have submitted all reconstructions described in this abstract to the organizers to include them in the global comparisons of techniques.

References

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