



HAL
open science

Fast, Model-Free , Analytical ODF Reconstruction from the Q-Space Signal

Jian Cheng, Aurobrata Ghosh, Tianzi Jiang, Rachid Deriche

► **To cite this version:**

Jian Cheng, Aurobrata Ghosh, Tianzi Jiang, Rachid Deriche. Fast, Model-Free , Analytical ODF Reconstruction from the Q-Space Signal. the Sixteenth Annual Meeting of the Organization for Human Brain Mapping (OHBM), 2010, Barcelona, Spain. <inria-00497243>

HAL Id: inria-00497243

<https://inria.hal.science/inria-00497243v1>

Submitted on 2 Jul 2010

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

Fast, Model-Free, Analytical ODF Reconstruction from the Q-Space Signal

Poster No:

827 WTh-AM

Authors:

Jian Cheng¹, Aurobrata Ghosh², Tianzi Jiang¹, Rachid Deriche²

Institutions:

¹Institute Of Automation, Chinese Academy Of Sciences, Beijing, China, ²INRIA Sophia Antipolis, Sophia Antipolis, France

Introduction:

The orientation distribution function (ODF) is very important in diffusion MRI. There are two types of ODFs. One is proposed using radial projection in Q-ball imaging [7]. Another one is the marginal pdf proposed in diffusion spectrum imaging (DSI) [8]. Since the marginal pdf is much sharper and mathematically correct, it could be more useful. Recently some reconstruction methods were proposed for this kind of ODF [1, 6]. They are both based on mono-exponential model, globally or locally, which has some intrinsic modeling error [4]. Although the authors in [1] extended the mono-exponential model to multi-exponential model, this multi-exponential model needs to be estimated non-linearly for every voxel and only in some special sampling scheme it has a analytical solution. Here we give a model-free analytical reconstruction method based on the Spherical Polar Fourier expression of the signal. It can estimate the ODF fast and analytically from the signal.

Methods:

Spherical Polar Fourier expression is a kind of orthonormal basis representation and it has been shown in [2] that it can represent the diffusion weighted image signal sparsely. See formula (1), where $R_n(q)$ is the nth Gaussian-Laguerre polynomial and Y_l^m is the l order m degree spherical harmonics (SH). After we estimate the coefficients of the signal under the basis from a least square fitting or a nonlinear robust estimation [2], some PDF features could be calculated through an inner product of the coefficients $a_{n,l,m}$ and a kernel $b_{n,l,m}$. The problem in [2] is that the kernel needs to be calculated numerically from FFT for every direction or calculated for one direction then rotated for other direction. That is inefficient and may bring some numerical error. In [1] the authors showed that the ODF could be represented in the formula (2), where ∇_b^2 is the Laplacian-Beltrami operator. Based on the spherical Polar Fourier expression, we proved that the ODF coefficients can be represented analytically by the same order of SH. Please see formula (3), where $P_l(0)$ is the Legendre polynomial of order l at 0. This formula tells us that we need to use at least order 1 of R_n to represent the anisotropic ODF. That is true because if we just use the radial basis of order zero, it is easily seen that the estimated signal is just an isotropic one, which means the estimated ODF is isotropic. Our method here is very fast since it is just a linear transformation on the coefficients, which is actually independent with data. Moreover, the coefficients of the signal could be estimated using least square with regularization term. Thus everything here is analytical and linear.

Results:

To estimate the coefficients using at least order 1 of radial basis, it means that we need to use at least two shells to get the reasonable results. Here we show a result from a public phantom data with 3 shells in q-space, where b-value is 650,1500,2000 s/mm² respectively. This data has been used in the fiber cup contest in MICCAI 2009 to evaluate tracking methods [5]. It could be downloaded from the website <http://www.Inao.fr/spip.php?article112>. We believe that it is complex enough to evaluate different reconstruction methods and tracking methods. We compare our reconstruction method using 3 shells with the method in [1] using one shell (b=2000), since the result of b=2000 is better than the results of b=650 and 1500 for the method in [1]. We choose N=3, L=4 in our method and use least square fitting with regularization term 5e-8 in the spherical part and 1e-9 in the radial part [2] for our method. To perform a fair comparison, we choose L=4 and tune the Laplacian regularization term lambda from 0.006 (suggested in [3]) to 0.02, 0.03 and 0.04 for the method in [1]. Two crossing areas were chosen for visualization and all the pictures were visualized using min-max normalization [7]. The results were shown below and the first column is the result from our method. It shows that the method using 3 shells is better. The bad performance of the method in [1] probably comes from the error of the mono-exponential model. It can always give sharper ODFs even if there is no obvious fiber.

Conclusions:

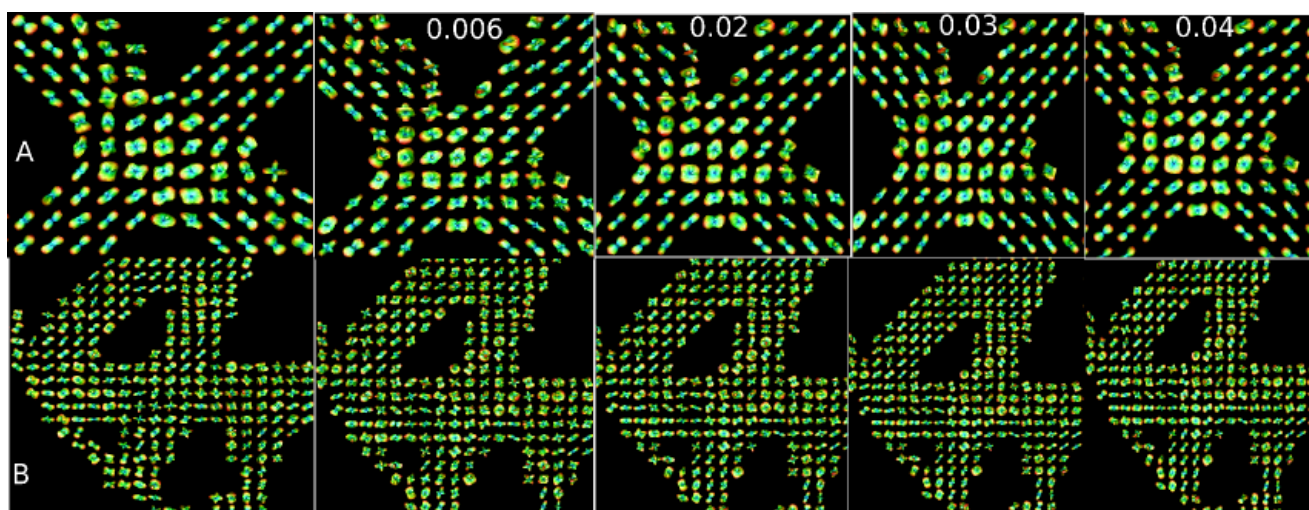
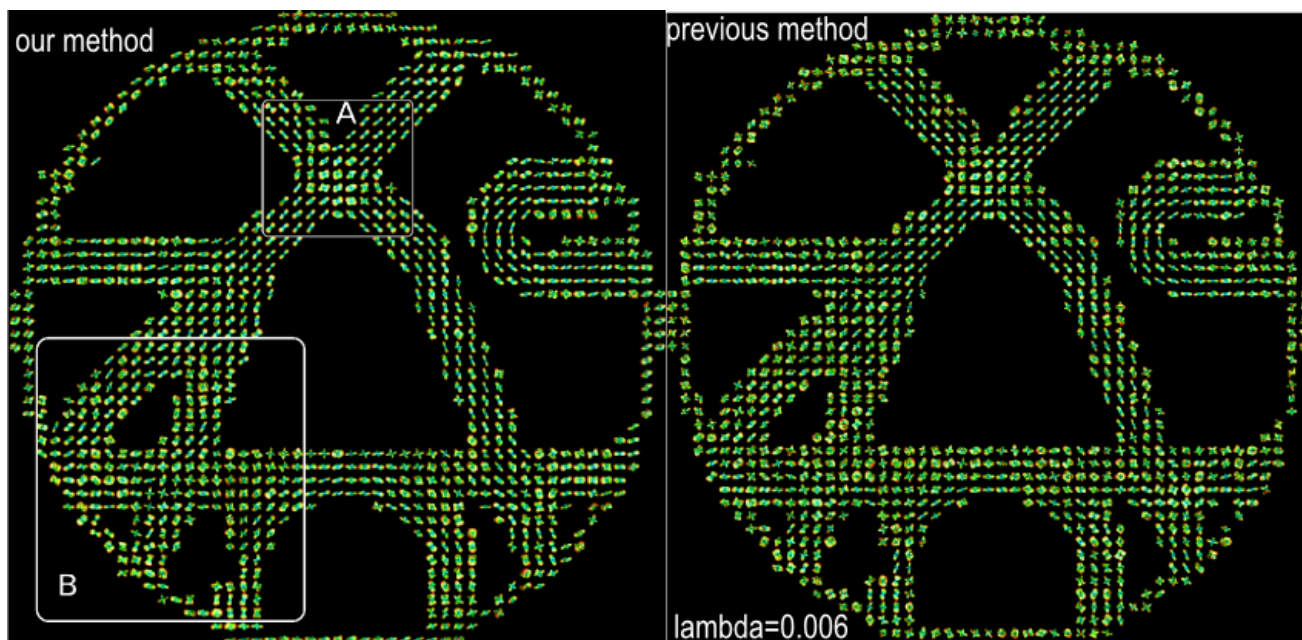
We proposed a fast analytical ODF reconstruction method based on spherical polar Fourier expression of the signal in Q-space. The coefficients of the ODF under Spherical Harmonics expression could be linearly and analytically calculated from the coefficients of the signal. It is a linear transformation that is independent with data. This transformation matrix is just needed to be calculated only once for a whole data set, which makes the method very fast.

$$E(\mathbf{q}) = \sum_{n=0}^N \sum_{l=0}^L \sum_{m=-l}^l a_{n,l,m} R_n(\|\mathbf{q}\|) Y_l^m(\mathbf{u}) \quad (1)$$

$$ODF(\mathbf{u}) = \frac{1}{4\pi} - \frac{1}{8\pi^2} \int_0^{2\pi} \int_0^\infty \frac{1}{q} \Delta_b E(\mathbf{q}) dq d\phi \quad (2)$$

$$ODF(\mathbf{u}) = \sum_{l=0}^L \sum_{m=-l}^l f_{l,m} Y_l^m(\mathbf{u}) \quad (3)$$

$$f_{l,m} = \frac{1}{\sqrt{4\pi}} \delta(l)\delta(m) - \frac{1}{8\pi} \sum_{n=1}^N \sum_{i=1}^n (-1)^i \binom{n+0.5}{n-i} \frac{2^i}{i} P_l(0) (-l)(l+1) a_{n,l,m}$$



References:

- Aganj, I. (2009), 'Reconstruction of the orientation distribution function in single and multiple shell q-ball imaging within constant solid angle', *Magnetic Resonance in Medicine*, vol. to appear.
- Asselmlal, H. (2009), 'Efficient and robust computation of pdf features from diffusion mr signal', *Efficient and robust computation of pdf features from diffusion mr signal*, vol. 13, pp. 715-729.
- Descoteaux, M. (2007), 'Regularized, fast and robust analytical q-ball imaging', *Magnetic Resonance in Medicine*, vol. 58, no. 3, pp. 497-510.
- Ozarslan, E. (2006), 'Resolution of complex tissue microarchitecture using the diffusion orientation transform (dot)', *NeuroImage*, vol. 31, pp. 1086-1103.
- Poupon, C. (2008), 'New diffusion phantoms dedicated to the study and validation of high-angular-resolution diffusion imaging (HARDI) models', *Magnetic Resonance In Medicine*, vol. 60, no. 6, pp. 1276-83.
- Tristn-Vega, A. (2010), 'A new methodology for the estimation of fiber populations in the white matter of the brain with the funkradon transform', *NeuroImage*, vol. 49, pp. 1301-1315.
- Tuch, D. (2004), 'Q-ball Imaging', *Magnetic Resonance in Medicine*, vol. 52, pp. 1358-1372.
- Wedeen, V. (2005), 'Mapping complex tissue architecture with diffusion spectrum magnetic resonance imaging,', *Magnetic Resonance In Medicine*, vol. 54, pp. 1377-1386.

Categories

- Diffusion MRI (Imaging Techniques and Contrast Mechanism)