The QSM 2016 Reconstruction Challenge

4th International QSM Workshop,
September 26th-28th 2016, Graz, Austria

www.qsm2016.com
Early concepts for QSM reconstruction date back to a decade ago, while more refined methods have been continuously developed from single orientation, in a clinical setup, with low recon artefacts.

- This allowed QSM to attract a high number of researchers (300 members in the Electro-Magnetic Tissue Properties study group).
- QSM is utilized in clinical studies of neurological disorders and is increasingly becoming a topic of research outside the brain.
The Challenge: Aims

- To test the ability of various QSM algorithms to faithfully recover the underlying susceptibility from noisy phase data acquired *in vivo*

- To provide a common ground-truth dataset that would help benchmark not only existing QSM algorithms, but also the methods that will be developed in the future

- To disseminate the results and lessons learned in the challenge in a participant-driven paper
Data Acquisition

- Healthy female age 30 @ 3T Siemens Tim Trio
- 3D-GRE with Wave-CAIPI acquisition
- 12 orientations sampled @ 1.06 mm iso
- TE / TR = 25 / 35 ms, @ BW = 100 Hz/pixel
- \( T_{\text{acq}} = 94 \text{ sec / orientation} \) @ R=15-fold acceleration
- Roemer/SENSE coil combine with sensitivities estimated from additional reference acquisitions with head/body coil reception
- Details: B Bilgic et al NIMG’16
Magnitude transversal orientation will be made available
Raw phase: BET brain mask [1]
Laplacian unwrapping [2]
Laplacian Boundary Value (LBV) background removal [3]
3D polynomial fit 4\textsuperscript{th} order: remove Tx phase

will be made available in ppm, normalized by \((\gamma \cdot TE \cdot B_0)\)

-0.05 ppm 0.05 ppm
COSMOS QSM [5] from 12 orientations

will be made available

-0.10 ppm  0.14 ppm

5. T Liu et al MRM’09
$\chi_{33}$ from 12 orientation STI solution [6]

will be made available

-0.10 ppm 0.14 ppm

6. C Liu MRM’10
\( \chi_{33} \) as ground truth

- Observed phase in subject frame of reference:

\[
\theta(k) = \frac{1}{3} H' \cdot \chi(k) \cdot H - H \cdot k \cdot \frac{k' \cdot \chi(k) \cdot H}{k^2}
\]
$\chi_{33}$ as ground truth

- For the transversal acquisition where $H = [0,0,1]$:

$$\theta(k) = \frac{1}{3} \chi_{33}(k) - k_z \frac{k_z \chi_{33}(k)}{k^2}$$
\( \chi_{33} \) as ground truth

- For the transversal acquisition where \( H = [0,0,1] \):

\[
\theta(k) = \left( \frac{1}{3} - \frac{k_z^2}{k^2} \right) \chi_{33}(k)
\]
Evaluation Metrics

- Susceptibility maps calculated from the single orientation scan provided will be tested against the gold-standard $\chi_{33}$ using the global metrics:

  i. RMSE – root mean squared error (lower the better, best possible RMSE=0%)
  ii. HFEN – high frequency error norm (lower the better, best possible HFEN=0%)
  iii. SSIM – structure similarity index (in the range [0, 1], best possible SSIM=1)

- Quantitative comparison within major Deep Gray Matter nuclei and White Matter regions of interest
Data and Source Code

- **Data provided:**
  1. Single axial oriented GRE (preprocessed by LBV and 4th-order TX phase removal)
  2. $\chi_{33}$ (will serve as ground truth for the QSM recon challenge)
  3. COSMOS QSM
  4. MPRAGE and GRE magnitude to serve as structural prior if needed

- **Matlab code provided:**
  1. Compute TKD and Closed-form L2 recons as example
  2. Evaluate performance metrics
THE QSM 2016 RECONSTRUCTION CHALLENGE

Quantitative susceptibility mapping allows the determination of a basic physical property in vivo. Early concepts for QSM were introduced a decade ago and more refined methods have been proposed recently to allow the calculation of magnetic susceptibility from a single orientation, in a clinical setup, and with low reconstruction artefacts. Therefore, QSM has attracted a high number of researchers (there are currently around 300 members in the ISMRM Electro-Magnetic Tissue Properties (EMTP) study group). It is utilized in clinical studies of neurological disorders and is increasingly becoming a topic of research outside the brain.

AIM
The aim of this QSM 2016 reconstruction challenge is to test the ability of various QSM algorithms to faithfully recover the underlying susceptibility from noisy phase data acquired from a healthy volunteer.

GOLD STANDARD REFERENCE DATA SET AND MAGNETIC SUSCEPTIBILITY MAP
GRE data with 1 mm isotropic resolution acquired with a 32-channel receive coil array from a healthy human brain in 12 different head orientations.

TEST DATA SET PROVIDED
A single orientation (transversal) GRE data as well as the “ground truth” data set ($x_{32}$ of the STI).

EVALUATION AND ERROR METRICS
Susceptibility maps calculated from the single orientation scan provided will be tested against the “gold-standard” reference $x_{32}$. Deviations from the gold standard will be quantified using (i) RMSE – root mean squared error, (ii) SSIM - structure similarity index, (iii) HFEN – high frequency error norm, and (iv) quantitative errors in selected white and gray matter ROIs.

TIMELINE AND DATA
1. The QSM2016 challenge will be presented at the EMTP study group at the ISMRM in Singapore.
4. Results will be presented at the 4th QSM workshop in Graz at September 27th, 2016.

EMAIL MAILING LIST
If you would like to receive updates and additional information concerning the recon challenge please send us an email to qsm@neuroimaging.at.
Timetable

- Kickoff today (MRI data can be downloaded at www.qsm.rocks)
- Please join mailing list at qsm@neuroimaging.at (for updates and info)
- Deadline for submission of QSM results: September 4th, 2016
- Results will be presented at the 4th QSM workshop in Graz (September 27th 2016).

Thanks to Christian Langkammer and Ferdinand Schweser!