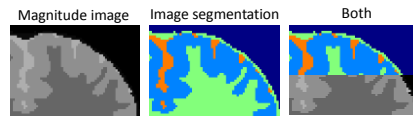


MRI Conductivity (UCL)

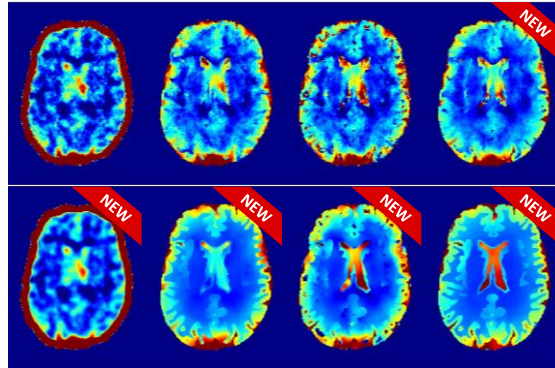
Anita Karsa and Karin Shmueli



$$\sigma = \frac{1}{\mu_0 \omega} \nabla^2 \varphi_0$$

Phase-based EPT:

$$\sigma = \frac{1}{\mu_0 \omega} \oint \nabla \varphi_0 ds$$



Abstract:

Karsa et al. "New Approaches for Simultaneous Noise Suppression and Edge Preservation in Quantitative Conductivity Mapping From Low-SNR Data." Proceedings of the 29th Annual Meeting of ISMRM. p.3774. 2021.

The MRI conductivity mapping tool developed at UCL contains MATLAB implementations of all methods presented in the abstract below. These methods are based on two different formulations of the phase-based Helmholtz equation and include edge preservation based on the magnitude image and/or the image segmentation.

MRI Conductivity (UCL)

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MRI Conductivity

State-of-the-art algorithms for MRI phase-based electrical conductivity mapping

Quantitative Conductivity Mapping (QCM) is a non-invasive technique that calculates the high-frequency tissue electrical conductivity (σ) from the phase (ψ) of the MRI signal. QCM has a range of potential clinical applications including measuring sodium levels¹, and distinguishing between different types of brain plaques².

a) Laplacian-based methods

Most QCM methods are based on the following differential equation¹, valid in regions with slowly varying σ :

$$\nabla \cdot (\mu_0 \sigma \nabla \psi) = \nabla^2 \psi$$

where μ_0 is the vacuum permeability, ω is the proton Larmor frequency, and ∇^2 is the Laplacian operator. Applying a finite-difference approximation of ∇^2 over a kernel (Figure 1a), which is why most current methods fit a 3D quadratic function within a kernel (Figure 1b) around each voxel and calculate the Laplacian of these fitted functions^{3,5}. This 3D quadratic fit is usually either i) weighted by the magnitude values within the kernel (Figure 1c) or ii) restricted to voxels from the same tissue type⁷ (Figure 1d) to avoid artifacts of the conductivity boundaries where Eq. 1 is not applicable.

While these are the most commonly used methods for QCM, there is a lack of readily available implementations that could be used as a standard. Here, we have implemented a MATLAB function that performs QCM by quadratic fitting within an ellipsoidal kernel of user-defined dimensions and with options for i) magnitude- or ii) segmentation-based edge preservation. Moreover, i) and ii) can be used in combination (Figure 1e), which is a new approach that shows promise for outperforming all the other techniques (Figure 1f).

MRI Conductivity - Academic Licence
Preview terms
Term: 24 months
Price per 1 unit: £0.00 excl vat
REQUEST NOW

Licence - Other Use
Preview terms
Term: 12 months
Price per 1 unit: TBD
REQUEST NOW

HowToUse_QCM.m

```
HowToUse_QCM.m
55 % Calculating the conductivity map by solving the integral equation
56
57 %-----Arguments-----
58
59 Inputs.PhaseMap = N(D array) -- N1 phase map in radians (you may need to
60 multiply by 2 to get the 0-2pi range)
61
62 Inputs.TimeMask = N(D array) -- Time mask including all voxels with
63 available phase information. This is different from the MRI mask which is
64 just a portion of the Tissue Mask.
65
66 Inputs.Method = {'string'} -- 'full', 'mag', 'seg', or 'magseg' specifies the
67 edge preservation method (see abstracts and paper for more details). 'all'
68 specifies a 3D quadratic fit within an ellipsoid around each voxel to cal-
69 culate the first derivatives followed by surface integration on another
70 ellipsoid. 'mag', 'seg', and 'magseg' include magnitude- and/or segmen-
71 tation-based edge preservation for both steps.
72
73 Inputs.KernelRadialDiff = N(vector) -- Radial (along x,y,z) in mm of the ellipsoid
74 before the 3D quadratic fit to calculate the first derivatives is performed.
75 We have found the optimal kernel radii in an image with magnitude SNR = 16
76 and 1 mm isotropic resolution to be:
77 % 'full' - [10 10 10]
78 % 'mag' - [10 10 10]
79 % 'seg' - [10 10 10]
80 % 'magseg' - [10 10 10]
81
82 Inputs.KernelRadialInt = N(vector) -- Radial (along x,y,z) in mm of the ellipsoid
83 before the surface integral is performed. We have found the optimal kernel
84 radii in an image with magnitude SNR = 16 and 1 mm isotropic resolution to
85 be:
86 % 'full' - [6 6 6]
87 % 'mag' - [14 14 14]
88 % 'seg' - [10 10 10]
89 % 'magseg' - [10 10 10]
```

Links:

https://xip.uclb.com/product/MRI_conductivity
(https://xip.uclb.com/i/software/MRI_conductivity.html also redirects here)

Email: anita.karsa.14@ucl.ac.uk or segueUCL@gmail.com

The MATLAB functions are licenced for free for academic use and can be downloaded from the UCL XIP website. The HowToUse_QCM.m file contains a detailed list of all the necessary inputs and their descriptions. If you have any questions, please don't hesitate to contact the authors via one of the email addresses below.