dMRE: Combination of Diffusion MRI and Magnetic Resonance Elastography

Problem Statement and Motivation

- Combination of Magnetic Resonance Elastography (MRE) and Diffusion MRI may provide complementary information on the changes of tissue cellularity and structure associated with pathology.
- Recent MRE approaches accounting for the anisotropy of tissue use the direction information obtained from Diffusion MRI as input parameters in novel wave inversion algorithms.
- Currently Diffusion MRI and MRE information is acquired consecutively in separate imaging blocks.

Technical Approach

- Synchronization of diffusion gradients and vibration by obeying a constraint for the diffusion time.
- Gradient shape tuning to have a good compromise between b-value and encoding efficiency.
- Encoding of intra-voxel coherent motion (MRE) and intra-voxel incoherent motion (diffusion MRI) in the phase and magnitude of the MR signal, respectively.

Key Achievements and Future Goals

- Simultaneous acquisition of diffusion MRI and MRE information in ex vivo tissues using dMRE yields the same stiffness and ADC values as the conventional approaches.
- dMRE reduces imaging time by a factor of two and allows for immediate co-registration of stiffness and ADC maps.
- Future Goals:
  - Verification of dMRE in in vivo human environments.
  - Refinement of dMRE towards DTI-MRE.

Problem Statement and Motivation

- In conventional 3D MRE, each component of the displacement vector is acquired in consecutive steps.
- Long imaging times in 3D MRE.
- Potential source of error: Image misalignment in between individual acquisition blocks.

Technical Approach

- Simultaneous application of motion encoding gradients (MEGs) along three directions.
- Use of direction specific sample interval of the phase difference between vibration and MEG projection.
- Encoding of displacement projections into direction-specific discrete frequency bins.

Key Achievements and Future Goals

- Acceleration of measurement time of 3D MRE by a factor of three.
- Immediate co-registration of the three components of the displacement vector potentially increases the accuracy of MRE-derived mechanical parameters of biological tissues.
- Increase in accuracy needs to be confirmed in reproducibility studies.


Problem Statement and Motivation

- Magnetic Resonance Elastography (MRE) applied to small geometries, such as fingertips or rodent organs requires the use of vibrations in the high frequency range.

- Tissue mechanics becomes increasingly rate dependent at higher vibration frequencies; therefore, the mechanical parameters need to be determined at multiple frequencies.

- Current MRE techniques are not capable of simultaneously acquiring multi-frequency vibrations without limiting the encoding efficiency.

Technical Approach

- SDP-MRE for the simultaneous acquisition of three vibration frequencies.

- Filter Condition is applied for selecting one frequency per projection of the displacement vector.

- Encoding efficiency correlates with number of cycles of the motion encoding gradient.

Key Achievements and Future Goals

- Full 3D three-frequency spectrum of a vibration can be acquired in only three temporally-resolved MRE experiments.

- No limitations to encoding efficiency as there are in fractional multi-frequency MRE approaches.

- Future Goals: Determination of the mechanical behavior of small biological structures in the high frequency range at multiple frequencies.

Towards the non-invasive determination of tissue pressure

**Problem Statement and Motivation**

- Various diseases are associated with imbalances in tissue pore pressure.
- Detection of pressure imbalances in the human body may enable early intervention and treatment of disease such as hydrocephalus and portal hypertension.
- Currently there is no non-invasive technique for the determination of pore pressure within the human body.
- Pore pressure affects the resistance of the surrounding tissue to deformation and thus may correlate with Magnetic Resonance Elastography (MRE)-derived parameters.

**Technical Approach**

- Two-layer Ecoflex phantom with hollow center exposed to various pressure values.
- Magnetic Resonance Elastography (MRE) for the determination of the shear stiffness at each pressure value.

**Key Achievements and Future Goals**

- Changes in pore pressure correlate with shear stiffness of surrounding tissue.
- MRE has the potential to serve as a noninvasive tool for the determination of pressure changes within biological tissue.
- Future plans:
  - Increasing the sensitivity of MRE-derived mechanical parameters to pore pressure changes by using 3D SLIM-MRE.
  - Testing the diagnostic capabilities of 3D SLIM-MRE in animal models of diseases associated with pressure imbalances, such as hypertension and hydrocephalus.

BIOGRAPHICAL SKETCH
Provide the following information for the Senior/key personnel and other significant contributors. Follow this format for each person. DO NOT EXCEED FOUR PAGES.

NAME
DIETER KLATT
POSITION TITLE
Assistant Professor

EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable.)

<table>
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<tr>
<th>INSTITUTION AND LOCATION</th>
<th>DEGREE (if applicable)</th>
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<td>German University Diploma</td>
<td>11/02</td>
<td>Geophysics</td>
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<tr>
<td>Humboldt University Berlin, Germany</td>
<td>Ph.D.</td>
<td>03/10</td>
<td>Physics</td>
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Positions

Since 02/2013 Assistant Professor at the Richard and Loan Hill Department of Bioengineering, Adjunct Assistant Professor in the Department of Mechanical Engineering, The University of Illinois at Chicago, Chicago, Illinois

Since 09/2012 Adjunct Assistant Professor at the Department of Radiology, Northwestern University, Feinberg School of Medicine, Chicago, Illinois


03/2010-06/2011 Post-Doc at the Department of Radiology, Charité - University Medicine Berlin, Germany

02/2004-02/2010 Research Associate at the Department of Radiology, Charité - University Medicine Berlin, Germany

2003 Geophysicist for Deutsche Montan Technologie, Essen, Germany

Professional Activities

08/2014 Organizer of symposium “Oscillating Gradients in Motion-Sensitive Magnetic Resonance Imaging (MRI): A tool to Combine Diffusion MRI and MR Elastography? ” at the 36th Annual International Conference of the IEEE Engineering in Medicine & Biology Society in Chicago, IL

09/2012 Organizer of symposium “Mechano-Imaging of the Brain” at the 34th Annual International Conference of the IEEE Engineering in Medicine & Biology Society in San Diego, Ca

10/2010 Implementation of Magnetic Resonance Elastography at Clinical Research Imaging Centre, University of Edinburgh, Scotland, UK
Research Stay at Freiburg Material Research Center, University of Freiburg, Germany

Experience as Reviewer

Magnetic Resonance in Medicine
Journal of the American Society of Mechanical Engineers
Journal of Biomechanics
Physics in Medicine and Biology
Critical Reviews in Biomedical Engineering

Peer-reviewed Publications

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