

Living the DREAM -seminar
 Oulu, Linnanmaa campus, Room Lo124 (Arena)
<https://oulu.zoom.us/j/64048550868>

Schedule for Wednesday, June 10th, 9:00–15:00

Time	Speaker	Title
9:25	Opening	
	Cancelled Emile Vaysse	Quantitative MRI reconstructions under inhomogeneous B_0 field
9:30	Kalle Inget	Chemical Exchange Saturation Transfer MRI in Brain Tumor Imaging
9:45	Samu Majabacka	Normative T1 and T2 Relaxation Time Values of Healthy Knee Cartilage in a Single-Age, Population-Based Cohort
10:00 - 10:30	Coffee break	
10:30	Jemina Manninen	Space weather influence on ionospheric dynamics
10:45	Ayanew Shiferaw	Advanced methods for 3D observations of the ionosphere using the EISCAT3D radar
11:00	Antti Raasakka	Novel NMR methods for investigating chemical and physical properties of rubber compounds
11:15	Khaoula El Maddah	Computational methods for nonlinear inversion
11:30 - 13:00	Lunch	
13:00	Mansoure Giahi Sabour	A goal-oriented Bayesian algorithm to optimally select view angles in X-ray computed tomography
13:15	Dinidu Jayakody	Future Spectral CT
13:30	Antti Sällinen	On unsupervised iterative reconstructions and range characterization of 2D fan beam
13:45 - 14:15	Coffee break	
14:15	Manu Pradeep	Evaluation of iodine-based contrast agents in the micro computed tomography visualization and histology examination of swine hearts
14:30	Tero Hyvärinen	Underuse and Misapplication of Automatic Exposure Control Compromise Image Quality and Radiation Safety in Diagnostic Imaging
14:45	Minna Mannerkorpi	Raman spectroscopy for serum-based diagnosis and disease management in rheumatic diseases

Quantitative MRI reconstructions under inhomogeneous B_0 field

Emile Vaysse
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Abstract

We study the effect of the inhomogeneities of B_0 field in Quantitative MRI reconstructions. We show how important it is to take these inhomogeneities into account, more specifically in the Low - Field MRI case, where the inhomogeneities of the field can not be neglected.

Chemical Exchange Saturation Transfer MRI in Brain Tumor Imaging

Kalle Inget
University of Oulu

Abstract

Goal of the study is to distinguish glioma grade with amide proton transfer (APT) chemical exchange saturation transfer MRI (APT-CEST). A total of 20 patients is imaged with CEST (10 low grade and 10 high grade gliomas). We expect the CEST effect to significantly differ inside the tumor among the two groups. The results could significantly advance brain tumor diagnostics by enabling earlier detection and earlier initiation of treatment, ultimately leading to improved patient outcomes.

Normative T1 and T2 Relaxation Time Values of Healthy Knee Cartilage in a Single-Age, Population-Based Cohort

Samu Majabacka

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Abstract

Osteoarthritis (OA) is one of the most common joint diseases worldwide and involves the progressive degeneration of articular cartilage, often starting in early adulthood before clinical symptoms appear. Although conventional clinical MRI methods are useful for diagnosing OA, they often lack the sensitivity required to detect early microstructural changes in cartilage. Quantitative MRI (qMRI), in contrast, can reveal subtle compositional alterations at early stages of the disease, potentially enabling earlier interventions to slow OA progression.

Despite its promise, qMRI has not yet been widely adopted in clinical practice. This is partly due to relatively long acquisition times, variability in acquisition and analysis methods, and a limited availability of well-validated reference data in healthy populations. Although qMRI has been widely used to study knee cartilage, comprehensive normative values for healthy cartilage remain scarce.

In this study, we utilize data from the Northern Finland Birth Cohort (NFBC1986) to examine the influence of genetic and lifestyle factors on knee cartilage health. In addition, we will report detailed compartment-specific normative T1 and T2 values for healthy knee cartilage in young adults using multiple qMRI sequences. These reference values provide a benchmark for future studies investigating early cartilage degeneration and OA progression.

Space weather influence on ionospheric dynamics

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Abstract

Disturbances in the Earth's magnetic field observed on the ground can be used to estimate the horizontal electric currents flowing in the ionosphere. These estimates are referred to as ionospheric equivalent currents. During geomagnetic storms, the enhanced ionospheric currents can lead to induced currents in power grids, increased satellite drag, and navigation errors, highlighting the need for accurate modeling. We have developed two approaches to predict equivalent currents based on solar wind conditions: a statistical model and a deep-learning model. Solar Wind driven SuperMAG statistical equivalent current model (SW-SMEC) is based on data from 1997-2008 and obtained by averaging the equivalent currents over varying solar wind conditions [1]. It reproduces typical equivalent current behavior, but tends to underestimate the strongest currents and cannot capture smaller-scale features. For the deep-learning model we used the ResNet architecture which was trained on storm-time data from 1997-2008. Two different versions were trained with and without the ground-based magnetic indices as input. Case studies of geomagnetic storms show that the ResNet model captures small-scale features of the equivalent currents during storm conditions. The relative prediction error averaged over storms from 2009-2019 is 25% for ResNet with magnetic indices and 38% for SW-SMEC. The ResNet model without magnetic indices underestimates the current amplitude, resulting in lower accuracy (53% error), but still captures more small-scale variation than the statistical model.

- [1] J. T. Manninen, H. Vanhamäki, A. T. Aikio, and J. Gjerloev, "Statistical modeling and prediction of ionospheric equivalent currents based on supermag data," *Journal of Geophysical Research: Space Physics*, vol. 130, no. 10, 2025. <https://doi.org/10.1029/2025JA034125>.

Advanced methods for 3D observations of the ionosphere using the EISCAT3D radar

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Abstract

The ionosphere is an ionized region of the upper atmosphere that extends approximately from 60 to 1000 km above the Earth's surface, formed primarily through the ionization of neutral atmospheric constituents mainly by solar radiation. Incoherent scatter (IS) radars are ground-based instruments that transmit radio waves and detect those scattered from thermal density fluctuations of ionospheric plasma. Because the spectrum received by an IS radar is a known function of ionospheric plasma parameters, including electron density (N_e), electron temperature (T_e), ion temperature (T_i), bulk plasma velocity (V_i), and ion composition, the plasma parameters can be inverted from the measured spectra. The standard inversion provides four parameters, N_e , T_e , T_i , and V_i , while including the ion composition requires additional information.

EISCAT3D will be an advanced multistatic multibeam IS radar system in northern Fennoscandia. The radar is currently under construction, and first observations are expected in 2027. The rapid beam scanning capability of EISCAT3D with electronically steerable phased array antennas will allow volumetric observations of the ionosphere. However, new and advanced data analysis techniques need to be developed for the unprecedented observations. Ion composition inversion has been previously enabled for measurements along a geomagnetic field line by means of sequential filtering, smoothness priors, and chemistry modeling. We extend the technique by making optimal use of data from all beams from all receive sites of a multistatic radar system and bin the data to form field-aligned profiles to enable the ion composition fits. Because EISCAT3D is not yet available, we apply the technique to make 2D plasma parameter inversion using the EISCAT Svalbard Radar (ESR) meridional scan measurements during a geomagnetic storm period. Our results reveal the 2D structure of the ionospheric heating caused by the geomagnetic storm and the associated ion composition variations. These observations are potentially valuable for many applications, including understanding upper atmospheric density variations caused by the ionospheric heating, which affect atmospheric drag on low Earth orbit satellites, and plasma density fluctuations, which affect satellite navigation and communication systems.

Novel NMR methods for investigating chemical and physical properties of rubber compounds

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Abstract

Rubbers are an important materials for modern life, industry and science, presenting attributes not found on other materials. These attributes include an ability to undergo and recover from large deformations without breaking or permanent damage. Rubbers are elastomer chains that have been cross-linked into a three dimensional network. With fillers and various additives rubbers make a compound. Cross-links are the element giving rubber the unique characteristics. Thus one of the most important and desirable information on rubber compounds is the cross-link density. [1]

Nuclear magnetic resonance (NMR) spectroscopy is considered a powerful method for acquiring cross-link density and other information. In NMR a samples nuclei are excited with radio-frequency electromagnetic radiation and their response measured in high external magnetic field. Time-dimension NMR (TD-NMR) measures the time dependence of this response since it is dependent on the chemical and physical environment of the nuclei, thus giving information on these aspects.

Currently multiple different methods have been developed for investigating rubber materials with TD-NMR. Most commonly used method is called Double quantum measurement (DQ-measurement) [2], giving accurate information on cross-link density. It has disadvantages in industry applications, long measurement times and multi-step person-dependent data preparation. Therefore in this doctoral research project we develop and refine new TD-NMR methods which address these points.

References

- [1] Richard Arthur Pethrick, Taweechai Amornsakchai, and Alastair M North. *Introduction to molecular motion in polymers*. Whittles, 2011.
- [2] Kay Saalwächter. “Proton multiple-quantum NMR for the study of chain dynamics and structural constraints in polymeric soft materials”. In: *Progress in Nuclear Magnetic Resonance Spectroscopy* 51.1 (2007), pp. 1–35.

Computational methods for nonlinear inversion

Khaoula El Maddah
University of Oulu

Abstract

We develop computational methods for inverse problems arising in nonlinear models. The first project addresses a semilinear Calderón-type problem in two dimensions: given boundary data for

$$-\Delta u + q(x) u^p = 0 \quad \text{in } \Omega, \quad u|_{\partial\Omega} = f,$$

with $p \in \mathbb{N}_{\geq 2}$, on a bounded domain $\Omega \subset \mathbb{R}^2$ and Dirichlet data f . Our numerical approach is based on higher-order linearization of the nonlinear Dirichlet-to-Neumann map, by differentiating the DN map, we obtain auxiliary linear elliptic problems that gives Fourier transform of q . We then reconstruct q from these data using Tikhonov and total variation (TV) regularization, which remains effective in regimes where the corresponding linear inverse problem is challenging.

The second project considers inverse scattering for a Kerr-type nonlinear Helmholtz equation

$$\Delta u + k^2 u + k^2 q(x) |u|^2 u = 0 \quad \text{in } \mathbb{R}^n,$$

where $k > 0$ is the wavenumber and q describes the unknown potential. We propose a reconstruction strategy that extracts information on q from the third Fréchet derivative of the scattering amplitude, leading to a formula of Fourier data of the potential, which allow the reconstruction of the unknown by regularization methods.

The third project extends these ideas to nonlinear inverse problems for time-harmonic Maxwell equations, with the goal of recovering material parameters from boundary or far-field measurements by combining suitable linearization procedures with stable numerical inversion.

This is joint work with Teemu Tyni and Matti Lassas.

A goal-oriented Bayesian algorithm to optimally select view angles in X-ray computed tomography

Mansoure Giahi Sabour
University of Oulu

Abstract

X-ray computed tomography (CT) is an imaging technique that reconstructs the interior of an object from exterior measurements. Each measurement corresponds to a set of view angles, from which the object was hit by the X-ray beam. Ill-posedness of CT inverse problem becomes more severe when view angles are limited or not chosen carefully. A naive selection of These angles can waste experimental resources, because missing informative directions leads to larger uncertainty in the reconstructed image. In our goal-oriented Bayesian framework, the view angles are treated as experimental design parameters. The method proposes new angles that provide the most informative directional measurements for the boundary, such that uncertainty reduction is optimal. Additionally, we combine posterior uncertainty with ideas from microlocal analysis. We estimate the expected wavefront directions of the object, which reveals singularities that remain invisible under the available set of angles. The algorithm then selects the next projection angle orthogonal to these directions, at locations where the posterior variance is highest. Numerical experiments support optimality of this strategy. Our results turn wavefront analysis from a diagnostic tool into an active part of the design process. It links the direction of singularities with the reduction of posterior uncertainty.

Future Spectral CT

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Abstract

The research focuses on advancing medical imaging techniques, specifically addressing limitations in computed tomography (CT) and cone-beam computed tomography (CBCT), which are widely used for diagnosing conditions in the head, neck, and dentomaxillofacial regions, yet these modalities suffer from challenges such as beam hardening and metal artifacts due to dense bone structures and metal implants, as well as poor soft tissue visibility and exposure to ionizing radiation. This study aims to develop and optimize novel image reconstruction algorithms and spectral imaging methods using PCD technology for CT/CBCT imaging. It hypothesizes that combining spectral CBCT and CT with material decomposition (MD) and virtual monochromatic imaging (VMI) techniques can significantly reduce beam hardening and metal artifacts, and that IR and DLR can enhance image quality while minimizing radiation doses. Furthermore, spectral PCD-CT is expected to improve diagnostic capabilities, particularly in the assessment of stenoses, tissue classification, and artifact reduction in stroke imaging. The research employs a three-pronged approach: 1) Utilizing MD and VMI techniques for artifact reduction in CBCT and CT imaging, 2) MD and VMI techniques for delayed phase tumor enhancement, and 3) Implementing spectral PCD-CT for enhanced diagnostic accuracy. The project holds significant potential to revolutionize CT/CBCT imaging by improving image quality, reducing radiation exposure, and enhancing diagnostic precision.

On unsupervised iterative reconstructions and range characterization of 2D fan beam

Antti Sällinen
University of Oulu

Abstract

We study how to apply unsupervised training setting, Noise2Inverse, to previously supervised iterative reconstruction algorithm Learned Primal Dual. We show that this particular implementation succeeds to yield better reconstructions than U-Net post-processing with the same training setting. The algorithm in this implementation is novel and requires changes to the original Learned Primal Dual.

Another topic is about ongoing research on how to characterize the range of 2D fan beam geometry. First we study the John's equation, a partial differential equation that characterizes the range of X-ray transform in three or higher dimensions. We derive an approximation to 2D fan beam for this John's equation from a cone beam CT geometry, and show numerically that these results tend to satisfy the equation in question. We also discuss possible future directions about this project.

Evaluation of iodine-based contrast agents in the micro computed tomography visualization and histology examination of swine hearts

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Abstract

This study compares two iodine-based contrast agents, iodine in ethanol (I2E) and an aqueous solution of potassium triiodide (I2KI) in optimizing high-resolution, contrast-enhanced micro computed tomography imaging (micro-CT) of the cardiac conduction system (CCS) in porcine hearts. The work evaluates their relative efficacy in enhancing tissue contrast and anatomical delineation. To our knowledge, it is the first time I2E is introduced as a contrast agent in cardiac micro-CT imaging.

Dissected porcine hearts were stained with I2E and I2KI and scanned with micro-CT. Signal-to-noise ratio (SNR), contrast-to noise ratio (CNR), and volumetric shrinkage were evaluated. Additionally, qualitative visualization of CCS-related anatomical landmarks, such as the sinoatrial node (SAN), atrioventricular node (AVN), and Purkinje fibres, was performed, along with assessment of artifact occurrence and sample integrity. The efficacy of the contrast agents was also determined by segmenting the regions of interest corresponding to the CCS from micro-CT images. These were then further validated against histology.

I2E allowed for seamless post-processing and histological sectioning by offering better segmentation, CNR, fewer artifacts, and sample integrity. Compared to I2E (day 3), I2KI staining generated a greater soft-tissue signal intensity and a quicker stain saturation (day 2). However, I2KI exhibited leaching and introduced substantial staining artifacts. I2KI also exhibited structural disintegration, which, in turn, compromised downstream processing. These results suggest that I2E is a viable alternative to I2KI for CCS micro-CT imaging when sample preservation and downstream analyses are essential, whereas I2KI may be preferred for rapid, high-intensity staining where tissue integrity is less critical.

Underuse and Misapplication of Automatic Exposure Control Compromise Image Quality and Radiation Safety in Diagnostic Imaging

Tero Hyvärinen¹,

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Abstract

I study automatic exposure control (AEC) mechanisms in medical imaging. I develop an angular tube current modulation (ATCM) for cone beam computed tomography (CBCT). I study a situation where air kerma rate increases in angiography with tight collimation when automatic dose control region is obscured. Furthermore, I develop patient specific radiation detriment estimation framework where I can estimate the impact of the studied methods on lost life years due to X-ray caused harm.

ATCM in CBCT can reduce effective dose by almost 20% in thoracic vertebrae imaging. Tight collimation can increase paediatric patient air kerma rate by 850% and decrease image contrast. Medical imaging causes about 1.5 fatal cancers every year in Oulu university hospital.

Raman spectroscopy for serum-based diagnosis and disease management in rheumatic diseases

Minna Mannerkorpi

March 2026

1 Abstract

Rheumatic diseases, particularly Rheumatoid Arthritis (RA) and Juvenile Idiopathic Arthritis (JIA), significantly affect the musculoskeletal system and quality of life across age groups. Despite advances in understanding, challenges remain in the diagnosis and management of these conditions. In the initial stages, RA is often asymptomatic, and the sensitivities of current biomarkers in RA diagnosis often lead to false negatives. However, JIA is rarely asymptomatic; among young children, the expression of symptoms is not always clear. Furthermore, given the several subtypes of JIA, understanding the disease course is crucial for personalized treatment options. The absence of a single defining biomarker complicates the timely and robust diagnosis of both RA and JIA. In this doctoral research, machine learning and deep learning models will be trained to classify the Raman spectra of RA patients and healthy controls, providing a new method for diagnosing RA. Additionally, the potential of Raman spectroscopy to predict the disease course in JIA will be investigated. This research underscores the importance of early detection, timely treatment, and improved diagnostic tools to enhance patient outcomes in rheumatic diseases.