”Living the DREAM” Seminar (Tampere University)

Wednesday, June 17, 2026, at 09:00 – 15:30. Room: TAU Arvo B342

https://tuni.zoom.us/j/66126209958?pwd=0qClyLvmwlwJ32SElsNBeNuwVEcCaS.1

Meeting ID: 661 2620 9958

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Session 1

09:00 Welcome

09:05 **Ivan Perez-Torres**: How Neuron Type, Morphology, and Myelination Shape Temporal Interference Responses: A Computational Study

09:20 **Katja Törmä**: Functional connectivity methods in brain connectivity estimation

09:35 **Elaheh Sabbaghi**: Acute scalp EEG signatures of anterior nucleus of the thalamus DBS in epilepsy

09:50 **Kaisla Walls**: Imaging engineered heart tissues with inverted selective plane illumination microscopy

Coffee break

10:05-10:30

Session 2

10:30 **Philipp Schiller**: A Bayesian Framework for Ill-posed Geometric Primitive Reconstruction from Point Clouds using Prior Information

10:45 **Shahab Baloochi**: Topology-Aware Deep Learning for Structural Analysis of Tree Point Clouds from Terrestrial Laser Scanning

11:00 **Ishan Sen**: AI-Driven Context-Aware AAC System: Framework Design, Prototype Development, and Personalization

11:15 **Etna Lindy**: Multiplicities of eigenvalues of resultant matrices

Lunch

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Session 3

13:00 **Arash Zarrin Nia**: Improving EEG Source Localization Through Practical Head Modeling Choices

13:15 **Topi Pajala**: Exploratory Study for Radar Tomography of Dimorphos - the Asteroid Moon of 65803 Didymos

13:30 **G Harish Kaushik**: Hierarchical Bayesian modelling for predicting component failure

13:45 **Jetro Sihvonen**: Control of incompressible fluid flows

Coffee break

14:00-14.20

Session 4

14:20 **Dilshanie Prasikala**: Methodological Advancements in Standardized Kalman Filtering for EEG Source Localization

14:35 **Paavo Virtanen**: Computer modelling and simulations of phenotypic plasticity in electro-chemo-mechanical function of the heart

14:50 **Farnaz Javanpour**: Beyond Geometric Error: Learning Radiomic Consistency for Histology-μCT Registration Validation

15:05 **Babatunde Abdullahi Olatunji**: Enhanced Source Localization Usin Bidirectional Deep Brain Stimulation Electrodes: A Comparative Study with Scalp EEG

15:20 Closing words

How Neuron Type, Morphology, and Myelination Shape Temporal Interference Responses: A Computational Study

Ivan Perez-Torres[1], Jarno Tanskanen[1], Annika Ahtiainen[1], Jari Hyttinen[1]

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Abstract

Temporal interference stimulation (TIS) has emerged as a promising non-invasive neuromodulation technique capable of targeting deep brain regions using interfering high frequency electric fields. However, its underlying single cell mechanisms remain insufficiently understood, limiting its accurate interpretation and in vitro translation. In this study, we investigate how detailed biophysical properties of cortical neurons shape their sensitivity to TIS at the single cell level. Using morphologically and physiologically realistic multicompartment neuron models implemented in NEURON, we simulated a diverse set of cortical cell types, incorporating optional axonal myelination to evaluate structural contributions to TIS responsiveness. Our preliminary results show that TIS sensitivity varies across neuron types, with activation thresholds influenced by morphology, ion channel dynamics, and myelination status. Myelinated neurons exhibited lower stimulation thresholds. To approximate more realistic physiological conditions, we incorporated synaptic noise via Poisson distributed excitatory and inhibitory inputs. Under ongoing activity, TIS produced frequency specific modulations of subthreshold membrane dynamics, with effects dependent on both cell type and ongoing oscillatory state. Band power and phase locking analyses further demonstrated that inhibitory and excitatory interneuron classes exhibit distinct susceptibility profiles, suggesting that TIS interacts differentially with local microcircuit elements. Overall, our findings identify key cellular determinants, myelination, and intrinsic excitability—that drives TIS effectiveness at the single cell level. These mechanistic results provide the basis for developing circuit level models that preserve essential nonlinearities and guide future in vitro experimental designs.

Functional connectivity methods in brain connectivity estimation

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Abstract

Exploring how different brain regions are functionally connected provides valuable insight into cognitive processes and the underlying mechanisms of various brain disorders. Functional connectivity methods are based on the idea of studying the statistical interdependencies between signals and thus estimating the underlying functional connectivity structure of the network producing the signals. Network-based conditions such as epilepsy could be studied more effectively using approaches that provide information on how connections between brain regions transfer information and how such connections change.

Traditionally, research has relied on bivariate functional connectivity methods, but more recently, multivariate techniques have been developed and applied to brain signals to obtain improved estimation accuracy. However, the question about how different network properties affect the accuracy of multivariate methods remains unaddressed. Thus, the first objective of my PhD work is to evaluate the performance of three multivariate directed functional connectivity methods under different network properties.

If these analysis methods were able to identify brain regions with a high susceptibility to start a seizure, it would be crucial information for physicians and surgeons treating an epilepsy patient. Thus, the second objective of my PhD is to study how functional connectivity methods can be used to predict the outcome of surgical removal of epileptic tissue from drug-resistant epilepsy patients.

Finally, these multivariate methods are computationally expensive, and even though several attempts have been made to address the estimation accuracy of these methods, the problem of detecting spurious connections persists. Therefore, the third and final objective of my work is to determine how to improve multivariate methods to make them computationally more feasible and even more accurate.

Acute scalp EEG signatures of anterior nucleus of the thalamus DBS in epilepsy

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Abstract

Deep brain stimulation (DBS) of the anterior nucleus of the thalamus (ANT) is an established treatment for drug-resistant epilepsy, but it is still not well understood which scalp EEG changes reliably reflect the stimulation state. In this work, I studied whether scalp EEG shows reproducible spectral changes during ANT-DBS and how these changes evolve immediately after stimulation is turned off. Scalp EEG was recorded from five implanted patients at two time points approximately one year apart (10 patient-years) during cyclic stimulation with 1 s ON and about 5 s OFF periods. I compared stimulation ON with the mean OFF state using power spectral analysis, channel-by-frequency-by-time cluster-based analysis, and spectral parameterization to separate broadband aperiodic changes from oscillatory activity. The results showed a consistent increase in gamma-band activity during stimulation ON across all patient-years, with the most reproducible effects seen in central and frontal low-gamma regions. In contrast, lower-frequency changes in the theta, alpha, and beta ranges were more variable and were strongest immediately after stimulation offset, then gradually weakened across the OFF period, suggesting post-offset relaxation dynamics. The analyses also showed that DBS was associated with broadband aperiodic changes, including a flatter spectrum and reduced offset during stimulation, which explained a substantial part of the overall ON–OFF spectral difference. After correcting for these broadband effects, a smaller but still meaningful low-gamma enhancement remained. Overall, these findings suggest that ANT-DBS produces a reproducible scalp-EEG signature combining high-frequency enhancement, broadband aperiodic modulation, and transient post-stimulation low-frequency dynamics, which may serve as candidate indicators of DBS state.

Imaging engineered heart tissues with inverted selective plane illumination microscopy

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Abstract

Cardiovascular diseases (CVDs) have remained the highest in global mortality rate for decades. Advanced *in vitro* models that recapitulate the structure and function of the human heart could be used for better disease modeling and discovery of therapeutics. Engineered heart tissues are 3D human-based *in vitro* models that can be derived from patients, enabling the study of genetic CVDs in a personalized level. However, studying EHT tissue architecture has remained limited without technological advancements, which has hindered the usability of the *in vitro* model in clinical research. In this project, we take advantage of advanced imaging technology with the development and optimization of an inverted selective plane illumination microscopy (iSPIM) for EHT imaging. We show novel insights into the structural composition of the fixed EHT, and provide quantification tools for 3D structural analysis. With the current iSPIM platform, we aim to implement the method to studying tissue maturation through culture time. With ongoing and further development, the iSPIM will allow live imaging of dynamic events in beating EHTs, where we aim to combine the structural and functional information of EHTs on tissue section level. Finally, we aim to use the developed system for studying structural and functional changes in the most common inherited cardiac disease, hypertrophic cardiomyopathy (HCM).

A Bayesian Framework for Ill-posed Geometric Primitive Reconstruction from Point Clouds using Prior Information

Philipp Schiller[1]

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Abstract

Point clouds have become a standard representation for capturing the geometry of real-world objects and are typically obtained via range sensors such as LiDAR, depth cameras, or structured light scanners. In many practical applications, the point clouds are incomplete, and both sampling density and measurement uncertainty can vary significantly across the object. In such ill-posed conditions, even reconstructing simple geometric primitives (e.g., ellipses, spheres or cylinders) becomes a challenging task. Traditional distance-based fitting methods often yield biased or unstable results.

To address these issues, we propose incorporating prior information about the data acquisition process — such as the scanner position, sensor noise properties or visibility constraints — directly into the primitive-reconstruction. To enable this, we introduce a Bayesian reconstruction framework that explicitly models both the spatial distribution of observed points and their measurement uncertainty. This formulation naturally allows integration of prior knowledge about measurement-locations and noise-characteristics.

We demonstrate for two widely used geometric primitives, ellipses and cylinders, that under ill-posed conditions, integrating such prior information — especially about the measurement-origins — can significantly improve robustness and reconstruction quality compared to established methods.

Topology-Aware Deep Learning for Structural Analysis of Tree Point Clouds from Terrestrial Laser Scanning

Shahab Alaedin Baloochi[1], Pasi Raumonen[1], Esa Rahtu[1]

[1]Mathematics Research Centre, Faculty of Information Technology and Communication Sciences, Tampere University, Tampere, Finland

Abstract

Terrestrial Laser Scanning provides detailed three-dimensional measurements of forest environments and produces large point cloud datasets representing individual trees. These data offer valuable opportunities to study tree architecture and estimate structural properties important for forest monitoring and ecological research. However, extracting meaningful structural information from TLS point clouds remains challenging due to occlusions, irregular sampling, measurement noise, and the complex topology of stems and branches.

In this research, we develop topology-aware deep learning methods for analyzing TLS point cloud data. The proposed approach combines geometric features with graph-based neural networks to learn relationships between neighboring points. By modeling local structural organization, the method improves the identification of stems and branches in complex and high-density 3D measurements.

The framework is evaluated using high-density TLS datasets of individual trees. Experimental results show that incorporating topological information improves the robustness of stem and branch detection, particularly in regions affected by occlusion or sparse sampling.

These methods contribute to scalable artificial intelligence approaches for analyzing complex 3D natural structures. Potential applications include stem and branch detection, segmentation, tree reconstruction, biomass estimation, and large-scale forest monitoring from terrestrial laser scanning data.

AI-Driven Context-Aware AAC System: Framework Design, Prototype Development, and Personalization

Ishan Sen[1]

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Abstract

Augmentative and Alternative Communication (AAC) systems support individuals with complex communication needs. However, many current AAC systems rely on static vocabulary structures and limited contextual adaptation, which can make communication slow, effortful, and less responsive to users' everyday situations. This project addresses these limitations through three main objectives: to develop a flexible framework for context-aware AAC, to implement the framework through prototype design, and to enhance the system through personalization. The project investigates how multimodal contextual inputs, including location, time, audio, images, and user-specific information, can be integrated to provide more adaptive communication support. Prototype development is used to examine the practical implementation of the framework, while personalization enables the system to better respond to individual preferences, habits, and communication needs. The project ultimately aims to advance the design of more responsive, context-sensitive, and user-centered AAC systems.

Multiplicities of eigenvalues of resultant matrices

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Abstract

In the talk, I will go through our recent work regarding the Smith form of the Sylvester and Bézout resultant matrices. The partial multiplicities associated to the eigenvalue of a polynomial matrix tell us about the conditioning of computing the eigenvalue, and hence gives us hints about the expected stability of solving the polynomial system via resultant methods.

For bivariate polynomials $f, g \in \mathbb{K}[x, y]$, we make a connection between the partial multiplicities of the eigenvalues of the resultant matrices and the structure of the dual space of the zero-dimensional ideal $\langle f, g \rangle$. We show this by explicitly constructing the root polynomials for the matrix $S(y)$ using a *Gauss basis* of the dual space, introduced in [**3M96**].

Our main contribution is to deal with the case where f and g have a common factor leading coefficients. Using a Möbius transformation that takes the "infinte roots" in the x-coordinate to finite roots, we prove that the Smith normal form stays intact through the transformation, allowing us to lift the earlier assumption. In the talk, I aim to go through the associated definitions and structures as intuitively as possible using an example.

References

[1] M. G. Marinari, H. M. Möller, T. Mora. On multiplicities in polynomial systems solving. *Trans. Amer. Math. Soc.*, 348(8):3283–3321, 1996.

Improving EEG Source Localization Through Practical Head Modeling Choices

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Abstract

Electroencephalography (EEG) source localization depends strongly on how the head is modeled, but it is still not fully clear when adding more anatomical detail actually improves the results. In our work so far, we examined how different aspects of head modeling influence both forward and inverse EEG solutions. We compared several subject-specific multi-compartment head models that differed in anatomical detail, skull representation, mesh quality, and modeling choices. We then evaluated their performance using common inverse methods under different levels of noise to better reflect realistic recording conditions.

Our results showed that noise level and the choice of inverse method had the largest impact on localization accuracy. In general, performance improved as the signal quality increased, especially for Dipole Scan inverse solver, while sLORETA solver was less sensitive to these changes. We also found that adding more anatomical subdivisions did not necessarily lead to better results. In many cases, simpler models performed better than more detailed ones. By contrast, improving skull modeling and mesh quality led to more consistent gains, although these improvements were moderate.

Overall, our findings suggest that making head models more detailed is not always the most effective way to improve EEG source localization. Greater benefit may come from careful solver selection, better skull representation, and good mesh construction. These results highlight the importance of balancing anatomical realism with practical modeling choices when building multi-compartment head models for EEG analysis.

Exploratory Study for Radar Tomography of Dimorphos - the Asteroid Moon of 65803 Didymos

Topi Pajala[1], Sampsa Pursiainen [1], Alexandra Koulouri [1], Christelle Eyraud [2], Jean-Michel Geffrin [2], Alain Hérique [3].

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Abstract

Understanding the interior structure of small solar system bodies is essential for both understanding the formation of our galaxy and for planetary defence purposes. Dimorphos is a rubble-pile asteroid moonlet that is the target of the European Space Agency's (ESA) HERA mission, which is planned to rendezvous in December 2026 and perform thorough measurements of its electromagnetic, dynamical, and structural properties.

Current data inversion methods often rely on synthetic forward simulations, which are computationally too heavy for accurate results. Our aim in this study is to fabricate a 3D-printed asteroid model of Dimorphos using a stochastic process that follows prior knowledge about the composition of the asteroid, resulting in a realistic rubble-pile model. This analogue is later measured using a microwave tomography setup that scales with respect to the asteroid size to produce similar wave propagation effects as in the mission, allowing us to obtain a realistic set of tomographic data. This data can then be used to develop inversion methods that are robust enough for this type of structure.

Additionally, after obtaining the measurement data, we plan to implement our own inversion method to localize possible voids inside the structure and characterize the size of the scatterers present within the model using time–frequency analysis. If the proposed method works, the same workflow can then be used for the actual mission pipeline, providing similar statistics from the asteroid after the measurement data arrives.

As for now, we have been able to fabricate a total of 4 analogue models for Dimorphos that has all undergone a microwave radar measurement. The measurement data has already shown to have some minor deviations from the synthetic data, indicating that this type of measurement data is essential for the use of radar data inversion applications.

Hierarchical Bayesian modelling for predicting component failure

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Abstract

Probabilistic Risk / Safety Assessment (PRA / PSA) of components is an important field in structural, systems, risk engineering and related disciplines. This is a integral part of safety analyses conducted in nuclear power plants (NPPs), where robust techniques are required to estimate failure rates of their components such as diesel generators, pumps, etc. Several specialized modelling strategies such as Bayes-Empirical Bayes (BEB)[1], Parametric-Robust-Empirical-Bayes (PREB) and Parametric-Empirical-Bayes (PEB) currently exist. Most of these models are dated, and they also present notable deficiencies[2] – particularly in their ability to manage uncertainty in failure rate estimation, and zero-inflated data. There exist several promising avenues for addressing these limitation - using Markov Chain Monte Carlo (MCMC) to estimate the hyperpriors of the Bayesian model, using zero-inflated likelihood, and alternate Bayesian models which may also be implemented in STAN. In our work, we start from the BEB model and focus on reducing identified model limitations, utilising techniques which can leverage more computing power, and also aim to improve prediction of the failure rate. The primary motivation is to improve PRA in NPPs, however the Bayesian modelling framework and inference methods can be applied and transferred across other structural, and mechanical engineering domains.

References

1 K. Porn, "On empirical Bayesian inference applied to Poisson probability models," 1990, publisher: Division of Quality Technology, Dept. of Mechanical Engineering, Linkoping University.

2 C. Bunea, T. Charitos, R. M. Cooke, and G. Becker, "Two-stage Bayesian models—application to ZEDB project," Reliab. Eng. Syst. Saf., vol. 90, no. 2, pp. 123–130, Nov. 2005.

Control of incompressible fluid flows

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Abstract

The control of fluid flows is essential in numerous applications from cooling systems to blood circulation and aerodynamics. Over the years different questions have been investigated from the stability of systems to numerical feasibility. Motivated by blood flows we focus our attention on the incompressible Navier–Stokes equations in tubular domains and the problem of output regulation.

In output regulation the goal is to control a system in such a way that a given output of the system tracks a desired reference signal in spite of disturbances. While the theory is well developed for linear systems, both in finite and infinite dimensions, significantly fewer results exist for nonlinear PDEs like the Navier–Stokes equations. We extend the mathematical theory to boundary acting controllers and mixed boundary condition setups, which correspond to more realistic physical configurations.

For the simplest settings we have been able to solve the problem with an integral controller and we continue to extend to more general assumptions. As we increase difficulty by allowing for complex disturbances, an unstable system and multidimensional output measurements, the controller design necessarily becomes more sophisticated. We also use numerical simulations to illustrate our theoretical results.

Methodological Advancements in Standardized Kalman Filtering for EEG Source Localization

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Abstract

Electroencephalography (EEG) source localization aims to reconstruct brain activity from scalp measurements, but it is a severely ill-posed inverse problem affected by depth bias and measurement noise. Dynamic approaches based on Kalman filtering provide a natural framework for incorporating temporal information, yet conventional formulations tend to favor superficial sources. The Standardized Kalman Filter (SKF) addresses this limitation through a normalization step that balances source contributions across different depths, enabling improved reconstruction of deep brain activity.

In this work, we focus on methodological advancements of the SKF framework. First, we investigated the role of prior parameters, showing how the choice of evolution and measurement noise, together with the standardization exponent and RTS smoothing, governs the balance between reconstruction accuracy and noise robustness. This highlights the importance of principled prior modeling in dynamic EEG source localization.

To improve computational efficiency, we proposed a discrepancy-based rescaling of the lead-field matrix that replaces the iterative, time-dependent standardization of SKF with a static approximation. This significantly reduced computational cost while maintaining comparable reconstruction accuracy at low noise levels, while highlighting a trade-off between efficiency and noise robustness.

Ongoing work extends this framework by incorporating structural connectivity information derived from diffusion tensor imaging (DTI) into the process noise covariance. This aims to introduce biologically informed priors that better reflect network-level brain organization and improve reconstruction performance.

Computer modelling and simulations of phenotypic plasticity in electro-chemo-mechanical function of the heart

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Abstract

Computational modelling and simulation of electro-chemo-mechanical function of heart muscle cells, cardiomyocytes, play an increasingly significant role in cardiovascular research, clinical decision support, and emerging heart digital twin applications. Despite considerable advances, current models lack a critical biological property: phenotypic plasticity. This limits the models' ability to capture how cardiac cells adapt to short- and long-term changes in their electrical, biochemical, and mechanical environment.

Our research enhances existing cardiomyocyte models by integrating feedback mechanisms that link changes in stimuli and environmental conditions to cellular electro-chemo-mechanical function and phenotype adaptation. Regarding the foundational characteristics of the models, the objective is to improve the physiological accuracy of long-term stability of extra- and intracellular ion dynamics and their interdependencies. Building on that, the focus shifts to developing a mitochondrial module for energy utilisation in excitation-contraction coupling, and to protein-expression changes arising from transcriptional and translational regulation. Model implementation utilises Python and MATLAB for numerical simulation, data processing, and visualisation. Code will be openly available to support reproducibility and community adoption.

The research is structured into three sub-studies that examine ionic imbalance as an arrhythmogenic mechanism alongside integration of an energy-usage module, investigate RNA expression differences as a manifestation of phenotypic plasticity from healthy heart towards atrial fibrillation, and demonstrate the capabilities of the novel modelling framework by applying it to multicausal disease mechanisms using atrial fibrillation as an example disease case.

By bringing phenotypic plasticity and other adaptive mechanisms into computational cardiomyocyte models, my thesis enhances their explanatory and predictive capacity, and advances foundation for digital twin technologies in precision cardiology, where personalised medicine and patient-specific simulation approaches are becoming the standard.

Beyond Geometric Error: Learning Radiomic Consistency for Histology-µCT Registration Validation

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Abstract

Histology provides high-resolution microscopic detail, whereas micro–computed tomography (µCT) preserves intact 3D morphology. Accurate alignment of these complementary modalities is essential for true 3D histology and cancer diagnoses, as misregistration can result in incorrect spatial interpretation of diagnostically relevant tissue. However, validating multimodal registration remains challenging due to the absence of geometric ground truth under tissue deformation and the low intrinsic contrast of µCT, limiting clinical adoption. Existing approaches rely on subjective slice matching or geometric overlap metrics without objective biologically meaningful validation criteria. We propose a learning-based framework that evaluates alignment through cross-modal radiomic consistency, reframing registration assessment as a feature-level biological agreement problem rather than a purely geometric transformation task. The method learns a modality-agnostic quality score based on preservation of radiomic phenotypes, enabling objective and reproducible validation. Corresponding histology-µCT slices were identified using tissue mask overlap followed by expert-defined anatomical patch selection to ensure biologically consistent cross-modality sampling. Rigid and non-rigid registration were applied to compensate for histological deformation. Radiomic features were extracted and registration quality was classified using cross-modal feature differences, with reference labels derived solely from overlap metrics. The framework was evaluated on 18 paired rat skin specimens comprising 1,186 aligned patches using specimen-level cross-validation to prevent data leakage. A support vector machine (SVM) achieved 90.5of 85.1This work introduces a biologically meaningful, modality-invariant quality metric for multimodal registration validation, supporting reliable multimodal pathology and true 3D histopathology

Enhanced Source Localization Using Bidirectional Deep Brain Stimulation Electrodes: A Comparative Study with Scalp EEG

Babatunde Abdullahi Olatunji[1], Narayan Puthanmadam Subramaniyam[1], Jari Hyttinen[1], Jukka Peltola[1], Sampsa Pursiainen[2]

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Abstract

Accurate neural source localization remains a fundamental challenge in electroencephalography (EEG), particularly for deep brain structures that are difficult to reconstruct using conventional scalp-based methods. Bidirectional deep brain stimulation (DBS) electrodes offer a promising complementary approach to enhance source localization by enabling simultaneous recording and stimulation through the same electrode.

We investigate the impact of integrating bidirectional DBS electrodes with scalp EEG on source localization accuracy across varying noise conditions. A computational framework based on the Finite Element Method (FEM) and an extended Complete Electrode Model (CEM) jointly models scalp and intracranial electrodes with realistic electrode–tissue interactions. Three DBS configurations (4-, 8-, and 40-contact arrays) were evaluated alongside a 72-channel scalp EEG system, with source reconstruction performed using sLORETA and dipole scan under three SNR levels (30 dB, 17.5 dB, and 5 dB).

Multimodal integration significantly improves source localization accuracy, particularly for deep structures such as the thalamus. The 40-contact configuration achieves error reductions of up to 97.4% under low-SNR conditions, with near-perfect localization (0.0 mm error) at high SNR using dipole scan. While scalp EEG provides strong orientational coverage at high SNR, its performance degrades with noise, whereas bidirectional DBS electrodes maintain robustness due to source proximity. These findings underscore the complementary advantages of scalp and intracranial recordings, with implications for epilepsy research, post-implantation monitoring, and adaptive neuromodulation.