



天元數學國際交流中心

Tianyuan Mathematics Research Center

**Symposium on Medical Image Processing
Methods and Applications**

Conference Manual

May 3rd-9th, 2026

Tianyuan Mathematics Research Center

Kunming, China

Organizers:

Dexing Kong (Zhejiang University)

Xuecheng Tai (Norwegian Research Center)

Shihui Ying (Shanghai University)

Shousheng Luo (Zhejiang Normal University)



Schedule (May 4th)

Time	Speaker	Title	Chair
8:50-9:00	Opening Ceremony and Group Photo		
9:00-9:30	Bin Dong Peking University	AI and Mathematics: Some Issues Worth Deep Reflection	Dexing Kong Zhejiang University
9:30-10:00	Chong Chen Academy of Mathematics and Systems Science, CAS	GUMP-Net: An Interpretable Model-Data- Driven Intelligent Algorithm for Multi-Class Pelvic Segmentation	
10:00- 10:20	Tea Break		
10:20- 10:50	Chaomin Shen East China Normal University	Conditional Distribution Modeling Theory and Methods for Embodied Intelligence Vision-Language-Action Models	Zhengan Yao Sun Yat-sen University
10:50- 11:20	Faqiang Wang Beijing Normal University	Optimal Transport-based Image Fusion and its Applications	
11:30- 14:00	Lunch & Break		
14:00- 14:30	Zhengmeng Jin Nanjing University of Posts and Telecommunications	Deep Image Prior with Regularized Feedback for Sparse-View and Low-Dose CT Reconstruction	Chuanxian Ren Sun Yat-sen University
14:30- 15:00	Yunyun Yang Harbin Institute of Technology (Shenzhen)	AS2LS: Adaptive Anatomical Structure- based Two-layer Level Set Framework for Medical Image Segmentation	
15:00- 15:30	Chao Wang China Agricultural University	Inverse Problems in Proton Therapy	
15:30- 15:50	Tea Break		
15:50- 16:20	Yaxin Peng Shanghai University	Intelligent Computing	Shousheng Luo Zhejiang Normal University
16:20- 16:50	Wenxing Zhang University of Electronic Science and Technology of China	Stochastic Alternating Structure-adapted Proximal Gradient Descent with Variance Reduction for Nonconvex Nonsmooth Problem	
16:50- 17:20	Huan Han Wuhan University of Technology	Interpretable Neural Network for Diffeomorphic Image Registration: From Discrete and Continuous Aspects	
17:30- 19:00	Dinner		



Schedule (May 5th)

Time	Speaker	Title	Chair
9:00-9:30	Zhanli Hu Shenzhen Institute of Advanced Technology, CAS	Intelligent Fusion of Multimodality: Technological Breakthroughs and Prospects for Neurodegenerative Disease Diagnosis and Treatment	Shihui Ying Shanghai University/ Shanghai Institute of Applied Mathematics and Mechanics
9:30-10:00	Shoujun Huang Zhejiang Normal University	Active contours driven by hyperbolic mean curvature flow for image segmentation	
10:00-10:20	Tea Break		
10:20-10:50	Qiyu Jin Lazhou University	Fast Magnetic Resonance Imaging Methods Driven by Physical Variational Models	Jian Lu Shenzhen University
10:50-11:20	Na Zhang Shenzhen Institute of Advanced Technology, CAS	Intelligent Quantification and Risk Stratification of Stroke Plaque on Magnetic Resonance Imaging	
11:30-14:00	Lunch & Break		
14:00-14:30	Ronald Lok Ming Lui Chinese University of Hong Kong	Recent Advances in Quasiconformal for Medical Image Analysis	Suhua Wei Beijing Institute of Applied Physics and Computational Mathematics
14:30-15:00	Jianping Zhang Xiangtan University	Motion Estimation in Image Registration and Imaging	
15:00-15:30	Jianfeng Zhang Zhejiang Normal University	Research Progress on Mechanism and Data Fusion Methods for Vascular System and Ultrasound Image Computing	
15:30-15:50	Tea Break		
15:50-16:20	Youwei Wen Hunan Norma University	Spatial Adaptivity Variational Image Decomposition Methods Cartoon-Texture Based on Spatial Adaptivity	Zhifang Liu Tianjin Normal University
16:20-16:50	Yan Wang Chongqing Normal University	Pediatric Disease Prediction Based on Multimodal Data Fusion	
16:50-17:20	Xiaohong Fan Zhejiang Normal University	Nest-MGDL: Nesterov-Optimized Memory and Geometric Distillation Learning for Image Compressed Sensing	
17:30-19:00	Dinner		



Schedule (May 6th)

Time	Speaker	Title	Chair
9:00-9:30	Huibin Chang Tianjin Normal University	Mathematical Modeling and Optimization Algorithms for Ptychography: Thin Samples, Phase Unwrapping, and Multi-Slice Imaging	Qingtang Jiang Zhejiang Normal University
9:30-10:00	Jialin Peng Huaqiao University	Weakly Supervised Cross-Domain Transfer Learning Method for Segmentation Based on Preference Learning	
10:00-10:20	Tea Break		
10:20-10:50	Liangjian Deng University of Electronic Science and Technology of China	A General Embedded Modelling Framework for Data Fusion	Xiaohong Fan Zhejiang Normal University
10:50-11:20	Zhijie Wen Shanghai University	Key Technologies for Medical Image Analysis under Label Noise	
11:30-14:00	Lunch & Break		
14:00-14:30	Zai Yang Xi'an Jiaotong University	Positive Definiteness of Hadamard Product of Matrices and Its Applications	Xilei Zhao University of Electronic Science and Technology of China
14:30-15:00	Ziwei Nie Nanjing University	Regularized Optimal Transport Models for Image Analysis	
15:00-15:30	Meng Ding Southwest Jiaotong University	Low-Rank Tensor Representation for High-Dimension Data	
15:30-15:50	Tea Break		
15:50-16:20	Jun Liu Northeast Normal University	Diffusion Models, Orthogonal Projection Priors, and Semantic Guidance for Image Restoration	Daoping Zhang Nankai University
16:20-16:50	Ji Li Capital Normal University	Image Restoration and Data Assimilation for Numerical Weather Prediction Driven by Deep Learning	
16:50-17:20	Yi Ran Harbin Institute of Technology	A Tunable Despeckling Neural Network Stabilized via Diffusion Equation	
17:30-19:00	Dinner		



Schedule (May 7th)

Time	Speaker	Title	Chair
9:00-9:30	Zuoqiang Shi Tsinghua University	Generative Neural Physics Framework for High-Resolution 3D Ultrasound Tomography	Gaohang Yu Zhejiang University of Science and Technology
9:30-10:00	Wenfei Cao Shaanxi Normal University	Exponential-Family Tensor Completion via Nonconvex Dual Total-Variation Regularization	
10:00-10:20	Tea Break		
10:20-10:50	Qi Xie Xi'an Jiaotong University	Geometric Symmetry Priors and Deep Network Modules	Wenli Dai First Affiliated Hospital of Army Medical University
10:50-11:20	Si Li Guangdong University of Technology	Adversarial and Correlation-Aware Data Augmentation Framework for Multi-Label Chest X-Ray Image Classification	
11:30-14:00	Lunch & Break		
14:00-14:30	Yibao Li Xi'an Jiaotong University	Multiscale topology optimization method for lattice materials	Jijun Liu Southeast University
14:30-15:00	Cuijuan Lou Zhejiang Normal University	Research on Nonsmooth Methods for Sound Velocity Imaging via Full Waveform Inversion	
15:00-15:30	Yumeng Ren City University of Hong Kong	Iterative Unfolding Network with ℓ_1 Regularization for Sparse Object Segmentation	
15:30-15:50	Tea Break		
15:50-16:20	Heran Yang Xi'an Jiaotong University	Research on Generative Medical Image Analysis Methods Under Incomplete Data Conditions	Cuijuan Lou Zhejiang Normal University
16:20-16:50	Wenli Dai First Affiliated Hospital of Army Medical University	Risk Control and Uncertainty Quantification in Intelligent Diagnostic Prediction Pipelines	
16:50-17:20	Jiupeng Yu Nanjing University of Posts and Telecommunications	Computing Low-Rank Pure Quaternion Tensor Approximations for Color Videos	
17:30-19:00	Dinner		



Schedule (May 8th)

Time	Speaker	Title	Chair
Morning		Discussion	Cuijuan Lou Zhejiang Normal University
11:30-14:00		Lunch & Break	
Afternoon		Discussion	
17:30-19:00		Dinner	



Presentation Information Overview (sorted by Pinyin)

Exponential-Family Tensor Completion via Nonconvex Dual Total-Variation Regularization

Wenfei Cao, Shaanxi Normal University

Abstract: With the emergence of various tensor data, tensor completion from partial measurements has received widespread attention in the fields of data science and signal processing. Presently, Total Variation (TV) has been proven to be a powerful regularization for tensor completion. However, theoretical studies regarding TV regularization in tensor completion are relatively limited. In this work, we conduct a rigorous theoretical analysis for this regularization in tensor completion. Specifically, we first consider more comprehensive tensor completion with exponential-family noises that includes ordinary Gaussian tensor completion and Poisson tensor completion as two special cases. Then, we propose a family of dual-TV (DTV) regularization with transformed L1 function ($\| \cdot \|_{\infty}$) to handle exponential-family tensor completion, which can simultaneously encode the prior knowledge of sparsity and low-rankness in gradient tensor. Moreover, the upper-bound analysis and the minimax lower bound analysis are provided for the recovery error of the estimator with DTV regularization. Finally, multiple groups of experiments on synthetic, image and video tensor data sets are carried out to demonstrate the correctness of our theoretical results and the effectiveness of our method.

Mathematical Modeling and Optimization Algorithms for Ptychography: Thin Samples, Phase Unwrapping, and Multi-Slice Imaging

Huibo Chang, Tianjin Normal University

Abstract: This talk discusses mathematical models and efficient algorithms for three typical inverse problems in ptychography: phase recovery for thin samples, phase unwrapping under strong scattering, and multi-slice imaging for thick samples. The focus is on introducing ADMM, domain decomposition, low-memory BSPGe, reliability-enhanced phase unwrapping models, and chained multi-slice reconstruction methods. We establish discrete optimization structures starting from continuous physics and design algorithms that are both efficient and theoretically supported.



GUMP-Net: An Interpretable Model-Data-Driven Intelligent Algorithm for Multi-Class Pelvic Segmentation

Chong Chen, Academy of Mathematics and Systems Science, CAS

Abstract: Pelvic segmentation is one of the most important and fundamental research problems in precise and intelligent diagnosis and treatment, as well as surgical planning and navigation for pelvic fractures. In this talk, we will introduce the proposed GUMP-Net. Extensive experiments on pelvic and ankle datasets demonstrate the rationality and effectiveness of the proposed algorithm.

Risk Control and Uncertainty Quantification in Intelligent Diagnostic Prediction Pipelines

Wenli Dai, First Affiliated Hospital of Army Medical University

Abstract: The clinical implementation of intelligent diagnostic prediction pipelines requires not only "providing answers" but also effective evaluation of the reliability of these answers to achieve true risk control. Based on two previous works on ovarian tumor ultrasound AI diagnosis systems, this talk demonstrates how to construct systematic methods for structure recognition and uncertainty estimation through technologies such as multi-task learning, latent space modeling, and multimodal fusion. Furthermore, we extend our perspective to glioma, a more structurally complex scenario, and explore how to introduce weighted persistent homology and evidence theory into vascular topology modeling to achieve the transfer from segmentation uncertainty to topological feature confidence, as well as the structured decomposition of multimodal evidence conflicts. This provides traceable and evaluable mathematical tools for high-risk clinical decision-making.

A General Embedded Modelling Framework for Data Fusion

Liangjian Deng, University of Electronic Science and Technology of China

Abstract: This talk primarily explores how to embed deep learning priors and traditional variational optimization model into a general modelling framework, which can effectively enhance the accuracy, generalizability, and interpretability of current intelligence methods. The talk mainly covers two aspects: 1) introducing the general embedded modelling framework, which bridges traditional variational optimization models and deep learning models; 2) giving some examples of the general embedded modelling framework, which are successfully applied to some representative data fusion tasks, also analyzing the relationship between these techniques and current mainstream deep learning approaches.



Low-Rank Tensor Representation for High-Dimension Data Processing

Meng Ding, Southwest Jiaotong University

Abstract: Tensor analysis has received widespread attention in high-dimensional data learning. Unfortunately, the tensor data are often degraded by noise or insufficient for subspace representation. In this talk, we first study a generalized transformed tensor low-rank representation model for simultaneously recovering and clustering the corrupted tensor data and prove the recoverability with a high probability guarantee. Besides, we use hidden tensor data to address the problem of insufficient observed samples. We employ both observed samples and hidden tensor data under low-rank constraints so that a new bilateral tensor low-rank representation in subspace clustering is formulated. Furthermore, we introduce the bilateral low-rank representation to multi-view subspace clustering. Experiments on various datasets showcase the outstanding performance.

I and Mathematics: Some Issues Worth Deep Reflection

Bin Dong, Peking University

Abstract: AI's reasoning ability is undergoing a qualitative leap: from pattern matching to complex reasoning, from solving competition problems to participating in the frontiers of mathematical research. This change means that the relationship between AI and mathematics is undergoing a structural transformation, not one serving the other, but a two-way co-evolution. Centered on this judgment, this talk proposes 18 open questions in four sections: What kind of mathematics does AI really need, what kind of impact is mathematics experiencing, how to cultivate people in the AI era, and where will AI and mathematics take each other. These questions cover from the theoretical foundation of deep learning to the philosophy of mathematics, from automated theorem proving to educational reform, aiming to provide a common anchor for cross-disciplinary thinking collisions.

Nest-MGDL: Nesterov-Optimized Memory and Geometric Distillation Learning for Image Compressed Sensing

Xiaohong Fan, Zhejiang Normal University

Abstract: Compressed sensing (CS) reconstruction is a powerful technique for image compression and reconstruction. Most existing deep learning and deep unfolding reconstruction methods: 1) do not sufficiently analyze the proximal subproblem and naturally derive network architectures from mathematical theory; 2) lack the ability to correct errors and recover details via multidomain, multiscale, and multiresolution analysis; and 3) depend only on the previous stage and overlooking valuable information from earlier stages. In this study, we propose a Nesterov-optimized memory and geometric distillation learning (Nest-MGDL) framework, which effectively integrates interpretability and adaptability to achieve robust and



generalizable deep learning performance. By reformulating the proximal subproblem as the decomposition and distillation of memory and geometric priors across diverse domains and integrating a local multilevel feature aggregation (LMFA) strategy, Nest-MGDL enables theoretically grounded network design and accurate multiscale correction of errors. Inspired by the third-Nesterov (N-III) acceleration scheme with fast convergence, we incorporate gradient information from measurement errors across multiple historical stages to achieve more consistent and accurate reconstruction. It provides new insights into leveraging historical measurement errors and designing explainable network architectures. All parameters in our Nest-MGDL are learnable end-to-end with adaptive initialization, enhancing model flexibility and ensuring stable convergence. Extensive experiments show that Nest-MGDL outperforms other state-of-the-art methods.

Interpretable neural network for diffeomorphic image registration: from discrete and continuous aspects

Huan Han, Wuhan University of Technology

Abstract: Medical image registration is an inverse problem and a fundamental task in medical imaging, aiming to align two or more images into a common spatial coordinate system. Traditional image registration methods, such as variational frameworks, provide mathematically interpretable solutions but often suffer from high computational complexity, making them impractical for real-time applications. Though deep learning-based approaches have significantly improved registration speed, they still face challenges in preserving anatomical topology and maintaining interpretability. To address these limitations, we propose a two different kinds of Interpretable Diffeomorphic Image Registration Networks from discrete and continuous aspects, which integrates deep learning with diffeomorphic theory to achieve high accurate, topology-preserving, large deformation and real-time registration. Theoretical analysis demonstrates how the neural network guarantees diffeomorphic transformations, ensuring smooth and invertible deformations.

Intelligent Fusion of Multimodality: Technological Breakthroughs and Prospects for Neurodegenerative Disease Diagnosis and Treatment

Zhanli Hu, Shenzhen Institute of Advanced Technology, CAS

Abstract: This report focuses on the application of multimodal intelligent fusion technology in neurodegenerative diseases. Centering on the intelligent integration and analysis of multi-source data including imaging, omics and clinical data, it systematically elaborates on the technological breakthroughs achieved in early screening, precision diagnosis and prognostic assessment. Combined with current research progress and clinical pain points, this report discusses the challenges in algorithms, data and clinical implementation, and provides an outlook on the future direction of intelligent and individualized diagnosis and treatment.

Active contours driven by hyperbolic mean curvature flow for image segmentation

Shoujun Huang, Zhejiang Normal University

Abstract: In this talk, we construct Hyperbolic Mean Curvature Flow-driven ACMs (HMCF-ACMs), and prove the property of normalflow. Then, we establish the numerical equivalence to a wave equation via the level set method with signed distance functions. This new method has some advantages in the image segmentation by comparing with the traditional variational methods. To address the loss of fine-grained details and irregular boundaries in encoder-decoder models like the Segment Anything Model (SAM), we further design HMCF as a differentiable geometric prior module and embed it between the decoder of SAM and the final activation layer, which is called HMCF-SAM framework. HMCF-SAM retains the representation power while enforcing curvature-driven geometric smoothing, thereby enhancing boundary smoothness and anatomical plausibility. Experiments on medical image datasets demonstrate that HMCF-SAM outperforms a fine-tuned SAM baseline in segmentation accuracy, boundary quality and generalization.

Fast Magnetic Resonance Imaging Methods Driven by Physical Variational Models

Qiyu Jin, Lanzhou University

Abstract: This report addresses the critical challenges in undersampled magnetic resonance imaging (MRI) reconstruction: the limited expressive power of traditional variational models and the insufficient interpretability and generalization of deep learning methods. Guided by physical priors, we progressively propose three novel reconstruction methods: To overcome the lack of interpretability in self-supervised approaches, we develop a k-space low-rank structure regularization network. This network constructs a convolutional neural network based on the physical properties of Hankel matrices and guarantees convergence through non-expansive mappings, achieving high-quality reconstruction without fully-sampled data supervision. Its performance surpasses existing self-supervised and conventional methods. Breaking through the limitation of the "local" interpolability assumption in k-space, we start from global low-rank regularization and build a physics-informed variational model-driven white-box Transformer architecture. This architecture endows the attention mechanism with explicit physical meaning and enables global interpolation reconstruction, outperforming mainstream methods across multiple datasets and sampling patterns. To address the issues of prior knowledge corruption and poor adaptability during pretrained model fine-tuning, we propose a momentum memory-based fine-tuning method. Through a dual gradient descent framework, we freeze the pretrained parameters and introduce a lightweight regularization network, achieving fast and stable reconstruction in few-shot scenarios with superior generalization ability compared to traditional fine-tuning approaches.

Deep Image Prior with Regularized Feedback for Sparse-View and Low-Dose CT Reconstruction

Zhengmeng Jin, Nanjing University of Posts and Telecommunications

Abstract: Low-dose and sparse-view computed tomography (CT) reconstruction remains challenging due to severe photon noise and incomplete measurements. This work presents a novel reconstruction framework that integrates the Deep Image Prior (DIP) with Poisson log-likelihood-based data fidelity term and total variation (TV) regularization, thereby capturing photon-limited statistics while preserving edge information. To further enhance reconstruction quality, an explicit regularized feedback mechanism is introduced, where each intermediate reconstruction is refined through TV descent in the image-domain, and the updated result is recursively fed back as the network input. Besides, a theoretical convergence analysis is provided to establish the stability of the proposed iterative scheme. Finally, the comparative results demonstrate the effectiveness of the proposed method.

Recent Advances in Quasiconformal for Medical Image Analysis

Ronald Lok Ming Lui, Chinese University of Hong Kong

Abstract: Quasiconformal and Teichmüller theories provide a powerful geometric framework for analyzing complex shapes and mappings with controlled distortion. In this talk, I will present recent advances in quasiconformal models for medical imaging and computational anatomy. First, I will introduce quasiconformal surface registration methods for medical images and anatomical surfaces, with applications to brain surface parameterization and cortical mapping. I will then discuss quasiconformal models for shape-prior-based medical image segmentation. Beyond registration and segmentation, I will demonstrate how Teichmüller metric-based shape analysis enables quantitative studies of anatomical structures, including vestibular system analysis, spinal morphology assessment in adolescent idiopathic scoliosis, craniofacial shape analysis, and hippocampal surface analysis for Alzheimer's disease research. This work is supported by HKRGC GRF (Project IDs: 14307622, 14310224, 14309125).

Image Restoration and Data Assimilation for Numerical Weather Prediction Driven by Deep Learning

Ji Li, Capital Normal University

Abstract: Four-dimensional variational data assimilation (4D-Var) in image restoration and numerical weather prediction is a key problem in the field of scientific computing. While both problems are addressed by formulating variational optimization loss functions and minimizing them, there are significant differences in the physical mechanisms and mathematical objectives of their regularization terms. For image restoration problems, the data measurement constraint equations are typically underdetermined. The regularization terms are designed to compensate for the insufficiency of measurement data and overcome the ill-posedness of the problem.

Given that image priors are critical to restoration quality, providing priors using deep learning generative models has become a prominent research hotspot in recent years. In contrast, the data term constraints in 4D-Var are generally well-posed. Its core purpose is to correct the initial state of the numerical model using observational data, thereby suppressing the accumulation of prediction errors. The incremental 4D-Var problem in operational systems ultimately reduces to solving large-scale symmetric positive definite linear systems. Addressing its computational bottleneck of up to tens of millions of dimensions, accelerating these computations using deep learning holds significant practical application value. This report will present the speaker's research findings and preliminary attempts in applying deep learning methods to these two cutting-edge research directions.

Adversarial and Correlation-Aware Data Augmentation Framework for Multi-Label Chest X-Ray Image Classification

Si Li, Guangdong University of Technology

Abstract: Deep learning-based methods have shown promising results in multi-label chest X-ray (CXR) image classification. However, most existing methods rely on large-scale fully-annotated datasets, which are costly and laborious to obtain. Therefore, training a high-performance model with limited annotation remains a significant challenge in practice. To address this issue, we propose an Adversarial and Correlation-Aware Data Augmentation (ACAA) framework for multi-label CXR image classification. Specifically, we propose a Generalized Nesterov Iterative Fast Gradient Sign Method (GNI-FGSM) to generate effective adversarial examples as strongly-augmented data, and introduce an adversarial augmentation-based consistency regularization to perform supervision of model predictions on the above adversarial examples. Moreover, we propose a Batch-level Mamba module (BatchMamba) coupled with a batch-level Mamba-based correlation regularization to explore inter-sample correlations along batch dimension. Extensive experiments on two large CXR datasets demonstrate the effectiveness of the proposed ACAA framework for multi-label CXR image classification under limited-annotation scenario.

Multiscale topology optimization method for lattice materials

Yibao Li, Xi'an Jiaotong University

Abstract: In this talk, we will introduce an efficient multiscale topology optimization method for lattice materials. In macro-scale, we present a second-order unconditionally energy stable schemes for the topology optimization problem. Using porous media approach, our objective functional composes of five terms including mechanical property, Ginzburg-Landau energy, two penalized terms for solid and the volume constraint. A Crank-Nicolson method is proposed to discrete the coupling system. We prove that our proposed scheme is unconditionally energy stable. In macro-scale, we propose a simple volume merging method for triply periodic minimal structure. A modified Allen-Cahn type equation with a correction term is proposed. Computational experiments are presented to demonstrate the efficiency of the proposed method.



Diffusion Models, Orthogonal Projection Priors, and Semantic Guidance for Image Restoration

Jun Liu, Northeast Normal University

Abstract: This report focuses on multispectral pansharpening and zero-shot image restoration tasks, introducing three generative models and prior-guided methods for image fusion and restoration. For the multispectral pansharpening task, we first propose a Multi-Stage Diffusion-driven Pansharpening (MSDP) model. Through a three-stage conditional fusion mechanism and sparse attention modules, it achieves effective fusion of cross-modal priors. Combined with shearlet coefficients for multi-scale frequency enhancement, the method significantly improves both the spatial clarity and spectral fidelity of high-resolution multispectral images. Second, to address the low inference efficiency of existing generative models, we propose a Token-based Orthogonal Projection Pansharpening (TOPan) method. Utilizing an average velocity acceleration framework and token-based orthogonal projectors, it explicitly decouples shared features and modality-specific features, enabling efficient single-step generation. In the zero-shot image restoration task, targeting the limitations that traditional Deep Image Prior (DIP) struggles to recover semantic structures under extreme degradation conditions, and diffusion models suffer from heavy sampling computation and are prone to out-of-distribution artifacts, we propose an efficient adaptive restoration framework that integrates DIP and diffusion models. This method leverages a pretrained diffusion model to generate a semantic warm-initialization estimate, then adapts the model to the given degraded image through partial parameter fine-tuning, achieving flexible adaptation while maintaining semantic consistency. Experimental results demonstrate that the proposed method significantly outperforms existing zero-shot methods across various restoration tasks, achieving state-of-the-art performance in both restoration quality and inference efficiency.

Research on Nonsmooth Methods for Sound Velocity Imaging via Full Waveform Inversion

Cuijuan Lou, Zhejiang Normal University

Abstract: Focusing on the high-precision inversion problem in sound speed imaging for breast ultrasound tomography, this report proposes a Laplace-domain full waveform inversion method under a non-smooth optimization framework. By introducing an L_1 data fidelity term and anisotropic total variation (ATV) regularization, this method effectively improves the reconstruction accuracy of inversion results, leading to significant enhancements in both boundary sharpness and tissue contrast of the reconstructed images. Building on this, to address the issues of large number of channels and high hardware costs in ultrasound tomography systems, we further propose a Poisson disk sampling-based sparse sampling strategy for full waveform inversion imaging, and systematically compare the imaging performance of different sampling modes: transmitter-side sparsity, receiver-side sparsity, and transmitter-receiver hybrid sparsity. Furthermore, targeting the robust inversion problem under sparse sampling conditions, we construct a Laplace-domain full waveform inversion method that combines non-local TV regularization with an L_1 data fidelity term, to enhance the model's stability and noise resistance under incomplete observation conditions. Research results demonstrate that this series of methods provides a more efficient and robust numerical inversion framework for breast ultrasound tomography,



and is expected to promote its applications in early breast cancer screening and quantitative imaging.

Regularized Optimal Transport Models for Image Analysis

Ziwei Nie, Nanjing University

Abstract: Optimal transport (OT) theory and models have been widely used in the fields of computer vision, machine learning and image analysis. However, few works have considered regularization issues for optimal transport models, and even fewer have addressed their theoretical analysis, fast algorithms, or concrete applications. In this talk, we will introduce two distinct regularization approaches for optimal transport models, the second of which, to the best of our knowledge, is being considered for the first time in the academic community. We will also present theoretical results, efficient algorithms, and application examples corresponding to these regularized optimal transport models.

Weakly Supervised Cross-Domain Transfer Learning Method For Segmentation Based on Preference Learning

Jialin Peng, Huaqiao University

Abstract: Label scarcity and domain distribution shift are the key bottlenecks limiting the widespread application of deep models for image segmentation. Taking electron microscopy (EM) image analysis as a representative example, this report explores high-performance cross-domain segmentation methods under coarse-grained sparse annotation conditions. The report will further discuss cross-domain transfer learning segmentation methods that incorporate human preferences.

Intelligent Computing

Yaxin Peng, Shanghai University

Abstract: This report focuses on the new paradigm of intelligent computing. First, it introduces a novel type of Physics-Informed Neural Networks (PINNs), which significantly enhances the solving capabilities for both forward and inverse problems by fusing multimodal mathematical-physical models and observational data. Second, it explores how intelligent agents can achieve adaptive closed-loop control. Meanwhile, it elaborates that this new paradigm not only provides flexible and efficient mathematical tools for fields such as engineering design and imaging, but also conducts an in-depth analysis of its profound implications for scientific computing.

A Tunable Despeckling Neural Network Stabilized via Diffusion Equation

Yi Ran, Harbin Institute of Technology

Abstract: The removal of multiplicative Gamma noise is a critical research area in the application of synthetic aperture radar (SAR) imaging, where neural networks serve as a potent tool. However, real-world data often diverges from theoretical models,



exhibiting various disturbances, which makes the neural network less effective. Adversarial attacks can be used as a criterion for judging the adaptability of neural networks to real data, since they can find the most extreme perturbations that make neural networks ineffective. In this work, we propose a tunable, regularized neural network framework that unrolls a shallow neural denoising block and a diffusion regularization block into a single network for end-to-end training. The linear heat equation, known for its inherent smoothness and low-pass filtering properties, is adopted as the diffusion regularization block. The smoothness of our outputs is controlled by a single time step hyperparameter that can be adjusted dynamically. The stability and convergence of our model are theoretically proven. Experimental results demonstrate that the proposed model effectively eliminates high-frequency oscillations induced by adversarial attacks. Finally, the proposed model is benchmarked against several state-of-the-art denoising methods on simulated images, adversarial samples, and real SAR images, achieving superior performance in both quantitative and visual evaluations.

Iterative Unfolding Network with ℓ_1 Regularization for Sparse Object Segmentation

Yumeng Ren, City University of Hong Kong

Abstract: ℓ_1 sparse regularization occupies a central position in the fields of compressed sensing and image processing. The proposed ℓ_1 DecNet is a neural network unfolded from a variational decomposition model, which incorporates ℓ_1 sparse regularization and is solved via a non-standard scaled Alternating Direction Method of Multipliers (ADMM). ℓ_1 DecNet effectively separates spatially sparse features and dense features from input images, supporting subsequent image processing operations. Furthermore, we design a novel image segmentation architecture ℓ_1 DecNet+, which consists of a pre-processing ℓ_1 DecNet and a post-processing lightweight segmentation module. The segmentation module directly utilizes the sparse features without requiring the original image. This architecture organically combines the advantages of mathematical modeling and data-driven methods, introducing mathematical image priors into the feature extraction stage of segmentation networks. We validate its effectiveness on two typical sparse segmentation tasks: retinal vessel segmentation in medical image processing and pavement crack detection in industrial anomaly detection. Experimental results demonstrate that various lightweight segmentation modules under the ℓ_1 DecNet+ architecture can achieve performance that matches or even surpasses their corresponding expanded segmentation network counterparts, which has significant practical advantages on resource-constrained devices.

Conditional Distribution Modeling Theory and Methods for Embodied Intelligence Vision-Language-Action Models

Chaomin Shen, East China Normal University

Abstract: As mathematical models in image and signal processing expand into multimodal perception and intelligent decision-making, embodied Vision-Language-Action (VLA) models have become a major research focus. However, current approaches lack a unified probabilistic perspective, relying instead on ad-hoc architectures and task designs. We present a unified probabilistic framework that formulates multimodal continuous action decision-making as high-dimensional conditional distribution representation and inference. We discuss conditional distribution structure, the equivalence of probabilistic and energy-based representations, and unified inference methods. Our key insight is that model differences arise from conditional distribution structure and parameterization, not network architectures. We develop stable learning and efficient inference techniques for high-dimensional continuous action spaces, validated in both simulation and real robotic experiments. This work offers a novel mathematical perspective for VLA models and their applications in image and signal processing.

Generative Neural Physics Framework for High-Resolution 3D Ultrasound Tomography

Zuoqing Shi, Tsinghua University

Abstract : Ultrasound tomography (UT) holds inherent potential for in vivo biomechanical characterization by capturing transmitted and scattered wavefields, yet its widespread adoption has been limited by the lack of efficient and accurate full-wave scattering models. In this work, we introduce a generative neural physics framework that integrates generative models with physics-informed partial differential equation (PDE) solvers to enable rapid, high-fidelity 3D quantitative imaging of tissue mechanics. A compact neural surrogate for full-wave propagation is trained using limited cross-modality data, preserving physical accuracy while significantly improving computational efficiency. This approach achieves accurate and efficient volumetric imaging of in vivo human breast and musculoskeletal tissues within ten minutes. The resulting images demonstrate structural resolution comparable to 3T MRI, highlighting the broad clinical potential of this method.

Inverse Problems in Proton Therapy

Chao Wang, China Agricultural University

Abstract: Proton radiotherapy exhibits significant advantages in precision cancer treatment by leveraging the spatial selectivity of energy deposition of charged particles in matter. To fully exploit this advantage, treatment planning requires precise regulation of proton beam parameters while satisfying clinical constraints, which can be regarded as a complex inverse problem of inferring control variables from the target dose. This problem is typically characterized by high dimensionality, complex structure and sensitivity to perturbations, posing challenges in both theoretical analysis and numerical solution. This report systematically introduces dose calculation models in proton therapy and their corresponding inverse problem formulations. At the



algorithmic level, we will focus on gradient-based optimization methods and regularization strategies, explaining how to improve the stability and robustness of the solution by introducing structural constraints. In addition, we will present the latest research progress on spot parameter optimization, particularly the unified optimization framework that incorporates both spot intensities and spatial positions, which enhances treatment plan quality through joint modeling and solution.

Optimal Transport-based Image Fusion and its Applications

Faqing Wang, Beijing Normal University

Abstract: In this talk, we investigate cross-modal feature fusion for remote sensing and medical images based on optimal transport and Wasserstein barycenter theory. To address the distribution shift caused by imaging differences between optical and SAR images, we propose an entropy-regularized optimal transport-based feature alignment method, incorporating Gaussian positional encoding to preserve spatial structure, and further construct a multi-modal change detection method. For the MRI and CT image reconstruction and fusion task, we develop a symmetric fusion strategy based on the Wasserstein barycenter to achieves unbiased fusion.

Pediatric Disease Prediction Based on Multimodal Data Fusion

Yan Wang, Chongqing Normal University

Abstract: This report presents our research group's recent work on pediatric disease prediction, diagnosis and treatment, including X-ray-based pediatric pulmonary abnormality detection and medical vision-language models integrating medical imaging and text data. Additionally, it introduces our research on the diagnosis and educational rehabilitation of pediatric autism spectrum disorder (ASD), and discusses interdisciplinary research on brain cognition and rehabilitation for children with special needs.

Key Technologies for Medical Image Analysis under Label Noise

Zhijie Wen, Shanghai University

Abstract: Label noise is a critical bottleneck restricting the clinical translation of medical image analysis technologies. While deep learning has achieved remarkable results in medical image analysis, medical annotation faces challenges including long time consumption, high professional barriers, and significant inter-observer variability, leading to noise rates often exceeding 30% in real-world scenarios and severely compromising model generalization and decision reliability. This report systematically reviews key research techniques for medical image analysis under label noise conditions: first defining symmetric, asymmetric, and instance-dependent noise models and their characteristics; then organizing technical routes including data-level approaches (noise detection, reweighting, sample selection), loss functions (label smoothing, symmetric/generalized cross-entropy), model architectures (multi-network



collaboration, consistency regularization), semi-supervised learning (pseudo-labeling, contrastive learning), and pretraining-fine-tuning paradigms. It also presents our research group's recent achievements in this field, including research ideas and progress on long-tailed distribution data and open-set label noise environments.

Spatial Adaptivity Variational Image Decomposition Methods Cartoon-Texture Based on Spatial Adaptivity

Youwei Wen, Hunan Normal University

Abstract: Cartoon-texture image decomposition, which aims to separate an observed image into structured cartoon components and oscillatory texture components, is a classic inverse problem in image processing. Traditional variational models, such as those based on total variation (TV) and G-norm, have a clear theoretical framework but still face challenges in handling image spatial heterogeneity and numerical efficiency. This report integrates classic variational models, spatially adaptive weighting strategies and data-driven methods to construct a pixel-wise weighted quadratic variational model. It characterizes the prior properties of cartoons and textures respectively through spatially varying energy norms, effectively improving the model's expressive power while maintaining solution efficiency.

Geometric Symmetry Priors and Deep Network Modules

Qi Xie, Xi'an Jiaotong University

Abstract: Taking image processing as an example, this report explores the importance of geometric symmetry priors in deep network design. It focuses on the construction methods and fundamental theories of novel basic network modules, including high-precision rotation/scale equivariant convolutions, rotation-equivariant implicit neural representations, rotation-equivariant Vision Transformers (ViTs), and transform-learnable equivariant convolutions. Furthermore, through practical applications such as medical and natural image processing, image reconstruction, and multi-frame image matching, this report demonstrates that embedding prior geometric symmetries can significantly improve model performance and generalization ability.

Research on Generative Medical Image Analysis Methods Under Incomplete Data Conditions

Heran Yang, Xi'an Jiaotong University

Abstract: With the rapid advancement of medical imaging technologies, medical imaging has become increasingly prominent in disease diagnosis, treatment planning and prognostic assessment, and is now a core component of the modern healthcare system. However, in practical applications, medical image data often faces challenges of incompleteness, such as random missing modalities and difficulty in acquiring segmentation labels, which severely limit the usability and accuracy of medical image analysis methods and create significant technical bottlenecks for related research. To address these issues, this report presents our team's recent advances in applying

generative models to solve cross-domain generalization for medical image segmentation and medical image generation under random modality missing conditions, aiming to provide new insights and approaches for addressing medical image data incompleteness.

AS2LS: Adaptive Anatomical Structure-based Two-layer Level Set Framework for Medical Image Segmentation

Yunyun Yang, Harbin Institute of Technology (Shenzhen)

Abstract: Medical images often exhibit intricate structures, inhomogeneous intensity, significant noise and blurred edges, presenting challenges for medical image segmentation. Several segmentation algorithms grounded in mathematics, computer science, and medical domains have been proposed to address this matter; nevertheless, there is still considerable scope for improvement. This paper proposes a novel adaptive anatomical structure-based two-layer level set framework (AS2LS) for segmenting organs with concentric structures, such as the left ventricle and the fundus. By adaptive fitting region and edge intensity information, the AS2LS achieves high accuracy in segmenting complex medical images characterized by inhomogeneous intensity, blurred boundaries and interference from surrounding organs. Moreover, we introduce a novel two-layer level set representation based on anatomical structures, coupled with a two-stage level set evolution algorithm. Experimental results demonstrate the superior accuracy of AS2LS in comparison to representative level set methods and deep learning methods.

Positive Definiteness of Hadamard Product of Matrices and Its Applications

Zai Yang, Xi'an Jiaotong University

Abstract: According to the classical Schur product theorem, the Hadamard product (element-wise product) of two (semi-)positive definite matrices is (semi-)positive definite. Then, can the Hadamard product of two singular positive semi-definite matrices be positive definite? Can it be quantitatively characterized? What are its applications in signal processing and data analysis? This report will answer the above questions and briefly elaborate on how mathematics advances engineering research and how engineering inspires mathematical research.

Computing Low-Rank Pure Quaternion Tensor Approximations for Color Videos

Jiupeng Yu, Nanjing University of Posts and Telecommunications

Abstract: The key challenge in computing the optimal low-rank approximation for color videos represented as pure quaternion tensors lies in simultaneously preserving both the pure imaginary structure and the low-rank property. To address this, we



propose a novel quaternion tensor model that incorporates these two constraints, each of which is shown to form a manifold. The pure imaginary constraint ensures that the resulting tensor remains unaffected by nonzero real components, allowing the low-rank approximation to operate directly on the color information. A new iterative alternating projection algorithm is developed to compute the solution in the intersection of the low-rank quaternion tensor manifold and the pure quaternion tensor manifold, and it is theoretically guaranteed to converge. Numerical experiments on synthetic data and color videos demonstrate that our algorithms outperform the other state-of-the-art algorithms.

Research Progress on Mechanism and Data Fusion Methods for Vascular System and Ultrasound Image Computing

Jianfeng Zhang, Zhejiang Normal University

Abstract: Analysis of the human biological vascular system, key target recognition and precise segmentation based on medical images such as ultrasound have long been hotspots and challenges in the field of medical image computing. Integrating the physical laws governing vascular growth and expansion, knowledge mechanism constraints of medical targets, data-driven methods, and zero-shot generalization of large models, our team proposes mechanism-data fusion approaches for vascular system analysis and ultrasound image segmentation. These methods aim to better address challenges such as continuity and precision, meet practical needs in intelligent and precise auxiliary diagnosis and treatment, and provide valuable reference for the methodological system of medical image processing integrating biological knowledge mechanisms.

Motion Estimation in Image Registration and Imaging

Jianping Zhang, Xiangtan University

Abstract: The rapid evolution of imaging technologies—from MRI and CT to ultrasound and remote sensing—has generated an extraordinary amount of complex data. Transforming this raw pixel data into usable insight presents a significant challenge at the intersection of medicine, computer science, and applied mathematics. This talk will explore the pivotal role of advanced mathematical methods as the foundational learning engine for modern image registration and dynamical imaging.

Intelligent Quantification and Risk Stratification of Stroke Plaque on Magnetic Resonance Imaging

Na Zhang, Shenzhen Institute of Advanced Technology, CAS

Abstract: Ischemic stroke is characterized by high morbidity and disability rates, and atherosclerotic plaque rupture is the key risk factor for ischemic stroke. High-Resolution Vessel Wall Imaging (HR-VWI), which can clearly visualize the lumen, vessel wall and plaque components, is the primary modality for assessing plaque rupture risk. However, its image analysis faces three major challenges: inaccurate



observation on two-dimensional cross-sections due to tortuous vascular courses, poor reproducibility of manual segmentation caused by blurred plaque boundaries, and difficulty in capturing nonlinear relationships between multimodal imaging features and clinical outcomes. This report aims to introduce an end-to-end methodology for intelligent analysis of stroke-related plaques.

Stochastic alternating structure-adapted proximal gradient descent with variance reduction for nonconvex nonsmooth problem

Wenxing Zhang, University of Electronic Science and Technology of China

Abstract: The blocky optimization has gained a significant amount of attention in far-reaching practical applications. We develop a stochastic alternating structure-adapted proximal (s-ASAP) gradient descent method for solving blocky optimization problems. By deploying some variance reduced gradient estimators, s-ASAP is applicable to nonconvex optimization whose objective is the sum of a finite number of differentiable nonconvex functions. The sublinear convergence rate of s-ASAP is built upon the proximal point algorithmic framework, whilst the linear convergence rate of s-ASAP is achieved under the error bound condition.