Hongyu Zhou

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Education Background

Tsinghua University |Department of Electronic Engineering| PhD Candidate 2021.09—2026.06
GPA: 3.94/4.0 (8/115)
Supervisor: *Prof.* Maokun Li
Thesis Title: Research on Multi-physics Joint Inversion Driven by Both Data and Physics.

University of Illinois Urbana-Champaign |Coordinated Science Laboratory | Visiting Student 2024.08—2025.02
Supervisor: *Prof.* Yoram Bresler
Research Topic: Abdominal Adipose Imaging based on Combined Electromagnetic Modalities and Deep Learning.

Tsinghua University |Department of Electronic Engineering| B. Eng in ECE 2016.09—2021.06

Tsinghua University |School of Economics and Management| B.A. in Econ. (Second Degree) 2019.09—2021.06

Working Experience

Qinghai University |RA with the Department of Computer Science 2023.07—2023.08
- Worked on GPU acceleration of GRAPES (numerical weather prediction model).
- Implemented GPU parallelization using CUDA programming in Fortran.

Schlumberger Beijing Geoscience Center |Algorithm Development Intern 2021.08—2021.12
- Developed a flexible fault profile sampling algorithm adaptable to complex geological formations.
- Enable efficient and accurate dataset construction for training data-driven seismic horizon tracking models.

Research Summaries

My research interest primarily includes physical field modeling and imaging algorithms, with the goal of achieving fast, accurate, and reliable physical field computations. My research focus include wave field modeling in heterogeneous media, inversion and optimization for physical fields, integration of diverse multi-physics priors, and uncertainty quantification.

From the perspective of first principles, **I studied the stochastic framework for electromagnetic (EM) modeling** and proposed a purely stochastic simulation method to fully adapt to large-scale parallel heterogeneous computing hardware. From the perspective of data-driven approaches, **I embedded deep generative models into inversion** and extensively **applied deep learning optimization algorithms** to construct and successfully optimize objective functions with complex and diverse constraints.

As of now, the primary modality I have worked with is **EM fields**, with applications mainly in **geophysical exploration** and some **biomedical imaging**. However, I am also interested in modeling and imaging of other physical field modalities and their applications in various domains.

Research Details

Magnetotelluric (MT) inversion with the fusion of high resolution seismic information

| Part of PhD Thesis, supervisor: *Prof.* Maokun Li

- **Objective**: MT is sensitive to subsurface conductive structures, but has a lower resolution than seismic exploration. The interpretation knowledge of the experts are also not easy to incorporate into MT inversion. We seek approaches to incorporate multi-scale seismic information and experts' knowledge into MT inversion.
- **Approaches**:
  - *Work1*: Utilized CNN to generate resistivity reference from the seismic section and interpretation knowledge. The CNN is incorporated into the conventional gradient-based optimization as an additional reference regularization. See [J1] for more details.
  - *Work2*: Constructed a texture extraction operator (TEO) based on the pre-trained VGG19 and formed a texture data space with the TEO output span. The texture misfit is included in the objective function and jointly optimized with EM data misfit using ADAM optimization. See [J3] for more details.
- **Outcomes**:

- Improve the accuracy and resolution of MT inversion. The proposed algorithms are successfully used to process MT data from Luzong ore concentration area (Anhui, China) and Tarim Oilfield (Xinjiang, China).
- Best Student Paper Award (1st place) at 2024 Progress In Electromagnetics Research Symposium (PIERS2024) Student Paper Competition.

Intelligent EM inversion constrained by deep generative models

| Part of PhD Thesis, supervisor: *Prof.* Maokun Li

- **Objective**: Constrain EM inversion with prior knowledge on parameter distribution patterns, which may be abstract and diverse in informational content and effective region.
- **Approaches**: Studied feature-based EM inversion framework based on variational autoencoders (VAEs). The reconstructed model is expressed with the output of generator. This framework has been used in various EM inversions, including
  - *Work3*: 2D MT inversion. Generated a set of 1D models according to the prior knowledge under the layered media hypothesis, and with which a 1D VAE is trained. The model is expressed with the horizontal concatenation of various 1D VAE outputs, and the continuity is guaranteed with Tikhonov regularization. See [J2] for more details.
  - *Work4*: 2.5D controlled source electromagnetic (CSEM) inversion. The 2D VAE is fine-tuned based on the stable diffusion VAE, balancing the reconstruction ability and generalization ability. The objective function is optimized using projected Gauss-Newton (PGN), to reduce optimization iterations and circumvent local minima. See [J5] for more details.
- **Outcomes**:
  - *Work3*: An improvement of 75% in model misfit compared to conventional inversion. Successfully processed South Africa MT Experiment data (SAMTEX).
  - *Work4*: Improvements ranging from 50% to 75% in metrics such as MSE and SSIM compared to conventional inversion. Successfully processed Norway North Sea dataset (Troll Field).

Stochastic EM modeling leveraging intrinsic parallel mechanism

| NSFC Student Project, supervisor: *Prof.* Maokun Li

- **Objective**: High performance EM simulation highly relies on massive parallel computation hardware. Existing EM algorithms based on solving linear systems lack enough intrinsic parallelism. We reformulate and solve the EM equations under the stochastic framework to improve the parallel efficiency to the largest margin and make them better adapted to HPC (high performance computation) platforms.
- **Approach**:
  - *Work5*: For 2D MT modeling, we rewrite the Helmholtz equation as the formulation of stochastic path integral (SPI) based on the stochastic differential equation theory, hence transforming the main computation overhead from solving linear system to matrix-vector multiplication (MatVec). We build a surrogate model, partitioning the computation into the offline Monte Carlo simulation and online MatVec operations, therefore gain considerable parallelism, scalability and speedup. See [J4] for more details.
- **Outcomes**:
  - Achieve up to a 550x speedup compared with conventional modeling and 30% memory reduction at the relative error of 1.2%.
  - Best Student Paper Award at 2025 International Applied Computational Electromagnetics Society Symposium (ACES-China2025) Student Paper Competition.
  - Funded by 2024 National Natural Science Foundation of China (NSFC) Young Students Basic Research Program[1].

Abdominal adipose imaging based on combined EM modalities and deep learning

| Visiting Project at UIUC-CSL, supervisor: *Prof.* Yoram Bresler

- **Objective**: Abdominal fat has been an important predictor of all-cause mortality. Leveraging favorable features such as high convenience, low cost and no ionization of bio-impedance imaging, we aim to realize abdominal fat monitoring with EM imaging and improve the prediction accuracy of previous research.

[1] This NSFC grant, established in 2023, aims to support highly innovative research ideas by undergraduate and doctoral students in China. For doctoral students, the research proposal submitted for the grant should differ from their doctoral thesis, and students are required to independently prepare the application, complete the defense, and fully manage implementation and funds. The grant is highly competitive, with only approximately 500 applications across all research subjects awarded nationwide in the 2024 cycle. For reference, the number of enrolled doctoral students in China in 2024 was approximately 670,000. For more information, please click here.

- **Approach**:
  - *Work6*: We developed modeling (based on circuit theory, measuring both electric/magnetic excitations and electric/magnetic responses). A neural network was built using deep unrolling approach, and the neural units are built with Graph Neural Operators (GNOs) to tackle variable meshes.
- **Outcomes**:
  - Direct prediction of subcutaneous and visceral fat distribution from measured combined EM modality data.
  - Achieved a prediction IoU of 0.95 and Dice coefficient of 0.97 on the test set. See [C9] for more details.

Skills and Expertise

- **Hands-on Experience in:**
  - computational electromagnetic (CEM) algorithms, including FDM (Finite Difference Method), FEM (Finite Element Method), MoM (Method of Moments), and stochastic algorithms, etc.
  - 2D modeling, 2.5D modeling and 3D modeling, both in frequency domain and time domain.
  - optimization methods for physical fields, including adjoint method, gradient-based inversion and stochastic inversion.
  - machine learning techniques, including conventional machine learning, CNN (Convolution Neural Network), VAE (Variational Autoencoder), GAN (Generative Adversarial Network), NO (Neural Operator), and model fine-tuning, etc.
- **Familiar with:**
  - uncertainty quantification and Bayesian inversion.
  - experiment techniques, including microwave and ultrasound experiment system building, etc.
  - machine learning techniques, including diffusion models and LLMs (large language models), etc.
- **Courses:**
  - Full-GPA courses: Advanced Numerical Analysis, Numerical Methods in Electromagnetics, Modern Electromagnetic Theory, Machine Learning, Radio Wave Propagation, The Finite-Difference Time-Domain Method, Surface Electromagnetics, Theory and Methods in Electromagnetic Inverse Problems, Probability and Statistics, Quantum Mechanics and Statistical Mechanics, etc.
  - Other courses: Complex Analysis, Electronic Circuits and Systems, Stochastic Processes, Signals and Systems, etc.
- **Others:**
  - coding capability：Python (TensorFlow and PyTorch), MATLAB, C, C++, CUDA, etc.
  - software mastery: HFSS, CST, ADS, etc.
  - language: Chinese (native), English (fluent).

Selected Awards and Honors

1. National Scholarship. 2025.09
2. ACES-China2025, Best Student Paper Award. 2025.08
3. NSFC, Young Students Basic Research Grant. 2024.12
4. Tsinghua University, Scholarship for Overseas Graduate Studies. 2024.07
5. PIERS2024, Best Student Paper Award (1^{st} Place, in SC.5[2]), 2024.05
6. Tsinghua University, Excellent Social Work Scholarship for Postgraduate. 2022.12
7. Tsinghua University, Excellent Comprehensive Scholarship for Postgraduate. 2022.11
8. Tsinghua University, Outstanding Undergraduate Thesis of the Department of Electronics. 2021.06

Teaching and Academic Services

1. TA，including：
   (a) Theory and Methods in Electromagnetic Inverse Problems (Tsinghua, 80231023-0, 2024.03-2024.06)
   (b) Numerical Methods in Electromagnetics (Tsinghua, 70230173-0, 2023.09-2023.12)
   (c) Electromagnetic Field and Microwave Experiment (Tsinghua, 40230821-0, 2022.03-2022.06)
2. Undergraduate research mentoring, including:

[2] SC. 5: Remote Sensing, Inverse Problems, Imaging, Radar and Sensing Category

(a) Yutong Li (Tsinghua University, Research on Text-to-Geological Structure Generator for Deep Resource Prospecting, 2022.08-2023.08)

(b) Zihao Lian & Ieva Bagdonaviciute (UIUC, Joint Inversion of EMIT and Ultrasound Imaging based on Deep Learning, 2024.08-2025.02)

(c) Haoxuan Wang & Xi Chen (Tsinghua University, EM Inversion based on Deep Generative Models, 2025.03-Present)

3. I have served as reviewer for several leading journals, including

(a) IEEE Transactions on Geoscience and Remote Sensing

(b) IEEE Transactions on Antennas and Propagation

(c) Geophysics

Publications

- **Journals**

[J1] **Zhou H**, Guo R, Li M, et al. An intelligent MT data inversion method with seismic attribute enhancement[J]. **IEEE Transactions on Geoscience and Remote Sensing**, 2023, 61: 1-14.

[J2] **Zhou H**, Guo R, Li M, et al. Feature-based magnetotelluric inversion by variational autoencoder using a subdomain encoding scheme[J]. **Geophysics**, 2024, 89(1): WA67-WA83.

[J3] **Zhou H**, Guo R, Li M, et al. Super-resolution magnetotelluric data inversion with seismic texture constraint[J]. **Geophysics**, 2025, 90(3): WA153-WA168.

[J4] **Zhou H**, Li M, Yang F, et al. Two-Dimensional Magnetotelluric Modeling based on Stochastic Path Integral: TE Case[J]. **IEEE Transactions on Geoscience and Remote Sensing**, doi: 10.1109/TGRS.2025.3618304.

[J5] **Zhou H**, Sun H, Guo R, et al. Feature-based 2.5D Controlled Source Electromagnetic Inversion using Generative Priors[J]. **IEEE Transactions on Geoscience and Remote Sensing**, *Undergoing Review.*

- **Conferences**

[C1] **Zhou H**, Guo R, Tao D, et al. Joint inversion of audio-magnetotelluric and seismic travel time data using attribute fusion based on deep learning[C]//2021 International Applied Computational Electromagnetics Society (**ACES-China**) Symposium. IEEE, 2021: 1-2.

[C2] **Zhou H**, Guo R, Li M, et al. Joint inversion of magnetotelluric and seismic travel time data with intelligent interpretation of geophysical models[C]//Second International Meeting for Applied Geoscience & Energy (**SEG Annual Conference**). Society of Exploration Geophysicists and American Association of Petroleum Geologists, 2022: 1900-1904.

[C3] **Zhou H**, Guo R, Li M, et al. An intelligent MT data inversion method constrained by seismic texture[C]//2023 International Applied Computational Electromagnetics Society Symposium (**ACES-China**). IEEE, 2023: 1-2.

[C4] **Zhou H**, Guo R, Li M, et al. Magnetotelluric Data Inversion Using Subdomain Encoding Scheme with Variational Autoencoder[C]//2023 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting (**USNC-URSI**). IEEE, 2023: 255-256.

[C5] **Zhou H**, Guo R, Li M, et al. An MT data inversion method constrained by seismic texture[C]//Third International Meeting for Applied Geoscience & Energy (**SEG Annual Conference**). Society of Exploration Geophysicists and American Association of Petroleum Geologists, 2023: 1049-1053.

[C6] **Zhou H**, Guo R, Hu Z, et al. High-resolution Magnetotelluric Data Inversion Constrained with Seismic Texture[C]//2024 Photonics & Electromagnetics Research Symposium (**PIERS**, **Best Student Paper Award**). IEEE, 2024: 1-9.

[C7] **Zhou H**, Guo R, Hu Z, et al. High resolution MT data inversion with the seismic texture constraint[C]//International Workshop on Gravity, Electrical & Magnetic Methods and Their Applications (**GEM**), Shenzhen, China, May 19–22, 2024. Society of Exploration Geophysicists and Chinese Geophysical Society, 2024: 356-359.

[C8] **Zhou H**, Li M, Yang F, et al. Modeling Magnetotelluric Surveys Based on Stochastic Path Integral[C]//2024 IEEE International Symposium on Antennas and Propagation and INC/USNC-URSI Radio Science Meeting (**AP-S/INC-USNC-URSI**). IEEE, 2024: 2545-2546.

[C9] **Zhou H**, Lin Z, Zhang K, et al. Deep-E2M2IT: Deep learning-based combined electromagnetic impedance tomography for abdominal fat segmentation[C]//**Journal of Physics: Conference Series**. IOP Publishing, 2025, 3014(1): 012032.

[C10] **Zhou H**, Li M, Yang F, et al. MT-SPI: An Intrinsically Parallel Electromagnetic Modeling with Application

to 2D Magnetotellurics[C]//2025 International Applied Computational Electromagnetics Society Symposium (**ACES-China**, **Best Student Paper Award**). IEEE, 2025: 1-3.

- **Others**

[O1] Zhang H, Zhang T, **Zhou H**, et al. A microwave thorax imaging system based on symmetrical dipole antenna and one-step supervised descent method[J]. **IEEE Transactions on Microwave Theory and Techniques**, 2022, 70(11): 5000-5007.

[O2] Li Y, **Zhou H**, Guo R, et al. Generating geophysical models from text for constructing the dataset of learning-based MT inversion[C]//Third International Meeting for Applied Geoscience & Energy (**SEG Annual Conference**). Society of Exploration Geophysicists and American Association of Petroleum Geologists, 2023: 1040-1043.

[O3] Guo R, **Zhou H**, Wei X, et al. Deep joint inversion of electromagnetic, seismic, and gravity data[C]//International Workshop on Gravity, Electrical & Magnetic Methods and Their Applications (**GEM**), Shenzhen, China, May 19–22, 2024. Society of Exploration Geophysicists and Chinese Geophysical Society, 2024: 360-363.

[O4] Guo R, **Zhou H**, Wei X, et al. Deep joint inversion of multiple geophysical data with U-net reparameterization[J]. **Geophysics**, 2024, 90(3): WA61-WA75.

[O5] Ma J, Deng Y, Li X, Guo R, **Zhou H**, Li M. Recent Advances in Machine Learning-Enhanced Joint Inversion of Seismic and Electromagnetic Data[J]. **Surveys in Geophysics**, 2024: 1-29.

Patents and Copyrights

Based on my research results, I have applied for

1. six Chinese patents. One has been certified, the others are undergoing examination.
2. two Chinese software copyrights. Both have been certified (2021SR1542315, 2021SR1471064).

References

- *Prof.* Maokun Li, supervisor of my PhD study
  Department of Electronic Engineering, Tsinghua University, Beijing, China
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- *Prof.* Yoram Bresler, mentor for my study at UIUC
  Department of Electrical and Computer Engineering, UIUC, Illinois, USA
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