Zhengshou Lai - Curriculum Vitae

Ph.D., Associate Professor | School of Civil Engineering, Sun Yat-sen University

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Dr. Zhengshou Lai is an Associate Professor at the School of Civil Engineering, Sun Yat-sen University, and a dual-appointed faculty member at the Research Center for Applied Mathematics, Hong Kong Advanced Research Institute. He received his Ph.D. in Civil Engineering from Clemson University, USA, in 2018, and his Bachelor's degree from Sun Yat-sen University. From 2019 to 2023, he conducted postdoctoral research at Sun Yat-sen University and the Hong Kong University of Science and Technology (Hong Kong Scholars Program).

Dr. Lai's research focuses on multiscale computational mechanics of granular media, with an emphasis on developing advanced numerical algorithms and high-performance computing software for multi-physics simulation of complex granular systems. He has made systematic contributions to discrete element modeling and contact algorithms for irregular-shaped particles based on geometric descriptors including Fourier series, poly-Bézier curves, and signed distance fields. His recent work concentrates on fluid-solid coupling multiscale simulation frameworks (CFD-DEM), machine learning-enabled discrete element methods, and data-driven digital twin technologies for granular materials. His research provides theoretical foundations and computational tools for critical engineering problems including deep-sea mining, subseabed carbon sequestration, and multiscale modeling and uncertainty quantification of transportation infrastructure.

Dr. Lai serves as a reviewer for international journals including *Computers and Geotechnics*, *Acta Geotechnica*, and *Granular Matter*. His research has been supported by the National Natural Science Foundation of China, Guangdong Provincial Natural Science Foundation, and China Postdoctoral Science Foundation.

Research Interests

Computational geomechanics; Discrete element method; Fluid-solid coupling multiscale simulation; Machine learning and data science; Computational mechanics of granular materials; Software development

Education

- **Clemson University, USA**, Ph.D., Civil Engineering, 2015.01-2018.12
- **Sun Yat-sen University, China**, Direct Ph.D. Student (No Degree Awarded), Engineering Mechanics, 2012.09-2014.06
- **Sun Yat-sen University, China**, Bachelor, Transportation Engineering, 2008.09-2012.07

Work Experience

- **Sun Yat-sen University - School of Civil Engineering**, Associate Professor, 2023.03-Present
- **Sun Yat-sen University - Hong Kong Advanced Research Institute, Research Center for Applied Mathematics**, Dual-appointed Faculty, 2025.12-Present
- **Hong Kong University of Science and Technology - Department of Civil and Environmental Engineering, Sun Yat-sen University - School of Intelligent Engineering**, Postdoctoral Fellow ("Hong Kong Scholars" Program), 2021.02-2023.02
- **Sun Yat-sen University - School of Intelligent Engineering**, Postdoctoral Fellow, 2019.02-2021.02
- **Idaho National Laboratory, USA**, Research Intern, 2018.06-2018.12

Professional Skills

- Multiscale Simulation; Numerical Algorithm and Software Development; Computational Mechanics; Granular Media Simulation; Finite Element/Discrete Element Methods

Research Projects

Funded Research

- **Guangdong Provincial Department of Science and Technology, General Project (PI)**; Research on Gas-Liquid-Solid Multiphase Flow Mechanism and Coupled Numerical Methods in Hydrate Solid Fluidized Mining; 2026.01-Present (¥100,000)
- **Guangdong Provincial Department of Science and Technology, Major Basic Research Project (Participant)**; Multi-field Multi-scale Dynamic Coupling Disaster Mechanism and Mitigation of Offshore Wind Power Platforms under Extreme Marine Environment; 2025.09-Present (¥5,000,000)
- **State Key Laboratory of Mountainous Civil Engineering Safety and Resilience, Open Project (PI)**; Peridynamics-DEM Coupled Simulation and Disaster Response Mechanism of Rock Mass Dynamic Fracture in Mountainous Areas; 2025-Present (¥60,000)
- **National Postdoctoral Management Committee Office and Hong Kong Scholars Association, "Hong Kong Scholars" Program Project (PI)**; Multiscale Simulation of Granular Media; 2021.02-2023.02 (¥660,000)
- **National Natural Science Foundation of China, Youth Project (PI)**; Macro-micro Mechanical Testing and Multiscale Discrete Element Modeling of Calcareous Sand Based on CT Images and Machine Learning; 2020.01-2022.12 (¥250,000)
- **China Postdoctoral Science Foundation, General Project (PI)**; Research on Discrete Element Method for Irregular Particles Based on Fourier Series; 2020.01-2021.12 (¥120,000)
- **University Basic Research Funding, Young Teacher Development Project (PI)**; Intelligent Detection and Health Assessment of Transportation Infrastructure Based on Computer Vision; 2020.01-2021.12 (¥150,000)

Industry Projects

- **Institute of Mechanics, Chinese Academy of Sciences (PI)**; Contact Algorithm Development for Non-spherical Particles; 2025-Present (¥180,000)
- **China Railway 18th Bureau Group Municipal Engineering Co., Ltd. (PI)**; Deformation Behavior and Early Warning Control Technology for Deep Foundation Pit Construction in Deep Saturated Silt Strata of Metro Stations; 2024-Present (¥1,600,000)
- **Guangzhou North Second Ring Traffic Technology Co., Ltd. (PI)**; Pavement Wetness State Perception and Safety Early Warning System Application Research; 2023-Present (¥750,000)

Publications (†Student first author, #Corresponding author)

2026

- **Lai, Z.**, Huang, S., Kong, Y., Zhao, S., Zhao, J., & Huang, L. (2026). Hybrid resolved-unresolved CFD-DEM framework for multiscale fluid-particle systems with irregular-shaped and polydisperse particles. *Journal of Computational Physics*, 554, 114759.
- Li, C., Huang, L., **Lai, Z.**#, Huang, S., & Lin, Y. (2026). A diffusion-based generative framework for virtual porous granular media generation. *Powder Technology*, 473, 122230.
- Li, C., **Lai, Z.**#, Huang, S., & Huang, L. (2026). Neural network-driven shape representation and computational particle mechanics via signed distance fields. *Engineering Applications of Artificial Intelligence*, 167, 113913.
- Huang, S., Wang, P., **Lai, Z.**, Yin, Z.-Y., Huang, L., & Xu, C. (2026). Hybrid SDF-CFD-DEM analysis of suffusion behavior in coral sand incorporating irregular particle morphology and intraparticle voids. *Engineering Geology*, 364, 108616.

2024

- Huang, S.†, Wang, P., **Lai, Z.**#, Yin, Z. Y., Huang, L., & Xu, C. (2024). Machine-learning-enabled discrete element method: The extension to three dimensions and computational issues. *Computer Methods in Applied Mechanics and Engineering*, 432, 117445.

- **Lai, Z.**, Feng, Y. T., Zhao, J., & Huang, L. (2024). Unifying the contact in signed distance field-based and conventional discrete element methods. *Computers and Geotechnics*, 176, 106764.
- Lin, Y., **Lai, Z.**, Ma, J., & Huang, L. (2024). A combined weighted Voronoi tessellation and random field approach for modeling heterogeneous rocks with correlated grain structure. *Construction and Building Materials*, 416, 135228.
- Liu, Y. J., Yin, Z. Y., Huang, S., **Lai, Z.**, & Zhou, C. (2024). Resolved CFD-DEM Modeling of Suffusion in Gap-Graded Shaped Granular Soils. *Journal of Geotechnical and Geoenvironmental Engineering*, 150(4), 04024008.
- Kootahi, K., Leung, A. K., Jiang, Z., Liu, J., Qi, R., Lourenço, S. D. N., **Lai, Z.**, & Gao, Z. (2024). Evaluation of the Methods of Particle Morphology Characterization: CT Scanning, Digital Imaging and Light Microscopy. *Computers and Geotechnics*, 174, 106648.
- Wu, F.†, Huang, L., & **Lai, Z.**#. (2024). Particle surface discretization and reconstruction method based on spherical Voronoi. *Engineering Mechanics*, 41(9), 245-256.

2023

- **Lai, Z.**, Zhao, J., Zhao, S., & Huang, L. (2023). Signed distance field enhanced fully resolved CFD-DEM for simulation of granular flows involving multiphase fluids and irregularly shaped particles. *Computer Methods in Applied Mechanics and Engineering*, 414, 116195.
- **Lai, Z.**, Xia, Y., & Chen, Q. (2023). Discrete element modeling of granular hopper flow of irregular-shaped deformable particles. *Advanced Powder Technology*, 34(9), 104106.
- Lin, Y., Ma, J., **Lai, Z.**, Huang, L., & Lei, M. (2023). A FDEM approach to study mechanical and fracturing responses of geo-materials with stochastic inclusions using a novel reconstruction strategy. *Engineering Fracture Mechanics*, 282, 109171.
- Huang, S.†, Huang, L., **Lai, Z.**#, & Zhao, J. (2023). Morphology characterization and discrete element modeling of coral sand with intraparticle voids. *Engineering Geology*, 315, 107023.
- Zhu, B., Liu, J., **Lai, Z.**, & Qian, T. (2023). Sampling Gaussian stationary random fields: A stochastic realization approach. *ISA Transactions*, 142, 386-398.

2022

- Zhao, S., **Lai, Z.**, & Zhao, J. (2022). Leveraging ray tracing cores for particle-based simulations on GPUs. *International Journal for Numerical Methods in Engineering*, 124(3), 696-713.
- Xiao, R., Liang, B., Wu, F., Huang, L., & **Lai, Z.** (2022). Biocementation of coral sand under seawater environment and an improved three-stage biogrouting approach. *Construction and Building Materials*, 362, 129758.
- **Lai, Z.**, Zhao, S., Zhao, J., & Huang, L. (2022). Signed distance field framework for unified DEM modeling of granular media with arbitrary particle shapes. *Computational Mechanics*, 70(4), 763-783.

2021

- Chen, Q., & **Lai, Z.** (2021). Hydromechanical modelling of CO2 sequestration using a component-based multiphysics code. *Environmental Geotechnics*, 8(1), 38-54.
- Gleaton, J., **Lai, Z.**, Xiao, R., Zhang, K., Chen, Q., & Zheng, Y. (2021). Optimization of mechanical strength of biocemented Martian regolith simulant soil columns. *Construction and Building Materials*, 315, 125741.
- Huang, S.†, Huang, L., & **Lai, Z.**# (2021). An extension of the Fourier series-based particle model to the GJK-based contact detection and resolution framework for DEM. *Computational Particle Mechanics*, 9(2), 381-391.
- **Lai, Z.**, Chen, Q., & Huang, L. (2021). Machine-learning-enabled discrete element method: Contact detection and resolution of irregular-shaped particles. *International Journal for Numerical and Analytical Methods in Geomechanics*, 46(1), 113-140.
- **Lai, Z.**, Zhao, S., Zhao, J., & Huang, L. (2021). Revisiting the GJK and shape erosion method for contact resolution in DEM. *Powder Technology*, 394, 363-371.
- **Lai, Z.**, Chen, Q., & Huang, L. (2021). Evaluating the hydromechanical responses of seabed–pipelines with rotated anisotropic heterogeneous seabed properties. *Ocean Engineering*, 234, 109226.
- **Lai, Z.**, Chen, Q., & Huang, L. (2021). A semianalytical Hertzian frictional contact model in 2D. *Applied Mathematical Modelling*, 92, 546-564.

- **Lai, Z.**, & Huang, L. (2021). A polybézier-based particle model for the DEM modeling of granular media. *Computers and Geotechnics*, 134, 104052.

2020

- Huang, L., Huang, S., & **Lai, Z.**# (2020). On an energy-based criterion for defining slope failure considering spatially variable soil properties. *Engineering Geology*, 264, 105323.
- Huang, L., Huang, S., & **Lai, Z.**# (2020). On the optimization of site investigation programs using centroidal Voronoi tessellation and random field theory. *Computers and Geotechnics*, 118, 103331.
- **Lai, Z.**, Chen, Q., & Huang, L. (2020). Fourier series-based discrete element method for computational mechanics of irregular-shaped particles. *Computer Methods in Applied Mechanics and Engineering*, 362, 112873.
- Huang, L., Ye, W., & **Lai, Z.** (2020). Indoor triaxial test study on size effect of granular materials considering morphology and moisture content. *Journal of Railway Science and Engineering*, 17(9), 2262-2270.
- Liang, Y., Zhang, J., **Lai, Z.**, Huang, Q. Y., & Huang, L. C. (2020). Temporal and spatial distribution of the grout pressure and its effects on lining segments during synchronous grouting in shield tunnelling. *European Journal of Environmental and Civil Engineering*, 24(1), 79-96.

2019

- Gleaton, J., **Lai, Z.**, Xiao, R., Chen, Q., & Zheng, Y. (2019). Microalga-induced biocementation of martian regolith simulant: Effects of biogrouting methods and calcium sources. *Construction and Building Materials*, 229, 116885.
- **Lai, Z.**, & Chen, Q. (2019). Reconstructing granular particles from X-ray computed tomography using the TWS machine learning tool and the level set method. *Acta Geotechnica*, 14(1), 1-18.
- **Lai, Z.**, Chen, Q., Wang, C., & Zhou, X. (2019). Modeling dynamic responses of heterogeneous seabed with embedded pipeline through multiresolution random field and coupled hydromechanical simulations. *Ocean Engineering*, 173, 556-570.

2017

- **Lai, Z.**, & Chen, Q. (2017). Characterization and discrete element simulation of grading and shape-dependent behavior of JSC-1A Martian regolith simulant. *Granular Matter*, 19(4), 69.
- **Lai, Z.**, & Chen, Q. (2017). Particle swarm optimization for numerical bifurcation analysis in computational inelasticity. *International Journal for Numerical and Analytical Methods in Geomechanics*, 41(3), 442-468.

2016

- Mota, A., Chen, Q., Foulk, J.W., **Lai, Z.**, & Ostien, J.T. (2016). A Cartesian parametrization for the numerical analysis of material instability. *International Journal for Numerical Methods in Engineering*, 108(2), 156-180.

Honors and Awards

- **2024**; Testing Equipment and Anti-seepage Key Technologies for Fractured Rock Mass Seepage in Underground Engineering, Guangdong Province Technology Invention Award, First Prize
- **2023**; CFD-DEM Industrial Software Development and Simulation Technology Application for Multi-field Multiphase Processes, Second National Postdoctoral Innovation and Entrepreneurship Competition, National Finals Winner, Outstanding Postdoctoral Fellow
- **2022**; Performance Evolution Theory and Safety Control Technology for Soft Soil-Urban Tunnel Coupling System, Guangdong Province Science and Technology Progress Award, First Prize
- **2020**; Key Technologies for Engineering Geological Investigation and Collapse Early Warning in Carbonate Rock Areas Based on Karst Development Mechanism, Guangdong Province Science and Technology Progress Award, Second Prize
- **2020**; Key Technology and Application of Dynamic Sensing and Control of Mechanical Behavior Evolution of Geotechnical-Underground Structure Coupling System, Guangdong Province Mechanics Society Science and Technology Award (Invention), First Prize

Patents and Software Copyrights

Patents

- CFD-DEM processing method and system for arbitrary-shaped particles based on improved immersed boundary and signed distance field, 2024
- Particle shape simulation method and system based on particle swarm optimization and Bezier curves, 2021
- Shape simulation method, device and equipment for irregular particles, 2020
- Design and optimization method for borehole layout scheme based on Voronoi diagram, 2019
- Robustness evaluation method and device for borehole layout scheme, 2019
- Particle state analysis method, device and equipment for granular materials, 2019
- Intelligent monitoring system based on BIM, 2019

Software Copyrights

- Process Analysis and Simulation Platform - SDF-based CFD-DEM Fluid-Solid Coupling Software V1.0, 2024
- NetDEM Discrete Element Software V1.0, 2022

Student Supervision

- **2026.04**; First Prize, 7th Structural Design Competition, School of Civil Engineering, Team: "凡事不要太绝队" (He Junyan, Jiang Yihan, Gong Daxuan)
- **2025.09**; Second Prize (Numerical Simulation Group), First "Hailutong Cup" Intelligent Water Pool Competition and Pioneer Intelligent Computing Special Session, Sun Yat-sen University Internal Competition, Team: Liu Mingjing, Zhang Haoqin, Zhang Biao
- **2024.10**; Second Prize (Undergraduate Group), 14th APMCM Asia and Pacific Mathematical Contest in Modeling, Team: Zheng Zefeng, Mo Ziwei, Liang Weilin

Academic Reports

- **2025.08**; Keynote Lecture, Guangdong-Hong Kong-Macao Greater Bay Area Young Geotechnical Engineering Scholars Forum, Zhuhai, China
- **2025.05**; Discrete Element Software Design and Development for Engineering Applications, 1st National Conference on Computational Mechanics of Granular Materials, Lanzhou, China (Invited Report)
- **2024.10**; Machine Learning-Enabled Discrete Element Method for Computational Particle Mechanics, DACOMA 2024 (Invited Report)
- **2024.09**; SDF-CFD-DEM for Arbitrary Particle Shapes, ZWSoft Granular Materials Symposium (Invited Report)
- **2022.10**; CFD-DEM Simulation Method for Multiphase Flow and Arbitrary Shaped Particles Based on Signed Distance Field, 6th National Conference on Computational Mechanics of Granular Materials (CMGM), Hangzhou, China (Invited Report, Outstanding Young Researcher Presentation)
- **2022.06**; Multiscale modeling of granular media: Developments of irregular-shaped particle models and contact algorithms in discrete element method, Hong Kong Scholars Program Annual Academic Exchange Conference (Outstanding Poster Award)
- **2021.12**; Contact Algorithm and Software Development for Non-spherical Discrete Element Particles, China University of Geosciences Young Forum, Wuhan, China (Invited Report)
- **2020.12**; Component-based Multi-physics Simulation Software Albany - CO2 Geological Storage Simulation Case, "Guangdong-Hong Kong-Macao Greater Bay Area High-Performance Computing" National Postdoctoral Academic Forum (Outstanding Paper Award)

Professional Service

Journal Reviewer

- *Computers and Geotechnics*, *Acta Geotechnica*, *Granular Matter*, *Engineering Geology*, *Powder Technology*, *Applied Mathematical Modelling*, *Ocean Engineering*, etc.

Conference Organization

- **The 5th Soft Soil Engineering Academic Conference** (May 2026, Zhuhai)
- **The 3rd Interdisciplinary Innovation Forum & 17th Youth Rock Mechanics and Engineering Conference** (May 2025, Zhuhai)
- **CAE Engineering Science Seminar on Urban Safety Resilience & 2nd Urban Safety Technology Symposium** (Dec 2025, Zhuhai)
- **2024 China Tunnel and Underground Engineering Conference (CTUC)** (Oct 2024, Zhuhai)
- **Sun Yat-sen University Geotechnical Constitutive and Numerical Forum** (Jan 2026, Guangzhou)
- **CSRME Popular Science Forum** (Feb 2026, Guangzhou)

Academic Affiliations

- **Chinese Society for Rock Mechanics and Engineering** — Committee Member, Professional Committee on Practical Application of Artificial Intelligence Technology (2024.04–present)
- **Chinese Society of Particuology** — Committee Member, Particle Computing Professional Committee (2025.11–present); Fourth Term Youth Council Member (2025–2026)
- **Guangdong Society of Theoretical and Applied Mechanics** — Committee Member (2025.01–present)
- **IJMCE** — Guest Editor (2023–present)

Student Recruitment and Collaboration

Recruiting master's students in geotechnical engineering/engineering mechanics. Welcome students interested in computational mechanics.