KAI CHEN

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(Last updated: 2026/1/1)

EDUCATION

SHANGHAI JIAO TONG UNIVERSITY

- **Ph.D in Applied Mathematics** 2020/09 ~ 2025/09
- **MS in Physics** 2018/09 ~ 2020/06
- **BS in Physics** 2013/09 ~ 2017/06
- **Relevant Courses**: Numerical Analysis, Inverse Problems, Advanced Statistical Physics, Computational Physics, Biological Physics, Calculus, Linear Algebra, Complex Analysis.

PUBLICATIONS

** Indicates equal contribution*

- Zhong-qi K. Tian*, **Kai Chen***, Songting Li, David W. McLaughlin, and Douglas Zhou. 2024. "*Causal Connectivity Measures for Pulse-Output Network Reconstruction: Analysis and Applications.*" Proceedings of the National Academy of Sciences 121 (14): e2305297121. https://doi.org/10.1073/pnas.2305297121
- Mei, Jinlong*, **Kai Chen***, Yanyang Xiao, Songting Li, and Douglas Zhou. "*The Asymptotic Behavior of Conditional Granger Causality with Respect to Sampling Interval.*" (2024). https://doi.org/10.4208/csiam-ls.SO-2024-0003
- **Kai Chen**, Zhong-qi K. Tian, Wei P. Dai, and Songting Li, Douglas Zhou. "*Nonlinear Pulse-coupled Network Reconstruction by Pairwise Time-delayed Transfer Entropy.*" Posted on arXiv. (in preparation)
- **Kai Chen**, Yuxiu Shao, Songting Li, Douglas Zhou. "*Unveiling the Cognitive Computation Using Multi-area RNN with Biological Constraints.*" (in preparation)
- **Kai Chen**, Mingzhang Wang, Songting Li, Douglas Zhou. "*Network structural change point detection and reconstruction for balanced neuronal networks.*" Posted on arXiv. (in preparation)
- Bo Wang, **Kai Chen**, Shouwei Luo, Yanyang Xiao, Songting Li, Douglas Zhou. "*Anatomical Connectivity Reconstruction of Biological Neuronal Networks Using Granger Causality.*" Accepted by Neural Networks.

TALKS († *Indicates expected*)

- **"Linking causal and structural connectivity in pulse-output nonlinear networks."**
  @ 7th Symposium for Outstanding Ph.D Students in Computational & Applied Mathematics, Peking University, Beijing, China, *Nov. 2024*
- **"Quantitative relations among causality measures with applications to pulse-output nonlinear network reconstruction."**
  @ SIAM Conference on Applications of Dynamical Systems (DS23), Portland, Oregon, USA, *May 2023*
  @ The Annual Meeting of the China Society for industrial and Applied Mathematics (CSIAM2022), Online, *Nov. 2022*
- **"Modeling Attentional Modulated Spike Count Correlation in Macaque V1."**
  @ 3rd Chinese Computational and Cognitive Neuroscience Conference, Online, *Jun. 2021*

POSTERS († *Indicates expected*)

- **"Emergent hierarchical representations for multi-task learning in anatomy-constrained RNNs."**
  @ 23nd Annual Computational and Systems Neuroscience (COSYNE), Lisbon, Portugal, *Mar. 2026*
- **"Unveiling the cognitive computation using multi-area RNN with biological constraints."**
  @ 22nd Annual Computational and Systems Neuroscience (COSYNE), Montreal, Canada, *Mar. 2025*
- **"Nonlinear network reconstruction using pairwise time-delayed transfer entropy."**
  @ 4th Symposium on Neural Computation and Beyond (SYNCB), Shanghai, China, *Jan. 2025*
  @ 17th Annual Meeting of the Chinese Neuroscience Society, Suzhou, China, *Sep. 2024*
- **"Quantitative relations among causality measures with applications to pulse-output nonlinear network reconstruction."**
  @ 10th International Congress on Industrial and Applied Mathematics (ICIAM2023), Waseda University, Tokyo, Japan, *Aug. 2023*
  @ 16th Annual Meeting of the Chinese Neuroscience Society & 2nd CJK International Meeting, Zhuhai, China, *Jul. 2023*
  @ 4th Chinese Computational and Cognitive Neuroscience Conference, Online, *Jun. 2022*
- **"Modeling Attentional Modulated Spike Count Correlation in Macaque V1."**
  @ 3rd Chinese Computational and Cognitive Neuroscience Conference, Online, *Jun. 2021*

RESEARCH EXPERIENCE

"Computational Mechanism of Multitasking Multi-area RNNs" **2024/06 ~ 2025/09**
Collaborator: Dr. Yuxiu Shao

- Developed an universal training pipeline for biologically constrained multi-area Recurrent Neural Networks (maRNN).
- Revealed the impact of the large-scale connectome structure and the heterogeneity of local circuits (based on macaque data) on the emerging distributed neural representation on 15 commonly studied cognitive tasks.

"How Synaptic Configuration Shapes Learning and Memory via Synaptic Plasticity" **2024/11 ~ present**
Collaborator: Dr. Yuxiu Shao, Prof. Hang Zhou

- Investigated the impact of weight initialization to the trainability and task representation in RNNs, using synaptic configurations experimentally recorded from CA1 neurons as a basis for initialization.
- Explored how synaptic configurations influence the speed and stability of Hebbian-type plasticity based learning in transfer learning scenarios.

"Neural Mechanism Underlying Context-dependent Decision-making in Dual-area Low-rank RNNs" **2023/10 ~ 2024/03**
Collaborator: Dr. Yuxiu Shao

- Developed a novel supervised-reinforcement hybrid training pipeline to train a *dual-area low-rank recurrent neural network* (DAlrRNN) to perform context-dependent decision-making tasks;

- Demonstrated the heterogeneity of neural dynamics and the emergent contextual representation in DAlrRNNs;
- Developed a set of idealized Bayesian models to characterize the subcategories in the heterogeneous dynamical motifs;

"Comparing Computational Mechanisms for Reservoir Computers and RNNs" **2022/12 ~ 2023/06**

Supervisor: Profs. Songting Li; Douglas Zhou

- Built training and analysis pipelines for Reservoir Computers (RCs) and *recurrent neural networks* (RNNs) trained on perceptual decision-making task;
- Reverse-engineered well-trained RCs and RNNs to compare population dynamics in state spaces to reveal the differences between them in aspects of their dimensionality and structure of slow neural manifold;
- Extended the training and comparison to scenarios of multitasking, and studied how multitasking shapes the dimensionality and neural manifold of RCs and RNNs.

"Causal Connectivity Measures for Pulse-output Network Reconstruction" **2021/09 ~ 2023/12**

Supervisor: Profs. Songting Li; Douglas Zhou; David McLaughlin

- Developed a theory of the mathematical relationships between four commonly used causality measures when they are applied to pulse-output signals of complex nonlinear networks.
- Developed the theoretical foundation of the quantitative relationship between causal connectivity, inferred by the causality measure, and the underlying network structural connectivity;
- Designed an algorithmic framework to reconstruct the structural connectivity of nonlinear pulse-output networks by applying commonly used causality measures;
- Verified the effectiveness of the algorithm and pipelines of reconstruction on various types of neuronal network models and Neuropixel data recorded from the mouse cortex.

"Effective Inference of Functional Connectivity from ECoG Data Using TDMI" **2021/01 ~ 2021/08**

Supervisor: Profs. Songting Li; Douglas Zhou

- Developed time-delayed mutual information (TDMI) analysis framework for analyzing neurophysiological (ECoG) data.
- Showed that a strong TDMI inferred signal is highly consistent with anatomical connectivity (structure connectivity) with a high positive prediction correct rate for ECoG data.
- Demonstrated the merit of our TDMI inference framework by comparing our inference performance based on conventional Granger causality and conditional Granger causality.
- Developed banded inference framework for ECoG data.

"Modeling Attentional Modulated Spike Count Correlation in Macaque V1" **2019/12 ~ 2020/12**

Supervisor: Profs. Profs. Songting Li; Douglas Zhou

- Built a neural rate model to simulate the effective dynamics in the delayed color-change detection tasks of macaques.
- Fitted the non-monotonic modulations for spike count correlation w.r.t. task difficulty in our model to the experimental data.
- Obtained a set of optimized parameters for the structure of the model system with the help of *mean-field theory* analysis.
- Revealed the role of specific top-down inputs towards inhibitory neurons in attentional modulation.
- Built *spiking neuronal network* (SNN) model to verify prediction got from neural rate model.

"Causal Inference of Neuronal Data Based on Time-delayed Mutual Information" **2017/07 ~ 2018/12**

Supervisor: Prof. Douglas Zhou

- Developed time-delayed mutual information (TDMI) analysis between Gaussian random variables.
- Revealed the quantitative relation between inferred causality and coupling strength between Gaussian units.
- Designed a pipeline for TDMI estimation between spike train and local field potentials (LFPs) and confirmed its feasibility on causal inference between two types of neuronal signals.
- Determined the relation between interacting strength and the value of mutual information for weakly coupled neurons.
- Revealed the different behavior of excitatory and inhibitory neurons in TDMI analysis.
- Determined the feasible network dynamical regime for TDMI analysis.

"Study of Network Dynamics Based on Integrate-and-Fire Neuron Model" **2016/02 ~ 2017/06**

Supervisor: Profs. Douglas Zhou; David Cai

- Developed C/C++ code for the simulator of leak integrate-and-fire neuronal networks based on 4th *Runge-Kutta* numerical scheme, and overcame the fire-reset discontinuity to achieve the 4th order numerical convergence.
- Simulated dynamics of 'small-world' networks with up to few thousand neurons. Investigated the behavior of network oscillations using rasters and power spectrums as a function of input Poisson parameters.

"Coherent Diffraction Imaging of Micro-Scale Samples" **2014/09 ~ 2015/06**

Supervisor: Prof. Dao Xiang

- Implemented coherent diffraction imaging (CDI) retrieval algorithm, and tested it with numerical samples;
- Designed and built the optical system for 532nm laser-based CDI. Designed samples and recorded diffraction patterns;
- Optimized the performance of the system, and retrieved the structure of samples with ~2 um spatial resolution;

"Femtosecond Pump-probe Spectroscopy (FPPS) of Protein Photosynthesis" **2016/08 ~ 2016/09**

Supervisor: Prof. Stephen Cramer (@UCDavis, CA, US)

- Built and tuned systems of non-colinear optical parametric amplifiers and FPPS for putidaredoxin studies.
- Reconstructed reaction modes based on global analysis simulations with sequential photosynthesis models.

Awards

- 2025/01 | Cosyne New Attendee Travel Grant for COSYNE 2025
- 2021/07 | Best Poster Award, The 3rd Chinese Computational and Cognitive Neuroscience Conference
- 2017/06 | Outstanding Graduates of Shanghai Jiao Tong University
- 2016/09 | *National Scholarship* for Undergraduate Students
- 2016/02 | Successful Participant in COMAP's Mathematical Contest in Modeling
- 2015/11 | Second Prize in National Mathematical Contest in Modeling
- 2015/10 | Champion in Shanghai Mathematical Contest in Modeling

- ❖ 2014/09 | *Liuyuan Scholarship* of Shanghai Jiao Tong University
- ❖ 2014/08 | Champion in Shanghai Undergraduate Physicists' Tournament

TEACHING EXPERIENCES

2024/06 ~ 2024/07	Computational and Cognitive Neuroscience Summer School (TA)	Cold Spring Harbor Asia
2022/08 ~ 2022/08	CNeuro 2022 (TA)	Beijing, China/Basel Switzerland
2022/03 ~ 2022/06	Probability and Statistics (TA)	Shanghai Jiao Tong University
2021/09 ~ 2025/01	Linear Algebra (TA) [4 times]	Shanghai Jiao Tong University
2021/07 ~ 2021/08	Neuromatch Academy - Computational Neuroscience (Lead TA)	Asia Time-slot
2021/01 ~ 2023/01	Computational Neuroscience Winter School (TA) [2 times]	Shanghai Jiao Tong University
2020/07 ~ 2020/08	Neuromatch Academy - Computational Neuroscience (TA)	Asia Time-slot
2019/09 ~ 2021/01	Advanced Topics in Computational Neuroscience (TA) [2 times]	Shanghai Jiao Tong University
2018/09 ~ 2019/06	College Physics (TA) [2 times]	Shanghai Jiao Tong University

SUMMER SCHOOL EXPERIENCES

2023/07 ~ 2023/07	Computational and Cognitive Neuroscience Summer School	Cold Spring Harbor Asia
2021/08 ~ 2021/08	CNeuro 2021	Tsinghua University, Beijing, China
2019/07 ~ 2019/07	CNeuro 2019 (Auditing student)	Tsinghua University, Beijing, China
2018/01 ~ 2025/01	Computational Neuroscience Winter School [7 times]	Shanghai Jiao Tong University

SKILLS AND SPECIALISTS

Coding:

- **Python** (efficient RNN/ANN training and data analysis, experienced user of PyTorch, Jax/Flax, scikit-learn, neurogym, etc.)
- **C/C++** (fast simulator for spiking neuronal networks)
- **Shell** (regular maintenance of high performance computing servers/clusters)
- **MATLAB/Octave** (Data analysis)
- **LaTeX**

Hobbies: Chinese Calligraphy; Chinese Flute; Weightlifting; Road Cycling; Rock Climbing.