

## EDUCATION

### SHANGHAI JIAO TONG UNIVERSITY

- ❖ **Ph.D in Applied Mathematics** 2020/09 ~ Present
- ❖ **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.

## KAI CHEN

800 Dongchuan Rd.,  
Shanghai, 200240, China  
Email: [kchen513@outlook.com](mailto:kchen513@outlook.com)  
Web: <https://neoneuron.github.io>  
ORCID: [0009-0004-3834-9504](https://orcid.org/0009-0004-3834-9504)  
(Last updated: 2025/2/13)

## 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://doc.global-sci.org/uploads/admin/article\\_pdf/20240620/8bbc1503cf83530059ad0dc8402c4be1.pdf](https://doc.global-sci.org/uploads/admin/article_pdf/20240620/8bbc1503cf83530059ad0dc8402c4be1.pdf)
- **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.” (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. “Detection and Reconstruction of Structural Connectivity Changes in Balanced Spiking Neuronal Networks.” (in preparation)
- Bo Wang, **Kai Chen**, Shouwei Luo, Yanyang Xiao, Songting Li, Douglas Zhou. “Network Reconstruction by Granger Causality for Hodgkin-Huxley Type Models.” (in preparation)

## 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)

- ❖ “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 ~ present

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* (DAIrrNN) to perform context-dependent decision-making tasks;
- ❖ Demonstrated the heterogeneity of neural dynamics and the emergent contextual representation in DAIrrNNs;
- ❖ 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. 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 4<sup>th</sup> *Runge-Kutta* numerical scheme, and overcame the fire-reset discontinuity to achieve the 4<sup>th</sup> 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 | *Liyuan 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.