ZHICHAO ZHU

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RESEARCH PROFILE

I am a researcher studying the theoretical foundations of intelligence in physical neural systems from an observer-centric perspective. My work examines how representations, decisions, and learning emerge under constraints imposed by limited observation, noise, and energy, integrating insights from neuroscience, machine learning, and statistical physics. A central focus of my research is on stochastic spiking neural networks, where correlated neural variability and low-order statistical structure define the computational interface available to the observer.

EDUCATION

Ph.D. in Applied Mathematics *Sep 2020 – Dec 2024*

Institute of Science and Technology for Brain-Inspired Intelligence (ISTBI), Fudan University
Shanghai, China
Dissertation: *On probabilistic computation in spiking neural networks: a moment-based paradigm*
Supervisor: Prof. Jianfeng Feng

M.Sc. in Computer Science with Distinction *Oct 2018 – Oct 2019*

Department of Computer Science, University of Warwick
Coventry, UK

B.Sc. in Environmental Engineering *Sep 2011 – Jul 2015*

School of Marine Science and Technology, Northwestern Polytechnical University
Xi'an, China

RESEARCH EXPERIENCE

Postdoctoral Researcher *Jan 2025 – present*
ISTBI, Fudan University, Shanghai, China

- Proposed and developed a novel Forward-Forward learning method based on effective dimensionality compression, which exploits neural variability to eliminate the need for negative sampling. (Work accepted at NeurIPS 2025, Poster).
- Lead an interdisciplinary project on computational memory prostheses, formulating neural modulation algorithms to test causal hypotheses on CA1 dynamics in spatial memory.
- Supervise one Ph.D. student in neural data analysis and modelling.

Doctoral Researcher *Sep 2020 – Dec 2024*
ISTBI, Fudan University, Shanghai, China

- Developed the Moment Neural Network (MNN) framework to elucidate the role of noise in learning and inference within spiking neural networks (published in PNAS Nexus).
- Theorized and demonstrated how noise correlations encode information and propagate to downstream neurons (published in PLOS Computational Biology), and how regulating covariance enhances decision-making efficiency (published in Neural Computation).
- Constructed a neural network model to elucidate the algorithmic mechanisms underlying the orthogonalization decomposition of cognitive states in reward and punishment processing (published in *NeuroImage*).

PUBLICATIONS

- **Zhu, Z**., Qi, Y., Ma, H., Lu, W., & Feng, J. (2025). *Stochastic Forward-Forward Learning through Representational Dimensionality Compression.* The Thirty-ninth Annual Conference on Neural Information Processing Systems.
- Qi, Y.*, **Zhu, Z.***, Wei, Y., Cao, L., Wang, Z., Zhang, J., Lu, W., & Feng, J. (2025). Learning and inference with correlated neural variability. *PNAS Nexus*, *4*(10), pgaf284. (* contributed equally)
- **Zhu, Z**., Qi, Y., Lu, W., Wang, Z., Cao, L., & Feng, J. (2025). Toward a Free-Response Paradigm of Decision Making in Spiking Neural Networks. *Neural Computation*, *37*(3), 481–521
- **Zhu, Z**., Qi, Y., Lu, W., & Feng, J. (2024). Learning to integrate parts for whole through correlated neural variability. *PLOS Computational Biology*, *20*(9), e1012401.
- Xiang, S., Jia, T., Xie, C., **Zhu, Z.,** Cheng, W., Schumann, G., Robbins, T. W., & Feng, J. (2023). Fractionation of neural reward processing into independent components by novel decoding principle. *NeuroImage*, *284*, 120463.

TECHNICAL SKILLS

- Theory & Methods: Information theory, Bayesian inference, Theoretical neural coding
- Programing & Tools: Python (Pytorch, Scipy and Scikit-learn), MATLAB
- Modelling Frameworks: Stochastic processes, Spiking neural networks, Deep learning
- Data & Statistics: Neural data processing, information-theoretic analysis, Statistical inference.