090-2341-7951
Tokyo, Japan
rogerzhangheng@gmail.com

Heng ZHANG

Postdoctoral Researcher

IRCN in UTokyo Homepage
github.com/Roger2148
linkedin.com/in/heng-zhang-9a348725a

I am a project researcher at the International Research Center for Neurointelligence (IRCN), University of Tokyo, in collaboration with KTH Royal Institute of Technology. My research develops bio-inspired AI systems for computer vision and natural language processing by drawing on principles of predictive processing and self-organization observed in biological systems. I focus on creating adaptive and robust learning frameworks that excel in dynamic, uncertain environments. My work spans unsupervised learning, dynamical systems, neural representations, and sequence learning. Through computational modeling of brain functions, particularly prediction and complex sequence processing, I aim to develop artificial intelligence that reflects the efficiency and resilience of biological cognition.

Specialties

Artificial Intelligence	Neural networks, deep learning, adaptive learning, clustering, sequential learning, computer vision, natural language processing, segmentation, representation learning, robustness assessment.
Physics	Nonlinear phenomena, complex systems, phase transition, dynamical systems
Neuroscience	Self-organization, reservoir computing, bio-inspired mechanisms, chunking.
Engineering	MATLAB, Python, PyTorch, TensorFlow, Scikit-learn, parallel computing, signal processing, data analysis.
Software Development	Unreal Engine, Blueprints scripting, VFX design, AWS, Linux, ShadowSocks protocol, Git, SVN, deploying AI models on Android mobiles.

Working Experience

Project Researcher — **April 2025 — Present**
The University of Tokyo — *Tokyo, Japan*

- Joining International Research Center for Neurointelligence (IRCN) for a collaborative initiative with KTH Royal Institute of Technology. Using computational modeling to investigate various brain functions, including prediction and complex sequence processing, aiming to develop an bio-inspired AI that more accurately resembles the human brain.

Postdoctoral Researcher — **Oct 2024 — May 2025**
Kyushu University — *Fukuoka, Japan*

- Developing robust and adaptive machines learning models. Building bio-inspired AI systems that are not vulnerable to various types of attacks such as adversarial attacks and noise corruptions.

System Engineer — **May 2024 — Present**
MiraiX.org — *Itoshima, Japan*

- 3D Open-world game developer. Machine learning engineer. UI/UX designer.

Research Assistant — **July 2022 — Sept 2024**
Kyushu University — *Fukuoka, Japan*

- Research assistant for projects in mathematics and information engineering.
- Lab assistant for stem cell culturing.

Education

Ph.D. Artificial Intelligence and Information Science — **Oct 2021 — Sept 2024**
Kyushu University — *Fukuoka, Japan*

- Thesis: *Adaptive and Robust Learning with Self-Organizing and Nonlinear Dynamics*.
- Full-granted by SPRING program from JST, one of the biggest national funding agency in Japan.

MSc. Communications and Signal Processing — **Sept 2019 — Dec 2020**
The University of Manchester — *Manchester, The UK*

- Thesis: *Data Processing and Machine Learning for Human Gait Classification.*
- Graduated with the First-Class Honors degree (Top class). Plus the Outstanding Distinction grade in master's thesis.

BEng. Electronic and Information Engineering — **Sept 2015 — July 2019**
Shenzhen University — *Shenzhen, China*

- Final project: *Lightweight Real-Time Semantic Segmentation on Android Device.*
- Top 10 GPA among 200+ students at the same grade.

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Selected Projects

Self-organizing dynamical systems for learning complex temporal structures **3 Publications, 2 Submissions, 1 Draft**

- Developed bio-inspired systems leveraging self-organization and nonlinear dynamical principles to address complex learning structures in sequential data. The proposed paradigm, termed **Self-Organizing Dynamical Equations (SODE)**, employs attractor-repeller dynamics driven by Hebbian and anti-Hebbian rules, enabling robust chunking and adaptive learning without objective functions or back-propagation. The system demonstrate stable, emergent pattern recognition and outperform state-of-the-art unsupervised machine learning algorithms in linguistic chunking and hierarchical structure learning, providing insights into how intelligent behavior emerges from simple dynamical equations.

Robust and adaptive bio-inspired AI systems for computer vision **2 Submissions**

- Cognition is increasingly understood as transformations within representational spaces by neural populations, which has been realized in sparse random networks in machine learning. Building on these foundational ideas, we extend the SODE paradigm by combining it with random network-based feature generation to transition from learning temporal patterns to spatial segmentation. This approach achieves remarkable robustness in unsupervised image segmentation tasks under severe noise and corruption without loss functions or backpropagation, far outperforming conventional AI methods. By mimicking the continuous adaptability of human vision and Gestalt principles, our framework also sets a new standard for adaptive intelligence without re-initialization.

Adaptive algorithms for real-time distribution shift **1 Submission, 1 Draft**

- Distribution shift, where the statistical properties of input data change, is a critical challenge in machine learning, contrasting with the adaptability seen in the human brain. To bridge this gap, we introduce Xenovert, an adaptive algorithm inspired by biological flexibility, designed to adjust to input distribution shifts in an online manner. Xenovert uses a perfect binary tree to divide continuous input spaces into intervals of uniform density, effectively mapping source distributions to shifted target distributions while preserving relationships with downstream operations. This eliminates the need for retraining and ensures robustness even under drastic shifts, offering a versatile solution for real-world systems requiring adaptability.

Advancing Reservoir Computing: Bio-Inspired Frameworks for Robust Neural Representation **2 Publications, 2 Draft**

- Reservoir computing (RC), a bio-inspired sparse recurrent neural networks, leverages high-dimensional representations and rich nonlinear dynamics to process complex temporal and spatial data, drawing on principles observed in neural populations. We conducted a comprehensive review of RC and interdisciplinary applications across machine learning, neuroscience, physics, biology, chemistry, etc. Recent efforts have advanced frameworks based on SODE paradigm and random networks, enabling robust classification in neural spaces and bridging neural and physical computing paradigms.

Neuro-like temporal learning systems **1 Draft**

- Developing neuro-inspired sequence learning frameworks (BCPNN-based attractor networks with modular hypercolumn architecture) to address rare-event learning in realistic temporal data streams with finite length and imbalanced event frequencies. This relates to previously studied self-organizing dynamics for unsupervised discovery of temporal chunks and hierarchical structures, and robust learning methods stable under noise and distribution shifts. We implemented learning-replay pipelines with epsilon-bounded probability learning, multi-hypercolumn support, and noise-bias analysis during recall, in collaboration with KTH Royal Institute of Technology.

Selected Publications

Research Articles Published *Google Scholar Link*

- **Heng Zhang**, and Danilo Vasconcellos Vargas. “Symmetrical SyncMap for imbalanced general chunking problems.” *Physica D: Nonlinear Phenomena*. (Top 6%/9% Journal in Mathematics/Nonlinear Dynamics), IF: 3.7. (2023).
- Mao Po Yuan, Yikfoong Tham, **Heng Zhang**, and Danilo Vasconcellos Vargas. “Magnum: Tackling high-dimensional structures with self-organization.” *Neurocomputing*. (Top 4%/7% Journal in Cognitive Neuroscience/Computer Sciecne) IF: 5.7. (2023).
- **Heng Zhang**, and Danilo Vasconcellos Vargas. “Understanding SyncMap’s Dynamics and Its Self-organization Properties: A Space-time Analysis.” *In Proceedings of the 2022 5th Artificial Intelligence and Cloud Computing Conference*, (International AI Conference) (2022).
- Osugi, Masato, **Heng Zhang**, and Danilo Vasconcellos Vargas. "Sketch Generation with Reservoir Computing trained by Evolutionary Computation." *86th National Convention of IPSJ 7: 01* (2024).
- Chao Huang, and **Heng Zhang**. “Comparison of Disturbance Rejection Performance between Three Types of UAV Linear Controllers.” *In 2020 7th International Conference on Information Science and Control Engineering (ICISCE), IEEE*, (International Conference, 2 Citations) (2020).

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Review Article

- **Heng Zhang**, and Danilo Vasconcellos Vargas. "A survey on reservoir computing and its interdisciplinary applications beyond traditional machine learning." *IEEE Access* (Top 8% Journal in General Engineering) IF: 3.5. (20+ Google Scholar Citations in one year) (2023).

Articles in Submission

- **Heng Zhang**. "RECAP: Local Hebbian Prototype Learning as a Self-Organizing Readout for Reservoir Dynamics" Under Review. Neurocomputing. (2026).
- **Heng Zhang**, Zikang Wan, and Danilo Vasconcellos Vargas. "SyncMapV2: Robust and Adaptive Unsupervised Segmentation." In Submission to IEEE Trans. Pattern Analysis and Machine Intelligence. (2026).
- Danilo Vasconcellos Vargas, Tham Yik Foong, and **Heng Zhang**. "Self-Organizing to Learn Dynamical Hierarchies." Submitted *Scientific Reports*. (2025).
- Tham Yik Foong, **Heng Zhang**, Mao Po Yuan, and Danilo Vasconcellos Vargas. "Adapting to Covariate Shift in Real-time by Encoding Trees with Motion Equations." In Submission. (2025).

Presentations

- Oral Presentation: "Bio-inspired Hybrid Predictive Model for Robust Visual Scene Understanding." Presented at International Research Center for Neurointelligence (IRCN) Retreat, Odawara, October 23, 2025.
- Oral Presentation: "Introduction to Robust and Adaptive AI Paradigm." Presented at the AI Incubator Salon Talk, International Research Center for Neurointelligence (IRCN), The University of Tokyo, Japan, October 18, 2025.
- Poster Presentation: "Spatial Relativity - Robust AI for Approximate Computing." Displayed at the Second Open Symposium on Photonic Computing, titled "Photonics for Computing & Computing for Photonics," National Institute of Information and Communications Technology (NICT), Koganei, Japan, December 17, 2024.
- Oral Presentation: "Understanding SyncMap's Dynamics and Its Self-organization Properties: A Space-time Analysis." Presented at the 2022 5th Artificial Intelligence and Cloud Computing Conference, Osaka, Japan, December 17, 2022.

External Funding Contributions

Intrinsic functionalities of biological networks with multi-reservior systems **2025 — 2026**
WPI-IRCN Retreat Brainstorming Awards, UTokyo

- Funding Amount: 800,000 JPY
- Role: Co-Investigator

Improving AI security by developing unsupervised, robust, and adaptive AI systems **2025 — 2026**
The Telecommunications Advancement Foundation

- Funding Amount: 2,105,000 JPY
- Role: Co-Investigator

Creation of photonic computing utilizing the ultimate performance of light **2022 — 2026**
JSPS, MEXT Grant-in-Aid for Transformative Research Areas (A)

- Funding Amount: 20,000,000 JPY
- Role: Research Collaborator

Small anomaly detection algorithm for autonomous driving based on Inpainting **2023 — 2025**
Leading Company

- Funding Amount: 15,000,000 JPY
- Role: Research Collaborator

Learning based on Self-Organization - Pioneering a Novel Foundation for AI **2022 — 2023**
JSPS, Grant in Aid for Challenging Research (Exploratory)

- Funding Amount: 5,000,000 JPY
- Role: Major Research Collaborator

Support for Pioneering Research Initiated by the Next Generation (SPRING) **2021 — 2024**
Japan Science and Technology Agency (JST)

- Funding Amount: 8,500,000 JPY
- Role: Highly-selected Student

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Teaching Experience

Teaching Assistant of Prompt Engineering **Apr 2024 — Sept 2024**
Kyushu University

- Assits Prof. Danilo V. Vargas to give lecture on maximizing the power Large Language Models (LLMs) in academic activities in the Undergraduate Course of IUPE Programming Methodologies and Practices.

Lecturer of Education Career Planning **Apr 2022 — Sept 2022**
New Oriental Education & Technology Group *Online*

- Teaching and sharing my experiences to undergraduate students in China who seek for further educations aboard in the fields of Information Engineering, Artificial Intelligence and related science technologies.

Languages

English	Highly proficient	Japanese	Limited Conversational
Chinese	Native	Cantonese	Native