# Kai (Karol) Yan

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## EDUCATION

**Tongji University** **Shanghai, China**
B.S. in Engineering Mechanics GPA:86.99 Expected in July 2026
**University of California, Berkeley (UC Berkeley)** **CA, USA**
Visiting Student GPA:3.7/4.0 Jan. 2025- May 2025
Main courses: Reinforcement Learning in Neuroscience, Cognitive Decision Model, Electronic Engineering.

## RESEARCH INTEREST

My research interest mainly focus on the **Neural-inspired Algorithm&Hardware**, including **Algorithms inspired by Brain mechanisms**, **self-evolving Embodied Agent** and their applications on **Neuromorphic Devices** (**In-memory Computing Architecture** and **Edge Computing Wearable Devices**) .

## PUBLICATION

1. (Under Review) **Kai Yan**, Yanbing Jia, Huaguang Gu*, Complex dynamics related seizure in network composed of excitatory and inhibitory neurons modulated by inhibitory autapse, *Nonlinear Dynamics*
2. (In preparation for CVPR 2026) **Kai Yan**, Kaicheng Yu* Reinforcement Learning Enhanced Cognitive Self-Corrected Agent for Autonomous Driving.

## RESEARCH EXPERIENCE

**Neuromorphic Computing Co-design System based on Ferroelectricity 2D $Ga_2O_3$** **Hangzhou, China**
Research Assistant | Prof. Wei Kong at Westlake University Sep. 2025-Present

- **G**rew and exfoliated homoepitaxial β -$Ga_2O_3$films from single-crystal substrates using a Plasma-Assisted Molecular Beam Epitaxy (PAMBE) system, with real-time thickness growth monitored by Reflection High-Energy Electron Diffraction (RHEED). Successfully activated the film's ferroelectricity by depositing a metallic stressor layer.
- Utilized 2D $Ga_2O_3$ as a middle layer to prepare film memristors and developed a Verilog-A behavioral model for circuit simulation based on measured device metrics, including a decay factor of 0.039, a homogeneity larger than 90%, and a switch voltage of 0.8V.
- Designed and laid out a 1T1R memristor crossbar array using L-edit. Performed simulations to verify that the circuit design effectively mitigates sneak path and leakage currents. Deployed a MINIST hand-written number recognition task on simulation model to validate the design's effectiveness.

**Self-Evolving Autonomous Driving Framework** **Hangzhou, China**
Research Assistant | Prof. Kaicheng Yu at Westlake University July. 2025-October. 2025

- Designed a self-evolving framework where VLMs/LLMs work as a cognitive-motivated PMAgent to guide diffusion models to generate synthetic data based on ground truth boxes updated by reverse gradient descent. Implemented it to tasks such as Autonomous Driving or Open Vocabulary Detecting.
- Based on the native structure of E2E models' loss function, designed structural backpropagation flow to updated the GT. Set up a multi-round loop to let the system correct itself till the failure rate converge.
- Mixed synthetic data and original data to form a mixed dataset. Fine-tuned the E2E model with it via Full Parameters Fine-tuning. Improved the performance on failure cases by 62.5% after 3 rounds. Based on the native structure of E2E models' loss function, designed structural backpropagation flow to updated the GT. Set up a multi-round loop to let the system correct itself till the failure rate converge.
- Utilized high performance computing clusters such as H800. Got familiar with Docker building and server management.

**Non-invasive EEG Pattern Recognition and Classification by RNN** **CA, USA**

Research Assistant | Prof. Lexin Li at UC Berkeley Feb. 2025-July.2025

- Designed a Class-specific RNN from scratch, which assigns a next-step predicting RNN for 6 seizure types annotated in TUH EEG dataset and compare their reconstructing MSE to classify samples.
- Compared the Class-specific RNN with Vanilla RNN baseline on the same multi-classification task. Achieved 100% on all metrics while Vanilla RNN only gets all metrics around 70%.
- Utilized statistic methods such as PCA and t-SNE to analyze hidden state dynamics. Proved that predictors learned unique hidden dynamics by calculating their t-SNE similarity to be larger than 1.4.
- Planning to apply the classification method to EEG-Language Recovery, which can align the tokens with specific EEG patterns, and thus recover the semantic meaning of sentences from EEG data.

**Gain-Shift RSNN with Neural Inspired Feedback Control** **CA, USA**

Research Assistant | Prof. Kristofer Bouchard at UC Berkeley Jan.2025-July.2025

- Set up a standard platform codebase with in 2 weeks to run function approximation experiments and analyze results autonomously. Analyze more than 10 models hierarchically with ablation study.
- Inspired by FORCE algorithm, designed a Gain&Shift modulated Recurrent SNN with snnTorch package. Extended SNN type to both Spike-rate SNN and Membrane-potential SNN. Realized different parameter initialization strategies to learn the properties under various situation. Applied STDP & Hebbian Learning Rules to modulate the output weight to simulate biological-plausible behavior.
- Replacing standard stochastic gradient descent (SGD) with a linear-quadratic regulator (LQR) as a controller for parameter training; Imposing Dale's law on the network architecture and implemented this approach in both conventional RNNs trained with SGD and in the gain/shift-based Recurrent SNNs.

**Realization of Logic-operating Circuits based on Ion-Fluidic Memristor** **Shenzhen, China**

Research Assistant | Prof. Alessandro Siria at ENS Paris & TsingHua X Institute Aug. 2024-Sept. 2024

- Performed circuit simulation using Multisim to design NAND gates and conducting patch clamp experiments to validate ion-fluidic memristor behavior within nanoscale fluidic tubes, and adjusted the solution concentration to optimize the memristor's On/Off ratio to meet the performance requirements.
- Designed lithographic mask layouts with L-Edit and integrated fluidic memristors on silicon wafers and PDMS substrates, and validated the nanoscale ion-fluidic memristor effect.
- Conducted COMSOL simulations to reveal nonlinear ion migration dynamics governed by Poisson–Nernst–Planck (PNP), and demonstrated that surface charge density modulation ($\sigma$ = -0.02 to +0.05 C/m$^2$) significantly influences ion migration barriers.

**The Complex Dynamics of Seizure Modulated By Inhibitory Autapses** **Shanghai, China**

Research Assistant | Prof. Huaguang Gu at Tongji University Apr. 2023-Dec. 2024

- Developed a fast-spiking synchronous neural network in C++ with featuring excitatory and inhibitory neurons with inhibitory autapses. Utilized grid parameter searching to fine the key parameter range for epileptiform pattern, including gamma oscillations and interictal spike-wave complexes.
- Utilized OriginLab and MATLAB to plot figures to display the attractors on the parameter planes. Applied the Kuromoto-R1 index and firing rate to quantify the seizure extent of networks. Reduced the network synchronism from 0.99 to 0.2 and the Firing rate from 1 to 0 by autapses' modulation.
- Established evidence for dual-regime autaptic modulation according to bifurcation theory, identified the ($g_{syn}$, $\beta$) parameter plane boundaries through the simulation data, and demonstrated how autapses paradoxically increase firing through delayed negative feedback phase locking.

## PROJECT

**NeuroMatch: Predictive Coding Algorithm** **Remote**

Project Member | Prof. Shaonan Wang at Chinese Academy of Sciences July 2024

- Designed and conducted experiments to evaluate the performance of predictive coding vs. backpropagation (BP) algorithms on weight update trajectories and goal alignment, including metrics such as weight learning trajectory, output learning trajectory, goal alignment measures, and gradient variance analysis.
- Performed a comparative analysis of predictive coding's robustness in gradient consistency, adversarial resistance, continual learning, and concept drift.
- Proposed a novel cosine similarity index to quantify trajectory alignment, showing that the alignment between PC and STDP rules on the CIFAR-10 dataset was 32% higher than with BP.
- Quantified the stability of the PC algorithm's parameter update direction in deep neural networks (variance reduced to 28% of BP), providing future research directions for more different types of neural network such as CNN or GNN.

**SNN-RL Autonomous Driving System Based on Neuromorphic Computing** **Shanghai, China**
Team Leader | Prof. Peng Yi at Tongji University Mar. 2024-Apr. 2025

- Performed an in-depth review of 30+ papers spanning neuromorphic computing, spiking neural networks (SNNs), and event-based sensing, and reproduced key methodologies from a *Nature* publication on reducing event camera latency via Linux-based virtual environment
- Developed a STCNN-SNN-Transformer algorithm to address the energy-accuracy-latency trilemma, where low-frequent ST-CNN can extract spatiotemporal features from RGB inputs and event-driven dual-path SNN can achieve 12ms dynamic detection at 0.8mJ/inference
- Constructed comprehensive simulation environments in UE 4 and Microsoft AirSim, covering 50+ edge cases (adverse weather, sensor failures), and optimized SNN layers for compatibility with Synsense Tech's Xylo neuromorphic chip.

## SKILLS

**Programming**: C/C++, Python, MySQL, MATLAB, PyTorch, Docker, Bash, Git, Pandas, TensorFlow
**Software**: OriginLab, Markdown & LaTeX, Zotero, Verilog-A, L-edit, Multisim