Yi Ren
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Education

University of Science and Technology of China (USTC) Sep. 2019 – Jun. 2023
Master of Science in Computational Neuroscience (GPA: 3.24/4) *Hefei, China*

Lanzhou University Sep. 2015 – Jun. 2019
Bachelor of Science in Biology (GPA: 4.32/5.0, Rank: 12/360) *Lanzhou, China*

Research Interest

Mathmatical Princple of Machine Learning, Computational Neuroscience, The Intersection of AI and Neuroscience, AI for Scienceords

Research Experience

Image registering based on Implicit Neural Representation Jun. 2023 - Present
Research Assistant | Advisor: Prof. Jizhou Li, City University of Hong Kong *Shenzhen, China*

In this work, we developed a deep learning approach to address image registration and video stabilization issues. Instead of using a neural network to predict end-to-end transformations between images, we optimized a neural network to represent this continuous transformation, which is referred to as an Implicit Neural Representation (INR). Furthermore, we implemented optimizations for handling large image data. We constructed a Laplacian pyramid representation at different scales using a small MLP, facilitating registration from coarse to fine. Within each scale, we divided images into smaller patches with overlapping regions to accommodate the processing requirements of very large images. Here is my contribution:

- Developed a light and fast image registering method based on Implicit Neural Representation.
- Registered images using differentiable deformation vector fields represented in multilayer perceptrons.
- Used continuous complex Gabor wavelet as the activation function.
- Applied a pyramid strategy that processes images sequentially from low to high resolution, gradually increasing the resolution.

Reverberation, a model of mnemonic persistent activity Jun. 2020 – Nov. 2022
Research Assistant | Advisor: Prof. Guoqiang Bi and Prof. Yanyang Xiao, USTC *Hefei, China*

Hebb's theory suggests that persistent reverberatory activities in the brain may be responsible for information retention. In this study, we used a simplified cultured hippocampus system to circumvent the immense complexity of in vivo circuits. We observed rhythmic reverberatory activity with consistent spatiotemporal patterns in such networks when triggered by a single stimulus. These dynamics and network mechanisms, however, have remained elusive. In our research, we investigate these phenomena using a biologically accurate Spike Neural Network (SNN) model. Our findings indicate that the sequence of spikes is primarily influenced by the receiving weight of each neuron. Additionally, we explore the role of the STDP rule in this system and its potential for training the network to achieve a desired firing sequence. Here is my contribution:

- Investigated the formation of reverberation activity and found out the reason of neuron spike in certain spatiotemporal pattern in reverberation activity.
- Discussed the effect of STDP rule in this system, and the possibility of utilizing the effect to train the network to generate desired firing order.
- Cultured hippocampal neurons in small island using microfabricated polydimethylsiloxane (PDMS) devices.
- Gathered neuron activity by applying electrophysiological record and calcium imaging.
- Performed numerical simulation to investigate the reverberation dynamic characteristics.

Backdoor attack in frequency domain Jun. 2022 – Oct. 2022
Research Assistant | Individual research, USTC *Hefei, China*

Backdoor attacks have been proven to pose a serious threat to deep learning systems, such as biometric authentication and autonomous driving. Effective backdoor attacks can force the model to misbehave under certain predefined conditions (i.e., triggers). However, the triggers of existing attacks are directly injected into the pixel space and can be detected by current defense mechanisms during both training and inference stages. In this paper, inspired by the characteristics of human vision, we have designed a pipeline that introduces triggers in the frequency domain. Disturbances in the frequency domain correspond to small pixel disturbances scattered

throughout the image, breaking the fundamental assumptions of existing defenses and making poisoned images visually indistinguishable from clean ones. When a deep learning model is trained using tainted data and the trigger is present, it exhibits erroneous behavior, such as misclassifying the test input to a predetermined label. Yet, in the absence of the trigger, the model operates as expected during inference. This work will soon be uploaded to arXiv.

- Designed a pipeline that inject trigger in frequency domain which was inspired by the properties of human vision.
- Found out that deep learning models trained with poisoned data would misbehave when the trigger was presented but behaved normally otherwise at inference time.

Biphasic cholinergic modulation of reverberatory activity Dec. 2020 – Jul. 2022
Research Assistant | Advisor: Prof. Guoqiang Bi and Prof. Yanyang Xiao, USTC *Hefei, China*

Acetylcholine (ACh) is an important neuromodulator in various cognitive functions. However, it is unclear how ACh influences neural circuit dynamics by altering cellular properties. Here, we investigated how ACh influences reverberatory activity in cultured neuronal networks. We found that ACh suppressed the occurrence of evoked reverberation at low to moderate doses, but to a much lesser extent at high doses. Moreover, high doses of ACh caused a longer duration of evoked reverberation, and a higher occurrence of spontaneous activity. With whole-cell recording from single neurons, we found that ACh inhibited excitatory postsynaptic currents (EPSCs) while elevating neuronal firing in a dose-dependent manner. Furthermore, all ACh-induced cellular and network changes were blocked by muscarinic, but not nicotinic receptor antagonists. With computational modeling, we found that simulated changes in EPSCs and the excitability of single cells mimicking the effects of ACh indeed modulated the evoked network reverberation similar to experimental observations. Thus, ACh modulates network dynamics in a biphasic fashion, probably by inhibiting excitatory synaptic transmission and facilitating neuronal excitability through muscarinic signaling pathways. Here is my contribution:

- Investigated how Ach modulates network activity dynamic by infecting neuron ion channels.
- Used electrophysiological record and found that Acetylcholine (ACh) suppresses the occurrence of evoked reverberation at low to moderate doses, but to a much less extent at high doses.
- Used numerical simulation to investigate how Ach effects the reverberation activity.

Quantifying c-Fos positive cells in the whole brain Dec. 2020 – Jul. 2022
Research Assistant | Advisor: Prof. Guoqiang Bi, USTC *Hefei, China*

In this project, I developed an analytical software based on deep learning to quantitatively measure the expression levels of c-Fos in different brain regions. It is designed to analyze the activity of brain regions in animals under various behavioral conditions. The software employs a 3D U-net and random forest model to segment and locate target neurons, and it automatically matches the identified signal's location to its respective brain region based on the location coordinates. Here is my contribution:

- Developed a software to analyze c-Foc distribution among all the brain regions from 3D light sheet microscope image.
- Applied 3D U-net and random forest models to perform the segmentation and locate target neurons.
- Implemented a GUI for the software.

Research on brain blood vessel segmentation Jul. 2018 – Dec.2018
Research Assistant | Advisor: Prof. Guoqiang Bi, USTC *Hefei, China*

In this project, we labeled brain tissue with FITC-conjugated lectin. Following this, we processed the brain tissue using whole-brain transparency techniques, resulting in a transparent brain tissue. Subsequently, we used a light-sheet microscope to capture high-resolution fluorescence images of the entire brain. Based on this, we utilized the Res-Dense network to segment the vessels marked with fluorescence, and analyzed the topological properties of the segmentation results. Here is my contribution:

- Studied the structure and topology of mice whole brain vessel.
- Labeled tissue with FITC-Lectin, and treated tissue with tissue clearing techniques.
- Collected brain-wide high-quality microscopic image using light-sheet microscopy.
- Used Res-50 net to do segmentation, and applied some image augmentation and self-supervision methods.

Publications

- Li, X.W., **Ren, Y.**, Shi, D.Q., Qi, L., Xu, F., Xiao, Y., Lau, P.M. and Bi, G.Q., 2023. Biphasic Cholinergic Modulation of Reverberatory Activity in Neuronal Networks, *Neuroscience Bulletin*, pp.1-14.
- **Ren Y.**, Li X.W., Xiao Y., Lau P.M., Bi G.Q., Reverberation, a model of mnemonic persistent activity, Manuscript in Preparation.
- **Ren Y.**, Li J., Gaussian pyramid WIRE, Manuscript in Preparation.

Honors and Awards

- Master scholarship in USTC 2019-2022
- Bronze-prize in International Genetically Engineered Machine Competition (iGEM) 2017
- College scholarship in Lanzhou university (4%) 2017
- Excellent student cadre in Lanzhou university 2016

Skills

Programming: Python, MATLAB, Pytorch, Tensorflow.
Techniques: machine learning, deep learning, Kubernetes, numerical simulation, biological experiments, animal surgery, biological data processing.