ISTBI

INSTIUTE OF
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FOR BRAIN-INSPIRED

INTELLIGENCE

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NEWSLETTER CONTENTS

Research Highlights

Cortical-Subcortical Morphometric Dissimilarity Related to Preadolescent Cognitive and Psychiatric Status

Adolescence is a critical period characterized by dramatic morphological changes and accelerated cortico-subcortical development. Moreover, the coordinated development of cortical and subcortical regions underlies the emerging cognitive functions during this period. Deviations in this maturational coordination may underlie various psychiatric disorders that begin during preadolescence, but to date these deviations remain largely uncharted.
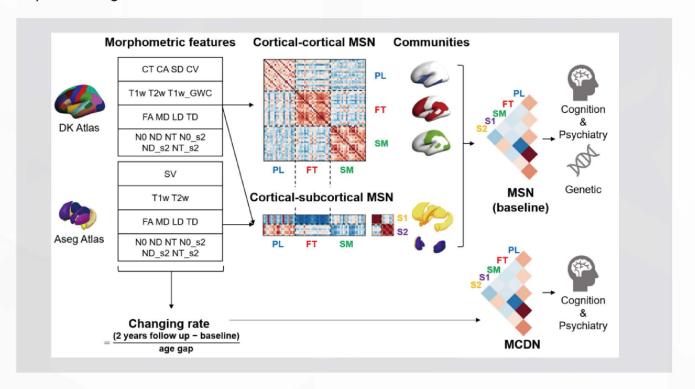
Prof. Jie Zhang at ISTBI worked with researchers from McGill University, University of Cambridge and East China Normal University to construct a comprehensive whole-brain morphometric similarity network (MSN) from 17 neuroimaging modalities in a large preadolescence sample (N=8,908) from Adolescent Brain Cognitive Development (ABCD) study and investigate its association with 10 cognitive subscales and 27 psychiatric subscales or diagnoses. Based on the MSNs, each brain was clustered into five modules with distinct cytoarchitecture and evolutionary relevance. While morphometric correlation was positive within modules, it was negative between modules, especially between isocortical and paralimbic/subcortical modules; this developmental dissimilarity was genetically linked to synaptic function and neurogenesis. The cortico-subcortical dissimilarity becomes more pronounced longitudinally in healthy children, reflecting developmental differentiation of segregated cytoarchitectonic areas. Higher cortico-subcortical dissimilarity (between the isocortical and paralimbic/subcortical modules) were related to better cognitive performance.

In comparison, children with poor modular differentiation between cortex and subcortex displayed higher burden of externalizing and internalizing symptoms. These results highlighted cortical-subcortical morphometric dissimilarity as a dynamic maturational marker of cognitive and psychiatric status during the preadolescent stage and provided insights into brain development.

The result was published in Molecular Psychiatry on 6 December 2022.

[About the Authors]

👨‍🔬 Prof. Jie Zhang

Prof. Jie Zhang is Research Professor at the ISTBI. The main research directions of Prof. Zhang are brain function network and computational neuroimaging. In 2007, he obtained a doctorate degree from the Hong Kong Polytechnic University. He won the "Hong Kong Young Scientist Award" nomination award.He is an honorary member of the "Systematic Modeling Analysis and Prediction" Laboratory at Oxford University. More than 60 SCI papers were published, and two were selected as top-1% global ESI papers. Published journals include PNAS, Brain, Cerebral Cortex and so on, cited more than 2,100 times. Among them, the work on the dynamic brain function network published by Brain in 2016 was selected as the cover article. Prof. Bassett, the 2014 MacArthur Prize winner, wrote a commentary for Brain for this work.

Research Highlights

A Multi-task Learning Framework and a New Benchmark for Age-Invariant Face Recognition and Synthesis

Face recognition has been a hot research topic in computer vision for many years. Despite the remarkable success of general face recognition (GFR), how to minimize the impact of age variation is a lingering challenge for current face recognition systems in correctly identifying faces in many practical applications such as tracing long-missing children. Therefore, it is of great significance to achieve face recognition without age variation, i.e., age-invariant face recognition or AIFR. AIFR, however, remains extremely challenging in the following three aspects.

First, when the age gap becomes large in cross-age face recognition, age variation can dominate the facial appearance, which then significantly compromises the face recognition performance. Second, face age synthesis (FAS) is a complex process involving face aging/rejuvenation (a.k.a age progression/regression) since the facial appearance changes dramatically over a long time and differs from person to person. Last, it is infeasible to obtain a large-scale paired face dataset for training a model to render faces with natural effects while preserving identities.

In a paper published in IEEE Transactions on Pattern Analysis and Machine Intelligence, Dr. Hongming Shan at ISTBI and Prof. Junping Zhang at School of Computer Science propose a unified, multi-task learning framework to simultaneously achieve AIFR and FAS, termed MTLFace, which can enjoy the best of both worlds; i.e., learning age-invariant identity-related representations while achieving pleasing face synthesis. More specifically, the researchers propose an attention-based feature decomposition to decompose the mixed high-level features into two uncorrelated components—identity- and age-related features—in a spatially constrained way. they then decorrelate these two components in a multi-task learning framework, in which an age estimation task is to extract age-related features while a face recognition task is to extract identity-related features; in addition, a continuous cross-age discriminator with a gradient reversal layer further encourages extracting identity-related age-invariant features. Moreover, they propose an identity conditional module to achieve identity-level transformation patterns for FAS, with a weight-sharing strategy to improve the age smoothness of the synthesized faces; i.e., the faces are aged smoothly.

Extensive experimental results demonstrate the superior performance of the proposed MTLFace over existing state-of-the-art methods for AIFR and FAS, and competitive performance for general face recognition in the wild.
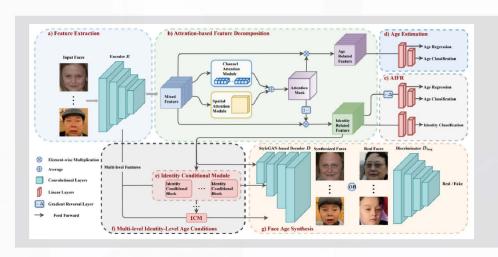

Fig. 1
An overview of the proposed MTLFace

Deep clustering aims to learn the representation of images and perform clustering in an end-to-end fashion. Existing deep clustering methods heavily rely on contrastive representation learning. Although achieving promising results, contrastive-based methods usually require a large number of negative examples to learn uniform representations. The involved negative pairs may inevitably lead to the class collision issue. An alternative perspective is to separate the typical contrastive loss into two terms: 1) alignment term to improve the closeness of positive pairs, and 2) uniformity term to encourage instances to be uniformly distributed on a unit hypersphere by pushing away the negative pairs. Apparently, the uniformity term could introduce class collision issue. Different from contrastive learning, non-contrastive learning only involves the alignment term using the representations of one augmented view to predict another. The non-contrastive learning can avoid the class collision issue as there are no negative pairs. Lacking the uniformity term in contrastive loss, it is not guaranteed to learn uniform representations.
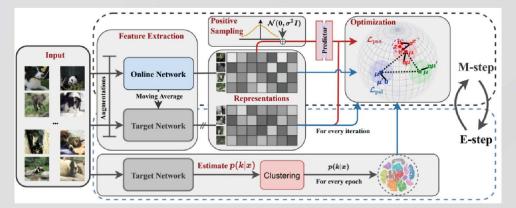

Fig. 2
The overall framework of the proposed ProPos in an EM framework

Research Highlights

» Full Article:
Z. Huang, J. Chen, J. Zhang and H. Shan, "Learning Representation for Clustering Via Prototype Scattering and Positive Sampling," in IEEE Transactions on Pattern Analysis and Machine Intelligence, 2022, doi: 10.1109/TPAMI.2022.3216454.

[About the Authors]

🧑‍🔬 Dr. Hongming Shan

Dr. Hongming Shan is a Young Principal Investigator at the Institute of Science and Technology for Brain-inspired Intelligence, Fudan University; "Qiusuo" Research Leader at the Shanghai Center for Brain Science and Brain-inspired Technology; IEEE Senior Member. Before joining Fudan University, he worked with Prof. Ge Wang at the Biomedical Imaging Center, Center for Biotechnology and Interdisciplinary Studies, Rensselaer Polytechnic Institute. He received his Ph.D. in machine learning from Fudan University in 2017. He has published research papers in top journals including Nature Machine Intelligence, IEEE Transactions on Pattern Analysis and Machine Intelligence, IEEE Transactions on Cybernetics, IEEE Transactions on Medical Imaging. His research interests include machine learning, medical imaging, and computer vision. He was recognized with Youth Outstanding Paper Award at World Artificial Intelligence Conference 2021.
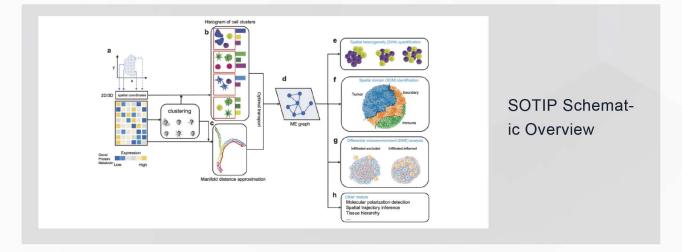
🔬 New Method for Microenvironment Modelling with Spatial Omics Data

The rapidly developing spatial omics techniques generate datasets with diverse scales and modalities. However, most existing methods focus on modeling dynamics of single cells while ignore microenvironments (MEs) which bridge single cells to tissues. In a study published in Nature Communications on 28 November 2022, Dr Zhiyuan Yuan and his research team present SOTIP (Spatial Omics mulTIPle-task analysis), a versatile method incorporating MEs and their interrelationships into a unified graph.

Based on this graph, multiple tasks can be performed, including three main tasks, i.e., spatial heterogeneity (SHN) quantification, spatial domain (SDM) identification and differential microenvironment (DME) analysis, and other downstream tasks, i.e., molecular polarization detection, spatial trajectory inference and tissue hierarchy construction. The researchers validate SOTIP's accuracy, robustness, and interpretability compared with state-of-the-art methods on various spatial omics datasets with positive controls. For the scalability, they validate SOTIP's compatibility on most spatial omics data modalities, including two recently published 3D spatial omics datasets. For the new task of DME analysis, they validate SOTIP by correctly identifying fibrotic liver-specific microenvironment on a spatial metabolomics dataset. Apart from these validations, they apply SOTIP on a range of cases to reveal novel biological and clinical discoveries.

In two independent mouse cerebral cortex datasets, they reveal a striking gradient SHN pattern with strong correlations with the cortical depth. In human triple-negative breast cancer (TNBC), they identify previously unreported molecular polarizations around SOTIP-detected tumor-immune boundaries. In clinical cases, they discover MKT (a microenvironment dominated by 3 cell types, i.e., Macrophage, Keratin+ tumor, and CD8 T cell), a type of TNBC subtype-specific microenvironment, which exhibits interesting compositional and spatial features, and could not be identified by existing methods. The researchers analyze the relevance between MKT and prognosis, and find that patients with lower occurrence of MKT is associated with increased survival, which could be a powerful clinical indicator only requiring measurement of 3 cell types. Overall, by modeling biologically explainable microenvironments, SOTIP outperforms state-of-art methods and provides new perspectives for data interpretation and exploration, which facilitates further understanding of spatial information on a variety of biological applications.

SOTIP Schematic Overview

Research Highlights

» Full Article:
Yuan, Z., Li, Y., Shi, M. et al. SOTIP is a versatile method for microenvironment modeling with spatial omics data. Nat Commun 13, 7330 (2022). https://doi.org/10.1038/s41467-022-34867-5

[About the Authors]

Dr. Zhiyuan Yuan

Zhiyuan Yuan received his Ph.D. from Tsinghua University in June 2022, under the supervision of Prof. Michael Q. Zhang. In September 2022, he joined the Institute of Brain-Inspired Intelligence Science and Technology, Fudan University as a young research associate. Yuan's research focused on bioinformatics, especially the development of spatial omics computational methods. The main theories involved include deep learning, probabilistic graphical models, and optimal transport; application scenarios include the construction of large-scale brain spatiotemporal atlas, and spatiotemporal modeling of brain diseases and tumor microenvironments.
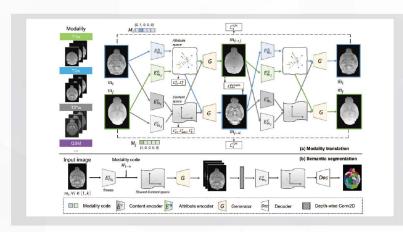
Mouse Brain MRI Synthesis and Structural Segmentation

Recently, research teams led by Dr. Xiao-Yong Zhang at ISTBI and Dr. Tingying Peng at Helmholtz AI developed an deep learning-based framework, MouseGAN++, for simultaneous image synthesis and segmentation for mouse brain MRI. Based on a disentangled representation of content and style attributes strengthened by contrastive learning, MouseGAN++ is able to synthesize multiple MR modalities from single ones in a structure-preserving manner and can hence handle cases with missing modalities. Furthermore, it uses the learned modality-invariant information to improve structural segmentation. The study was published in IEEE Transactions on Medical Imaging on November 30, 2022.

The multi-modality structure images of the mouse brain were acquired with a 11.7T MR scanner at Zhangjiang Imaging BrainBank, Fudan University, including T2w imaging, T1w imaging, T2*w imaging, quantitative susceptibility mapping (QSM), and Magnitude MR images (Mag). This dataset covered 75 mouse brains with 56,970 MR slices.

A novel synthesis-and-segmentation model, MouseGAN++, comprising modality translation module based on feature disentanglement and contrastive learning to synthesize all modalities, and semantic segmentation module to get fine brain structures.
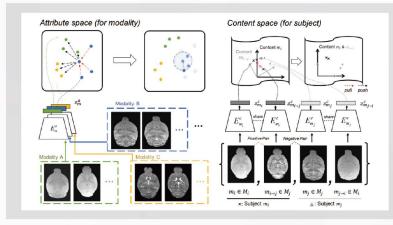

Schematic of MouseGAN++.

Illustration of the attribute discrimination (left) and content discrimination (right) achieved by contrastive learning.

	T1w → T2w				
Method	PSNR ↑	SSIM ↑	MS-SSIM ↑	VIF ↑	LPIPS ↓
CycleGAN	20.51±1.36	0.685±0.021	0.726±0.046	0.178±0.010	0.239±0.012
SynSeg	20.10±1.32	0.677±0.035	0.725±0.036	0.182±0.013	0.252±0.015
UNIT	19.98±1.32	0.579±0.075	0.727±0.039	0.145±0.018	0.240±0.012
MUNIT	20.88±1.21	0.602±0.085	0.751±0.039	0.160±0.017	0.202±0.018
StarGAN-v2	21.13±1.68	0.677±0.071	0.717±0.026	0.126±0.021	0.212±0.014
MouseGAN	20.46±1.13	0.693±0.036	0.775±0.033	0.197±0.015	0.186±0.014
MouseGAN++	22.72±1.02	0.716±0.031	0.796±0.029	0.215±0.017	0.173±0.010
	T2w → T1w				
Method	PSNR ↑	SSIM ↑	MS-SSIM ↑	VIF ↑	LPIPS ↓
CycleGAN	25.61±1.38	0.813±0.018	0.842±0.032	0.256±0.013	0.248±0.021
SynSeg	23.39±1.54	0.789±0.024	0.809±0.028	0.241±0.016	0.246±0.018
UNIT	25.17±2.02	0.754±0.059	0.871±0.019	0.261±0.020	0.178±0.014
MUNIT	24.39±1.83	0.740±0.070	0.871±0.015	0.231±0.028	0.177±0.015
StarGAN-v2	23.05±1.47	0.810±0.028	0.836±0.044	0.179±0.050	0.188±0.017
MouseGAN	24.39±1.53	0.820±0.023	0.873±0.016	0.304±0.033	0.169±0.011
MouseGAN++	26.70±1.30	0.841±0.019	0.899±0.013	0.349±0.025	0.151±0.012

Translation performance comparison with different methods from T1w to T2w and vice versa

Research Highlights

In the above Table, for two-direction translations, MouseGAN++ surpasses other methods in terms of all five metrics that are used to measure image synthesis quality. More specifically, for the translation from T1w to T2w, MouseGAN++ achieves the best performance with the highest SSIM of 0.716 and the lowest LPIPS of 0.173. Besides, MouseGAN++ produces sharper and more realistic textures, with the content better aligned with anatomy than other methods.

Comparison of segmentation performance of different methods on T1w and T2w using multi-modality dataset.

The quantitative results of brain structural segmentation on T1w and T2w, the two most important MR modalities used in mouse brain studies, are summarized in the following Table. In both modalities, MouseGAN++ consistently surpasses comparison methods, demonstrating the effectiveness of our proposed framework.

Our results demonstrate that MouseGAN++ achieves significant performance improvement over both translation and segmentation tasks and has the potential to be applied in more neuroimaging applications. We release our method as a packaged tool for free academic usage at https://github.com/yu02019.

» Full Article:
Z. Yu, X. Han, S. Zhang, J. Feng, T. Peng and X. -Y. Zhang, "MouseGAN++: Unsupervised Disentanglement and Contrastive Representation for Multiple MRI Modalities Synthesis and Structural Segmentation of Mouse Brain," in IEEE Transactions on Medical Imaging, doi: 10.1109/TMI.2022.3225528.

[About the Authors]

🕵 Dr. Xiao-Yong Zhang

Xiao-Yong Zhang is an Associate Professor at the Institute of Science and Technology for Brain-Inspired (ISTBI), Fudan University. His research interest mainly focuses on magnetic resonance imaging of the brain, artificial intelligence analysis and molecular imaging. He has made several original contributions in the field of magnetic resonance metabolic imaging technology. At present (2022.12), he has published more than 50 papers, including more than 30 papers as the corresponding author or the first author. His representative papers have been published in "Advanced Science", "IEEE Transactions on Medical Imaging", "JBHI", and "Cancer Research". Dr. Zhang has been awarded several grants, including 2 National Natural Science Foundation of China projects and 2 Shanghai Science Foundation projects.

🔬 *A Spatial Omics Database and a Fast Data Loading Method*

Cell fate is jointly determined by the intracellular molecular regulatory network and the extracellular microenvironment. Single-cell omics technology can measure molecular expression profiles in cells, but loses spatial location information. In recent years, the rapid development of spatial omics technologies has enabled researchers to obtain the spatial information in addition to measuring rich molecular expression profiles.

Mainstream spatial omics technologies include spatial transcriptomics, spatial proteomics, spatial metabolomics, etc. With the development of these technologies, a large amount of spatial omics data is rapidly generated and maintained in various heterogeneous data platforms. Before specific data analysis, researchers must first download the raw data and then process it correctly into a standard format, which is usually time-consuming and laborious. Another problem is the amount of data, because some advanced experimental techniques currently provide large fields of view and high spatial resolution (such as Stereo-seq, MERFISH, etc.), processing these data requires a lot of memory and time consumption.

Research Highlights

The latest research of Zhiyuan Yuan from the ISTBI of Fudan University, Professor Michael Q. Zhang from the University of Texas at Dallas, and Dr. Jianhua Yao from Tencent AI Lab have given a solution to support users to quickly browse, visualize, and load the spatial data of interest. The relevant research were recently published in Nature Methods entitled "SODB facilitates comprehensive exploration of spatial omics data".

SODB provides data from 26 spatial omics technologies, with a data volume of more than 50 million cells (spots). All data are processed into Anndata format by standard procedures, and are compatible with various analysis software such as SCANPY and Squidpy. SODB also provides a variety of data analysis and visualization modules, including gene spatial expression, cell type annotation, gene expression comparison, SOView visualization analysis, etc. (Figure 1). In addition, the supporting Python toolkit pysodb is also provided, which can easily read data with only one line of code. Compared with traditional data processing and loading methods, it brings improved time efficiency and memory efficiency. Taking Slide-seq data as an example, the time efficiency is increased by 160 times (the traditional method takes 19.04 minutes to read, and pysodb only needs 7.16 seconds); the memory efficiency is increased by 549 times (the traditional method requires 21.97GB, and pysodb only needs 0.04GB peak memory).
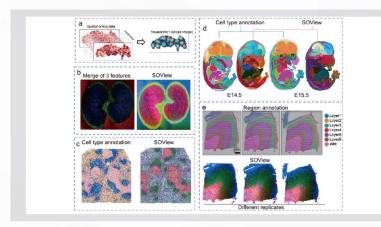
Figure 1. SOView visualization module

Currently, SODB is open to everyone, and the data can be accessed through the website [https://gene.ai.tencent.com/SpatialOmics/] or the Python package [https://github.com/TencentAILabHealthcare/pysodb].

The co-corresponding authors of this project are Zhiyuan Yuan (and the first author)

of ISTBI of Fudan University, Dr. Jianhua Yao of Tencent AI Lab, and Professor Michael Q. Zhang of the University of Texas at Dallas. The co-first author is Wentao Pan of Tsinghua University. Professor YiZhao from the Institute of Computing Technology, Chinese Academy of Sciences, Professor Xiu Li from Tsinghua University, Xuan Zhao and Zhimeng Xu of Tencent AI Lab, and other collaborators have made significant contributions to this project.

» Full Article:
Yuan, Z., Pan, W., Zhao, X. et al. SODB facilitates comprehensive exploration of spatial omics data. Nat Methods 20, 387–399 (2023). https://-doi.org/10.1038/s41592-023-01773-7

[About the Authors]

🧑‍🔬 Dr. Zhiyuan Yuan

Zhiyuan Yuan received his Ph.D. from Tsinghua University in June 2022, under the supervision of Prof. Michael Q. Zhang. In September 2022, he joined the Institute of Brain-Inspired Intelligence Science and Technology, Fudan University as a young research associate. Yuan's research focused on bioinformatics, especially the development of spatial omics computational methods. The main theories involved include deep learning, probabilistic graphical models, and optimal transport; application scenarios include the construction of large-scale brain spatiotemporal atlas, and spatiotemporal modeling of brain diseases and tumor microenvironments.

🔬 *Neuroimaging Biomarkers Define Neurophysiological Subtypes with Distinct Trajectories in Schizophrenia*

Schizophrenia is highly heterogeneous in terms of etiology, symptoms, and disease progression, which greatly affects the effectiveness of clinical diagnosis and treatment. "How to achieve individualized precision subtyping" is a scientific challenge that urgently needs to be addressed in this field.

Research Highlights

The team at the Institute of Science and Technology for Brain-inspired Intelligence (ISTBI) of Fudan University conducted research on large-scale brain imaging data from multiple centers, including 2170 participants, of which 1124 were individuals with schizophrenia. They utilized a Bayesian-based disease progression model to estimate the neurophysiological trajectory. This approach does not require prior definition of different stages of the disease, but rather enables intelligent learning and modeling from a large amount of cross-sectional neuroimaging data, accurately estimating the disease trajectory and spatiotemporal distribution map of brain atrophy. They inferred two distinct but stable trajectories of brain atrophy in schizophrenia, with the starting points located in the Broca's areas and hippocampus, respectively.

Furthermore, longitudinal data from 523 schizophrenia patients who received antipsychotic medication (APM) or transcranial magnetic stimulation (TMS) showed that the outcome of APM was associated with interindividual differences in phenotypes within the subtypes (i.e., medication was more effective in the Broca's area subtype), while the outcome of TMS was associated with intra-individual differences in phenotypes within both the Broca's area subtype and the hippocampal subtype (i.e., TMS had better outcomes during the "pre-atrophy" stage of patients).

» Full Article:
Jiang, Y., Wang, J., Zhou, E. et al. Neuroimaging biomarkers define neurophysiological subtypes with distinct trajectories in schizophrenia. Nat. Mental Health 1, 186–199 (2023). https://doi.org/10.1038/s44220-023-00024-0

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Dr. Yuchao Jiang

Yuchao Jiang, PhD in biomedical engineering (neuroimaging). He is working as a postdoctoral fellow at the Institute of Science and Technology for Brain-Inspired Intelligence (ISTBI) at Fudan University. He conducts research in the cross-disciplinary fields of brain imaging methodology and computational psychiatry,

using multimodal magnetic resonance imaging (MRI, fMRI and DTI) techniques and artificial intelligence methods to explore the pathogenesis and treatment mechanisms of schizophrenia. Over the past five years, he has published 19 peer-reviewed papers as the first author in journals including Nature Mental Health, Radiology, Schizophrenia Bulletin and Neuroimage.

Prof. Jianfeng Feng

Jianfeng Feng is Chair Professor at Shanghai National Centre for Mathematic Sciences, Dean of Institute of Science and Technology for Brain-inspired Intelligence and Dean of School of Data Science at Fudan University. He has been developing new mathematical, statistical and computational theories and methods to meet the challenges raised in Brain Science and mental health researches. Recently, his research interests are mainly in big data analysis, mining for neuroscience and brain diseases and developing brain-inspired algorithms and theory. He was recognized as one of the Chinese Most Cited Researchers in Neuroscience of 2019 and one of the Chinese Most Cited Researchers in Mathematics of 2020 and 2021 by Elsevier. He was also named the 2020 World's Top 2% Scientists by Stanford University.

Dr. Wei Cheng

Wei Cheng is now a Young Principal Investigator at Institute of Science and Technology for Brain-Inspired Intelligence, Fudan University. He obtained a Ph.D. in Applied Mathematics from Fudan University, supervised by Prof. Jianfeng Feng. Dr. Cheng completed postdoctoral fellowship at the Department of Statistics of Fudan University from Jul, 2016 to April, 2018, during which he visited University of Warwick, UK as exchange scholar for one year. Dr. Cheng is the recipient of National Scholarship for Doctoral Students, The National Natural Sciences Foundation of China, Shanghai Sailing Program Research Grant, among many other awards and grants in the last five years.

Collaboration and Exchange

2022 Progress on Fudan-Sydney Brain and Intelligence Science Alliance (BISA)

The Fudan-Sydney Brain and Intelligence Science Alliance (BISA) was established in 2019 as a platform to raise the research impact of Fudan University and the University of Sydney through interdisciplinary translational research in fields related to Cognitive Neuroscience and Brain Disorders, Computational Neuroscience, Digital Healthcare and Implementation Science, and Neuroimaging. The ultimate goal is to train research leaders, advance technological innovation and scientific research, and secure practical applications for science and technology research.

Despite the disruption of the COVID-19 pandemic which has affected regular physical faculty and student exchanges over the years, we have managed to maintain dynamic activities across various aspects and have strengthened the research links and momentum of the Brain and Intelligence.
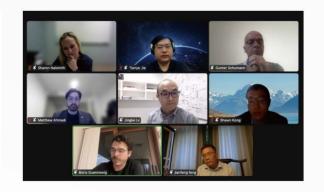
🌐 *Academic Exchange via workshops*

In 2022, BISA held two workshops: "Use Large Open-Access Datasets to Understand Brain and Mental Health" and "Navigating Funding Opportunities to Support Your Brain and Mind Research and International Collaboration", attended by about 140 participants from both universities.

In addition to sharing academic knowledge and research expertise, these workshops have made extra effort to exchange practical tips and experience of brain and mind research using UK Biobank, Human Connectome Dataset, IMAGEN, etc. and discuss relevant funding opportunities and approaches to prepare for successful applications, aiming to build researchers' capacity to leverage external and global resources and funding and develop solid cross-institutional multi-disciplinary research collaborations.

🎓 *Research Mentoring Program*

We are also committed to broadening young scholars' interest in global engagement and widening their perspectives through provision of academic experiences abroad.

The BISA Research Mentoring program co-initiated with the University of Sydney was launched in 2022, particularly focusing on the capacity building of Early-Career Researchers (ECR) from Fudan University as well as the leadership development of senior researchers from the University of Sydney, strengthening their international networks, and fostering collaborative research in key areas. Two projects have been selected as below:

Collaboration and Exchange

2022 BISA Research Mentoring Program

Fudan Mentee
Mr. Jie Chen
PhD Candidate, School
of Data Science

USyd Mentor
Prof. Junbin Gao
Professor of Big Data Analytics, Business School

Research Proposal: Universal Deep GNNs

Graph Neural Networks (GNNs) have achieved remarkable success in many research areas, including the social network, drug discovery, traffic forecasting, and recommendation system. However, the well-known over-smoothing problem of GNNs limits its application to various complex graph datasets. Hence, the main research goal is to investigate the over-smoothing problem of GNNs to unlock their potential for various types of graphs and improve their performance.

The mentee works with the mentors on the following projects:
» Project 1: Understand the non-smooth signal on graph
» Project 2: How can we help standard GNNs overcome the over-smoothing?
» Project 3: Can we make the MLP as powerful as GNNs?

The project will analyze the over-smooth problem and skip connection from a path decomposition perspective and develop a Universal Deep GNN framework that helps arbitrary graph convolution to maintain performance at arbitrary depths and handle various types of graph data (Homophily and Heterophily). This new generalizable framework would extend the application of deep GNNs to the various domain of graph research.

Fudan Mentee
Dr. Yang Qi
Postdoctoral Research
Fellow, Institute of Science
and Technology for Brain-inspired Intelligence

USyd Mentor
A/Prof. Pulin Gong
Faculty of Science

Representation and learning of prior distributions in neural circuits

How the brain represents and manipulates information is a fundamental question in neuroscience yet to be resolved. The Bayesian framework considered in the proposed project is one of the most promising candidate theories and it has been successful at providing conceptual explanation to many aspects of neurophysiological and behavioral observations in human and animals. The proposed project aims at furthering our understanding of the neural circuitry underlying probability representation and inference and has a number of potential implications.

First, by developing a theory of probabilistic representation of prior knowledge, the proposed project may potentially lead to new testable predictions for future experiments. Second, by understanding how learning is incorporated into probabilistic neural codes it may shed new light on neural plasticity. Finally, the proposed project may lead to new brain-inspired learning algorithms for solving problems involving a high amount of uncertainty in artificial neural systems.

Aims
To develop theories of how prior distribution is represented in brain.
To design neural circuit implementations for such prior distributions.
To develop learning rules for updating the prior knowledge represented in the neural circuit model.

Collaboration and Exchange

🎓 *Seed Fund Programs*
Outcome and Renewal of 2019 Round BISA Flagship Research Program

The two joint research projects awarded in 2019 involving 24 researchers from multi-disciplinary fields after the Sydney and Fudan joint committees reviewed the applications have managed to carry on collaboration activities despite of the covid-19 pandemic and have made remarkable progress against the KPI required.

📁 *2022 BISA Flagship Research Program*

Flagship Research Project I: Accelerating clinical neuroscience with magnetic resonance imaging (MRI) enhancement: development of deep learning solutions to boost clinical imaging quality and resolution

Fudan Lead Investigator
A/Prof He Wang
Zhangjiang International Imaging Centre & Institute of Science and Technology for Brain-inspired Intelligence, Fudan

Fudan Collaborators:
» A/Prof Chun-Yi Zac Lo,
» Prof Ching-Po Lin,
» A/Prof Chenyan Wang,
» Ms Hui Zhang,
» Mr Rencheng Zheng g

USYD Lead Investigator
Dr Tim Wang
Faculty of Medicine and Health

» USyd Collaborators:
» Prof Matthew Kiernan (BMC),
» Prof Fernando Calamante (Sydney Imaging Core Research Facility),
» Prof Dachang Tao (Engineering),
» Prof Michael Barnett (Sydney Neuroimaging Analysis Centre),
» A/Prof Armin Nikpor (FMH),
» Prof Cindy Lin (FMH),
» Dr Luping Zhou (Engineering)

The team has been awarded AUD $230,000 to renew the project for another year (2022-23), with AUD 115,000 being awarded to Dr Wang and RMB amount equivalent to AUD $115,000 awarded to Associate Professor Wang.

Flagship Research Project II: Neural oscillations across space and time: properties and functional roles

Fudan Lead Investigator
Professor Jianfeng Feng
Institute of Science and Technology for Brain-inspired Intelligence

Fudan Collaborators:
» Prof Wenlian Lu,
» Dr Ningning Ma,
» A/Prof Wei Chang,
» Dr Xinyi Geng

USyd Lead Investigator
A/Prof Pulin Gong
Brain Dynamics Group,
Faculty of Science

USYD Collaborators:
» Prof Paul Martin (FMH),
» Prof Peter Robinson (Science/Physics),
» Dr Angela D'Rozario (Science/ Psychology),
» Dr Mac Shine (FMH),
» Dr Ben Fulcher (Science),
» Dr Tancy Kao (Woolcock Institute),
» Dr Svetlano Postnova (Science),
» Prof Junbin Gao (Business)

Collaboration and Exchange

The team has been awarded AUD $50,000 to strengthen international collaboration for another year (2022-2023), with AUD 25,000 being awarded to Associate Professor Gong and the RMB amount equivalent to AUD $25,000 awarded to Professor Feng.

New Seed Fund Programs in 2022

We also launched two BISA seed fund programs to support collaborative initiatives between the two universities:

- BISA Flagship Research Program to support two joint projects over two years, targeting teams of researchers to strengthen existing collaborations on high-impact projects (each awarded project may receive up to CNY￥455,000 per year from each university),

- BISA Accelerator Research Program to support three projects over one year, targeting Sydney researchers, especially early and mid-career researchers, to work with Fudan colleagues on highly viable projects that will lead to tangible research outputs and impact at the end of the one-year timeframe (each awarded project may receive up to AUD$75,000 per year from the University of Sydney).

Fudan Chief Investigator
Dr. Zhensen Chen
Young Principal Investigator,
Institute of Science and Technology for Brain- Inspired Intelligence

Fudan Collaborators:
» Prof. He Wang, ISTBI
» Dr. Hao Li, ISTBI
» Dr. Xiao Chang, ISTBI
» Dr. Yuchuan Qiao, ISTBI

USyd Chief Investigator
Dr. Jinglei Lv
Senior Lecturer, Faculty of Engineering

USyd Collaborators
» Prof. Fernando Calamante, Faculty of Engineering,
» Prof. Sharon Naismith, Faculty of Science,
» A/Prof. Mac Shine, Faculty of Medicine and Health
» Dr. Claire O'Callagen, Faculty of Medicine and Health
» Dr. Shawn Kong, Brain and Mind Centre

2022 BISA Flagship Research Program

Reliable Measurement of Cortico-subcortical Functional Connectivity of Human Brain with 7T MRI

Drs Zhensen Chen and Jinglei Lv will collaborate to optimize 7T imaging and analysis methods to measure superior cortical and subcortical dynamics and reliable cortico-subcortical connectivity. The methods will realize precision diagnosis by defining high-quality imaging biomarkers for brain diseases like Alzheimer's Disease and Schizophrenia, facilitating personalized intervention or treatment.

Towards Efficient and Reliable AI with Stochastic Computation Inspired by Biological Neural Systems

Professors Li Zhang and Luping Zhou will develop theories and methods in linear-complexity transformers and efficient Bayesian probabilistic inference with temporally fluctuating neural activity, then apply the methods to analyzing high-resolution medical images for effective learning even with limited or incomplete training data, with simultaneous quantification of prediction and assessment of reliability. This project combines the latest theories from computational neuroscience and deep learning and may lead to more accurate and reliable AI applications.

Collaboration and Exchange

Fudan Chief Investigator
Prof. Li Zhang
Professor, School of Data Science

Fudan Collaborators
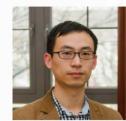» Prof. Wenlian Lu, School of Mathematical Sciences
» Dr. Qi Yang, ISTBI

USyd Chief Investigator
A/Prof. Luping Zhou
Associate Professor, Faculty of Engineering

USyd Collaborators
» Prof. Jinman Kim, Faculty of Engineering, Director of the Biomedical Data Analysis and Visualisation (BDAV) Lab, and Research Director of the Telehealth and Technology Centre, Nepean Hospital

Fudan Chief Investigator
Prof. Qiang Luo
Professor, Institute of Science and Technology for Brain- Inspired Intelligence

Fudan Collaborators:
» Prof. He Wang, Acting Director, Zhangjiang International Brain Imaging Centre

USyd Chief Investigator
Dr. Yuhong Fu
Research Fellow, Faculty of Medicine and Health

Fudan Collaborators:
» Prof. Glenda Halliday, Faculty of Medicine and Health, Brain and Mind Centre
» Dr. Paul Austin, Faculty of Medicine and Health, Brain and Mind Centre

Other Collaborators：
Prof. Jun Liu, Head of Neurology department, Ruijin Hospital, Dr Liche Zhou, Neurology department, Ruijin Hospital, Shanghai Jiao Tong University

A new generation of imaging atlas for machine learning-based disease models

Prof. Qiang Luo and Dr. Yuhong Fu aim to generate a multimodal high-resolution human brain imaging atlas by modelling > 41,000 cases from five different image recourses, including Caucasian and Asian datasets, ranging from 23-75 years old, under the guidance of recognised molecular clusters of deep brain structures revealed from novel high throughput histological data. The atlas will be applied to a longitudinal cohort of neurodegenerative disorders to generate imaging disease models by machine learning.

Collaboration and Exchange

📄 *2022 BISA Accelerator Research Program*

Towards the Development of Reproducible Models for the Classification of High-dimensional Actigraphy Data on Deeply Phenotype International Cohorts with Improved Interpretability

Dr. Boris Guennewig's team will collaborate with Prof. Shouyan Wang to generate methodological insights that will predict disease progression with increased accuracy by combining the deeply phenotyped cohort of 500 individuals with the scoped 20,000 participants in the Fudan health district. These new insights will improve stratification of clinical patients for intervention research projects (such as lifestyle interventions, sleep therapies, neuromodulation) and gain greater precision in determining sub-types and symptoms so that ultimately the molecular mechanisms behind these can be derived.

USyd Chief Investigator
Dr. Boris Guennewig
Senior Lecturer, Faculty of Medicine and Health

USyd Collaborators:
» Prof. Sharon Naismith, Faculty of Science
» Dr. Shawn Kong, Faculty of Science
» Dr. Andrew McKinnon, CSIRO Health and Biosecurity, The Australian e-Health Research Centre,

Fudan Collaborator
Prof. Shouyan Wang
Professor, Institute of Science and Technology for Brain- Inspired Intelligence

» A/Prof. Chris Gordon, Faculty of Medicine and Health
» Prof. Kevin Keay, Director of Neuroscience, Brain and Mind Centre,
» Mr. Ping-Hsiu Lin, Brain and Mind Centre /Charles Perkins Centre (PhD candidate)
» Mrs. Kosar Hosshamend , Brain and Mind Cenre (PhD candidate)

USyd Supervisor:
Prof. Kevin Keay, Director of Neuroscience, Chief Anatomist, Brain and Mind Centre, Faculty of Medicine and Health

Development of a Therapeutic Brain Bio-adhesive to Reduce Cognition Impairment Post Intracerebral Haemorrhage

Dr. Jingjing You's team recently developed a collagen based bio-adhesive that can adhere to brain tissue. This collaborative project aims to further develop this bio-adhesive to carry BDNF to facilitate the healing of neuronal tissue and to reduce the cognition impairments in ICH patients. The developed method could also have potential to be used to deliver therapeutic drugs to treat other brain diseases.

Collaboration and Exchange

USyd Chief Investigator
Dr. Jingjing You
Senior Researcher, Faculty of
Medicine and Health

USyd Collaborator:
» Prof. Mary Collins, Deputy Executive
Dean (Academic), FMH

USyd Supervisor:
» Prof. Cheryl Jones, Head of School
and Dean, Sydney Medical School

Testing the Role of Sleep for Memory Consolidation in Large Community Samples: the Translation, Implementation, and Validation of a Sleep-dependent Memory Task into a Mobile Application for Use in China

Dr. Aaron Lam and his team aim to translate and validate a sleep-dependent memory task for Mandarin speakers to be delivered through a mobile device. It will also examine factors (e.g., sleep, cardiovascular, neuroimaging) that are related to sleep-dependent memory performance in clinical samples (older adults at-risk of dementia, and adults with severe insomnia). This project will enable the investigation of SDM for English and Mandarin speakers globally without necessarily attending a sleep laboratory. Enabling researchers and clinicians to routinely examine SDM in clinical cohorts to understand how different disorders can impair an overlooked aspect of memory.

Fudan Collaborator
Dr. Peiliang Li
Associate Chief Physician in
Neurosurgery, Huashan Hospital

USyd Chief Investigator
Dr. Aaron Lam
Research Associate, Faculty
of Science

USyd Collaborators:
» Prof. Sharon Naismith, Faculty
of Science
» Dr. Shawn Kong, Faculty of
Science
» Prof. Lee-Fay Low, Professor of
ageing and Health, Faculty of
Medicine and Health
» Dr. Ling Zhang, Faculty of Medicine and Health

USyd Supervisor:
» Dr. Angela D'Rozario, Research
Leader, Sleep Neurobiology -
CIRUS, Centre for Sleep and
Chronobiology, Woolcock Institute
of Medical Research

Fudan Collaborator
Dr. Cong Fu
M.D., Ph.D., Sleep and Wake Disorders'
Center, Department of Neurology,
Huashan Hospital, Fudan University

Join Us

Postdoctoral Fellows

We are recruiting young scholars who would like to take up a postdoc position in Shanghai and have a strong interest in the following research areas:

1. Cognition and Neuromodulation
2. Bioinformatics and Neuroscience
3. Whole-brain Computation and Digital Brain
4. Brain-inspired Intelligence Technology and Application
5. Neuroimaging and Translational Medicine

» *Requirements*

1. Under the age of 35
2. PhD degree in relevant fields of the aforementioned research areas, including but not limited to Mathematics, Statistics, Neuroscience, Bioinformatics, Artificial Intelligence, Biomedical Engineering, Clinical Neuroscience, etc.
3. Haven't returned/come to China or haven't been (back) in China for more than 1 year

» *Benefits*

1. Salary: ≈ 450k CNY/per annum (≈ 64k USD/per annum), for 3 years
2. One-off relocation fee
3. Potential opportunities to apply for national fellowship programs
4. Given preference to application for Teaching and Research Positions at Fudan University, with the same competence and eligibility

» *How to Apply*

Please contact istbi_ic@fudan.edu.cn

Senior Researchers

1.Fudan Fellow Program 2023

Fudan Fellow Program welcomes outstanding scholars from around the world to Shanghai for on-campus academic interaction with the Fudan community.

» *Eligibility*

Applicants should be citizens of a foreign country and have a good command of Chinese or English. Those who have previously been accepted into this program may not apply for the same category again. There are four categories:

1. Honorary Fudan Scholar: Applicants who have won the Nobel Prize, Turing Award, Fields Medal, or other similar awards;
2. Distinguished Fudan Scholar: Applicants who are academicians from a country (region) or top scholars with equivalent academic honors, or scholars recommended as having the potential to win the Nobel Prize, Turing Award, Fields Medal and other similar awards.
3. Fudan Scholar: Applicants who are full-time Chair Professors or Full Professors (tenure-track) of higher education and research institutions, and have outstanding scientific research potential;
4. Fudan Fellow: Applicants who are assistant professors or above in higher education or research institutions, or postdoctoral scholars from top universities with outstanding research potential, who are active and innovative thinkers and have an ongoing research project;
5. Applicants with experience working in government or international organizations, well-known enterprises, high-end think tanks or media organizations, with the ability to conduct higher academic communication and scientific and policy research, are recommended to apply for the appropriate category based on their personal circumstances.

» *Program*

1. Schedule: Honorary Fudan Scholars are invited to campus for no less than 1 week. Distinguished Fudan Scholars are invited to campus for no less than 2 weeks.

Collaboration and Exchange

Fudan Scholars and Fudan Fellows are invited to the Fudan campus for 60 days, exceptionally no shorter than 30 days and no longer than 90 days. All are required to visit Fudan University in person.

2. Activities: Every four weeks on campus, fellows are asked to give at least one lecture, either to students or fellow researchers, or to host workshops and seminars.
3. Publications: Fellows are encouraged to publish papers after the visit under the title of Fudan Scholar/Fudan Fellow. A copy of the publication shall be presented to and kept by Fudan University.

» *Allowances & Services*

1.International round-trip airfare allowance: The program provides an airfare allowance of up to RMB 35,000 for each Honorary Fudan Scholar/Distinguished Fudan Scholar/Fudan Scholar and up to RMB 10,000 for each Fudan Fellow, with actual travel expenses. The maximum Economy and Business Class allowances are as follows:

Region	The Maximum Allowance for Economy Class (RMB)	The Maximum Allowance for Business Class (RMB)
Aisa	3000	10000
Europe	8000	25000
North America	8000	35000
South America	15000	50000
Africa	8000	25000
Oceania	8000	30000

2. Stipends:
For Honorary Fudan Scholar: 1600 RMB/day * number of visiting days (tax included)
For Distinguished Fudan Scholar: 1600 RMB/day * number of visiting days (tax included)
For Fudan Scholar: 1000 RMB/day * number of visiting days (tax included)
For Fudan Fellow: 300 RMB/day * number of visiting days (tax included)

3. Services:
Designated facilities and offices are provided by the invitation platform or institution during the visit.

Application
All applications must be in English. An application form and a research proposal form are required. For different categories of applications:
1. Honorary Fudan Scholar: Application Form and Curriculum vitae;
2. Distinguished Fudan Scholar: Application Form and Curriculum vitae;
3. Fudan Scholar: Application Form, Curriculum vitae, and Research Proposal;
4. Fudan Fellow: Application Form, Curriculum vitae, Research Proposal and 2 Recommendation Letters.

How to apply
Please contact istbi_ic@fudan.edu.cn

2.*Fudan Brain and Intelligence Fellowship for Sabbatical Leave*

The Fudan Brain and Intelligence Fellowship for Sabbatical Leave has been opened to invite oversea scientists in relevant disciplines to carry out academic activities at our institute during their Sabbatical Leaves.

» *Requirements:*

1.Fellows should be Assistant Professor or above.
2.Fellows should conduct research in the following areas and relevant ones:
(1)Cognitive Neuroscience
(2)Neuromodulation, Digital Healthcare and Neural Engineering
(3)Bioinformatics and Neuroscience
(4)Virtual Brain and Digital Brain Modelling
(5)Brain-inspired Intelligence Technology and Application
(6)Neuroimaging and Translational Medicine
3.Fellowship supports visits for up to 12 months, and potentially for up to 24 months.

Join Us

» *Responsibilities:*

1.Co-supervise young scholars (postgraduate students, postdoctoral fellows, and early-career researchers) on their research projects and provide constructive feedback.

2.Give lectures, or either take lead / participate in organizing an academic event, such as workshop, symposium, conference, etc.

» *Scope of the Fellowship:*

1.One-time travel expenses to and from China.

2.Stipends commensurate with experience: no less than CNY 1000 yuan * number of days visiting (tax included).

» *How to apply*

Please contact istbi_ic@fudan.edu.cn