Dr. Fangwen Yu

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Overview

Dr. Fangwen Yu is currently an assistant research fellow in the Center for Brain-Inspired Computing Research (CBICR) and the Department of Precision Instrument at Tsinghua University. He is a researcher of brain-inspired robotics. His research focuses on brain-inspired navigation in neurorobotics and neuroscience. His career vision is creating brain inspired robots that navigate as humans do intelligently and efficiently for the real world.

His research models the neural mechanisms in the brain underlying tasks like spatial navigation and spatial memory to develop new brain-inspired general intelligent navigation (BGINav) technologies for brain-inspired general intelligent robots (BGIBot). He has developed the brain-inspired 3D SLAM system - NeuroSLAM and the brain-inspired general place recognition system - NeuroGPR for neurorobots. He is currently working on the NeuroSLAM Project, the NeuroROS Project and the NeuroRobot Project.

He was a post-doctoral research fellow supervised by Prof. Luping Shi in the Center for Brain-Inspired Computing Research (CBICR) at Tsinghua University from July 2020 to November 2023. He is a member of IEEE, RAS, RIN, CCF, CAAI and CNS. He was a PhD student (2015~2020) supervised by Prof. Jianga Shang and Prof. Youjian Hu in National Engineering Research Center for GIS and School of Geography and Information Engineering at China University of Geosciences in Wuhan. He was a visiting PhD student (2017~2019) supervised by Prof. Michael Milford in the Australian Centre for Robotic Vision (ACRV) (currently QUT Centre for Robotics) and School of Electrical Engineering and Computer Science (currently School of Electrical Engineering and Robotics) at Queensland University of Technology (QUT). He received his B.E. degree in Software Engineering, the M.E. degree in Computer Science, and the Ph.D. degree in Science and Technology of Surveying and Mapping from China University of Geosciences in 2012, 2015, 2020 respectively, and the B.B.A. degree in Business Administration from Huazhong University of Science and Technology in 2012.

Research Highlight

Fangwen currently leads the NeuroSLAM project (www.neuroslam.net) which is creating brain inspired robots that navigate like humans do with a long-term goal. The project aims to model the neural mechanisms in the brain underlying tasks like 3D navigation and 3D spatial cognition to develop new brain-inspired 3D SLAM and 3D cognitive navigation technologies for land, sea, air and space based brain-inspired robots and vehicles.

The project has developed a novel brain-inspired SLAM (simultaneously localization and mapping) system for 3D environments, named NeuroSLAM. The system is implemented based upon computational models of 3D place cells, 3D grid cells and 3D head direction cells, integrated with a vision system that provides external visual cues and 3D self-motion cues. NeuroSLAM's neural network activity drives the creation of a 3D graphical experience map in a real-time, enabling relocalization and loop closure through sequences of familiar local visual cues. Using both synthetic and real-world datasets comprising complex, 3D indoor and outdoor environments, they demonstrate NeuroSLAM consistently producing topologically correct three-dimensional maps.

They are developing and extending the NeuroSLAM models based on the further discoveries of neural basis of 3D navigation, e.g. 3D goal-directed cells, time cells, speed cells, episodic memory, enabling the robots to navigate in complex 3D environments. They are deploying the NeuroSLAM models based on brain-inspired chips, e.g. Tianjic Chip, or Lynchip. Finally, they will develop a novel intelligent robot that navigate based on the artificial 3D navigation brain.

For further information, please visit their project website at www.NeuroSLAM.net.

Working Experience

2023/12-Now	Brain-inspired General Navigation, Brain-inspired Robotics, Brain-inspired Intelligence	Center for Brain Inspired Computing Research, Tsinghua University, China; Department of Precision Instrument, Tsinghua University, China	Assistant Research Fellow
2020/07-2023/11	Brain-inspired 3D Navigation, Brain-inspired Robotics, Brain-inspired Computing	Center for Brain Inspired Computing Research, Tsinghua University, China; Department of Precision Instrument, Tsinghua University, China	PostDoc Research Fellow

Education

2017/08-2019/08	Brain-inspired 3D SLAM (NeuroSLAM)	Queensland University of Technology, Australian Centre for Robotic Vision, Australia	Visiting Ph.D. Student
2015/09-2020/06	Survey and Mapping (Brain-inspired 3D SLAM)	China University of Geosciences, Wuhan National Engineering Research Center for GIS	Ph.D. Student
2012/09-2015/06	Computer Science (Indoor Positioning and Navigation)	China University of Geosciences, Wuhan	M.A.
2008/09-2012/06	Software Engineering (Indoor Positioning and Navigation)	China University of Geosciences, Wuhan	B.S.
2010/06-2012/06	Business Administration (Innovative Team Management)	Huazhong University of Science and Technology	B.S.

Selected Research Projects

[1] China. National Natural Science Foundation. Grant No. 42201456. **Brain-inspired 3D Navigation with Neuromorphic Computing Chips**. 2023.01-2025.12.(Leader)

[2] National Science and Technology Major Project of China (China Brain Project), Grant No. 20211810001. **Hybrid Brain-inspired Computing Research Platform**. 2021.12-2026.12 (participant).

[3] China Postdoctoral Science Foundation, Grant No. 2021M701835. **NeuroMap: Brain Inspired Encoding and Memory of 3D Spatial Experience Map with Neuromorphic Chip**. 2021.11-Now (Leader)

[4] China & Australia. **NeuroSLAM: A Brain Inspired SLAM System for 3D Environments**. 2016.09-Now (Leader)

[5] China. National Natural Science Foundation (Innovation Exploration Program), Grant No. 6205000340. **Quantitative Analysis and Evaluation of Completeness for Brain-inspired Computing System**. 2021.01-2021.12 (participant)

[6] China. National Natural Science Foundation (Key Program), Grant No. 20181311196，**General**

Architecture Model and Approach for Brain-Inspired Computing，2020.07-Now. (participant)

[7] China. National Key Program of Research and Development Plan, Grant No. 2016YFB0502200. **Smart Hybrid Indoor Localization with High Degree of Accuracy and Availability and Indoor GIS**. 2016.07-2020.12. (participant)

[8] China. National Natural Science Foundation, Grant No. 41271440. **Multi-Layered Semantic Location Model in Ubiquitous Computing Environments**. 2013.01-2016.12 (important participant)

[9] China. Fundamental Research Founds for National University, China University of Geosciences（Wuhan）, Grant No. 1610491T08. **Student Innovation Research Team, Research on Wearable Cognitive Navigation.** 2015.12-2017.12. (Leader)

[10] China. Fundamental Research Founds for National University, China University of Geosciences（Wuhan）, Grant No. 1310491B07. **Research on Context Aware Indoor Positioning and Navigation.** 2013.03-2014.03 (Leader)

[11] China. Teaching Lab Open Founds, China University of Geosciences（Wuhan）, Grant No. SKJ2012190. **Research on Indoor Spatial Model for Navigation and Positioning Applications.** 2012.12-2013.12 (Leader)

[12] China. Fundamental Research Founds for National University, China University of Geosciences（Wuhan）, Grant No. CUGL090247. **UbiEyes: Universal Real-time Locating System.** 2011.06-2013.06 (important participant)

[13] China. Teaching Lab Open Founds, China University of Geosciences（Wuhan）, Grant No. SKJ2011186. **Testing Methods and Experiments of Dynamic Positioning Accuracy.** 2011.08-2012.06 (Leader)

Seclected Published Papers

[1] Fangwen Yu, Yujie Wu, Songchen Ma, Mingkun Xu, Hongyi Li, Huanyu Qu, Chenhang Song, Taoyi Wang, Rong Zhao and Luping Shi. **Brain Inspired Multimodal Hybrid Neural Network for Robot Place Recognition**. Science Robotics, 2023, 8(78): abm6996. (Cover Paper)

[2] Songchen Ma, Jing Pei, Weihao Zhang, Guanrui Wang, Dahu Feng, Fangwen Yu, Chenhang Song, Huanyu Qu, Cheng Ma, Mingsheng Lu, Faqiang Liu, Wenhao Zhou, Yujie Wu, Yihan Lin, Hongyi Li, Taoyi Wang, Jiuru Song, Xue Liu, Guoqi Li, Rong Zhao, Luping Shi. **Neuromorphic Computing Chip with Spatiotemporal Elasticity for Multi-intelligent-tasking Robots**. Science Robotics, 2022, 7 (67): eabk2948. 10.1126/scirobotics.abk2948.

[3] Hanle Zheng, Zhong Zheng, Rui Hu, Bo Xiao, Yujie Wu, Fangwen Yu, Xue Liu, Guoqi Li & Lei Deng. **Temporal dendritic heterogeneity incorporated with spiking neural networks for learning multi-timescale dynamics**. Nature Communications, 2024, 15: 277. https://doi.org/10.1038/s41467-023-44614-z

[4] Fuqiang Gu, Fangming Guo, Fangwen Yu, Xianlei Long, Chao Chen, Kai Liu, Xuke Hu, Jianga Shang and Songtao Guo. **Accurate and efficient floor localization with scalable spiking graph neural networks**. Satellite Navigation, 2024. DOI: 10.1186/s43020-024-00127-8

[5] Shuai Zhong, Jiachao Zhou, Fangwen Yu, Mingkun Xu, Yishu Zhang, Bin Yu, Rong Zhao. **An Optical Neuromorphic Sensor with High Uniformity and High Linearity for Indoor Visible Light Localization**. Advanced Sensor Research, 2024. https://doi.org/10.1002/adsr.202300197

[6] Xiangwei Zhu, Dan Shen, Kai Xiao, Yuexin Ma, Xiang Liao, Fuqiang Gu, Fangwen Yu, Kefu Gao, Jingnan Liu. **Mechanisms, Algorithms, Implementation and Perspectives of Brain-inspired Navigation**. Acta Aeronautica et Astronautica Sinica, 2023, doi: 10.7527/S1000-6893.2023.28569. (Cover Paper)

[7] Hui Zhao, Fangwen Yu, Xuke Hu, Zhi Xiong, Jianga Shang and Fuqiang Gu. **Editorial: Brain-inspired navigation and sensing for robots**. Front. Neurorobot. 2023, 17:1329324. doi: 10.3389/fnbot.2023.1329324

[8] Xiaoyan Liu, Liang Chen, Zhenhang Jiao, Fangwen Yu, Xiangchen Lu, Zhaoliang Liu, Yanlin Ruan. **A Neuro-Inspired Positioning System Integrating MEMS Sensors and DTMB Signals**. IEEE Transactions on Broadcasting, 2023, 1-9.   doi:10.1109/TBC.2023.3284409

[9] Dan Shen, Gelu Liu, Tianci Li, Fangwen Yu, Fuqiang Gu, Kai Xiao, and Xiangwei Zhu. **ORB-NeuroSLAM: A Brain-Inspired 3D SLAM System Based on ORB Features**. IEEE Internet of Things Journal, 2023. doi:10.1109/JIOT.2023.3335417

[10] Xingxing Li, Xiaohong Zhang, Xiaoji Niu, Jian Wang, Ling Pei, Fangwen Yu, Hongjuan Zhang, Cheng Yang, Zhouzheng Gao, Quan Zhang, Feng Zhu, Weisong Wen, Tuan Li, Jianchi Liao, Xin Li. **Progress and Achievements of Multi-sensor Fusion Navigation in China during 2019—2023**. Journal of Geodesy and Geoinformation Science, 2023, 6(3): 102-114. https://doi.org/10.11947/j.JGGS.2023.0310

[11] Liao Wu, Fangwen Yu, Jiaole Wang, Thanh Nho Do. **Camera Frame Misalignment in a Teleoperated Eye-in-Hand Robot: Effects and a Simple Correction Method**. IEEE Transactions on Human-Machine Systems, 2023, vol. 53, no. 1, pp. 2-12. doi: 10.1109/THMS.2022.3217453.

[12] Fuqiang Gu, Yong Lee, Yuan Zhuang, You Li, Jingbin Liu, Fangwen Yu, Xuke Hu, Ruiyuan Li, Chao Chen. **MDOE: A Novel Event Representation By Considering the Magnitude and Density of Events**. IEEE Robotics and Automation Letters, 2022, vol. 7, no. 3, pp. 7966-7973. doi: 10.1109/LRA.2022.3186523.

[13] Shuai Zhong, Yishu Zhang, Hao Zheng, Fangwen Yu, Rong Zhao. **Spike-Based Spatiotemporal Processing Enabled by Oscillation Neuron for Energy-Efficient Artificial Sensory Systems**. Advanced Intelligent Systems, 2022. 2200076. https://doi.org/10.1002/aisy.202200076

[14] Ziyi Gong, Fangwen Yu*. **A Plane-Dependent Model of 3D Grid Cells for Representing both 2D and 3D Spaces under Various Navigation Modes**[J]. Frontiers in Computational Neuroscience, 2021. doi: 10.3389/fncom.2021.739515

[15] Fangwen Yu. **Brain Inspired SLAM System for 3D Environments** [D]. Wuhan, China: China University of Geosciences, 2020: 1-218.

[16] Fangwen Yu, Jianga Shang, Youjian Hu and Michael Milford. **NeuroSLAM: A Brain inspired SLAM System for 3D Environments**. Biological Cybernetics, 2019,113(5-6), 515-545.

[17] Fuqiang Gu, Kourosh Khoshelham, Jianga Shang, Fangwen Yu, Zhuo Wei. **Robust and Accurate Smartphone-based Step Counting for Indoor Localization**[J], IEEE Sensors Journal, 2017, 17(11): 3453-3460. https://doi.org/10.1109/JSEN.2017.2685999

Seclected Conferences Papers

[1] Fuqiang Gu, Weicong Sng, Xuke Hu, Fangwen Yu*. **EventDrop: Data Augmentation for Event-based Learning**[C]. In: 30th International Joint Conference on Artificial Intelligence (IJCAI-21), Montreal, 21st -26th August 2021.

[2] Fuqiang Gu, Kourosh Khoshelham, Jianga Shang, and Fangwen Yu. **Sensory Landmarks for Indoor Localization**[C]. In: Proceedings of The Fourth International Conference on Ubiquitous Positioning, Indoor Navigation and Location-based Service 2016 (UPINLBS 2016). Shanghai, China. November 3-4, 2016. (Best Paper Award)

[3] Zhiyong Zhou, Fangwen Yu, and Jianga Shang. **iGeoNoti: A Fine-grained Indoor Geo-notification System**[C]. In: Proceedings of The Fourth International Conference on Ubiquitous Positioning, Indoor Navigation and Location-based Service 2016 (UPINLBS 2016). Shanghai, China. November 3-4, 2016.

Seclected Patents (7 granted)

[1] Jianga Shang, Fangwen Yu, Xuke Hu, etc. **Context-aware Emergency Indoor Navigation System and approaches**. China Invention Patent, No：CN 2014 1 0156123.4. (Granted in June 15 2016)

[2] Jianga Shang, Xuke Hu, Fangwen Yu, etc. **Improving Wi-Fi Indoor Positioning via AP Sets Similarity and Semi-Supervised Affinity Propagation Clustering**. China Invention Patent, No：CN 2013 1 0432808.2. (Granted in March 23 2016)

[3] Jianga Shang, Fangwen Yu, Xinyi Tang, etc. **A Generation Method of Dynamic Path for Indoor Navigation.** China Invention Patent, No：CN 201510449347.9. (Granted in Sep. 26 2017)

[4] Jianga Shang, Fangwen Yu, Xinyi Tang, etc. **Relative Location-aware Query of Indoor Moving Objects**. China Invention Patent, No：CN 201610034743.2. (Granted in March 8 2019)

[5] Jianga Shang, Wen Cheng, Yongfeng Wu, Fangwen Yu, Zhiyong Zhou. **A Generation Approach of Graph Model for Indoor Positioning and Navigation**. China Invention Patent, No：CN201610545874.4. (Granted in Feb 1 2019)

[6] Jianga Shang, Fuqiang Gu, Fangwen Yu. **An Approach of Step Count and Electric Devices**. China Invention Patent, No： CN201610325891.7. (Granted in Feb. 26 2019)

[7] Jianga Shang, Zhiyong Zhou, Fangwen Yu, Xinyi Tang, Yongfeng Wu, Wen Cheng. **Indoor Social Navigation System**. China Invention Patent, No：CN201610338026.6. (Granted in April 23 2019)

[8] Jianga Shang, Zhiyong Zhou, Fangwen Yu, Xinyi Tang, Yongfeng Wu, Wen Cheng. **A System of Nearest Neighbor Location Query for Indoor Environments**. China Invention Patent, No: CN201610335134.8.

[9] Jianga Shang, Zhiyong Zhou, Fangwen Yu, etc. **A System of Indoor Mobile Social Service Network**. China Invention Patent, No：CN201610338027.0.

[10] Jianga Shang, Zhiyong Zhou, Fangwen Yu. **A Fine-grained Indoor Geo-notification System in Multi-floor Building**. China Invention Patent, No：CN201710089893.5.

Seclected Software Systems

[1] Fangwen Yu, Luping Shi, Rong Zhao. **NeuroSLAM: A Brain-inspired SLAM System for 3D Environments**. Computer Software Copyright, No：2020SR1721149

[2] Jianga Shang, Fangwen Yu, Xuke Hu, etc. **SmartENavi：Context-aware Indoor Emergency Navigation System.** Computer Software Copyright, No：2014SR087245.

[3] Jianga Shang, Fuqiang Gu, Fangwen Yu, etc. **UbiEyes: Universal Real-time Locating System.** Computer Software Copyright, No：2013SR055149.

[4] Jianga Shang, Zhiyong Zhou, Fangwen Yu, etc. **iSoNe: An Indoor Location-based Mobile Social Network System.**

Selected Honors and Awards

2020.07   The Pioneering Innovation Award of 6th Hubei Province Changjiang Student

2020.06   Award for Excellent Doctoral Thesis at China University of Geosciences, Wuhan

2020.06   Outstanding Graduate Award at China University of Geosciences, Wuhan

2019.10	¥300,000 Innovation Grand Prize at the 2019 International Collegiate Competition for Brain-inspired Computing
2016.11	IEEE UPINLBS 2016 Best Paper Award
2016.09	¥120,000 Fund, Hubei Province Collegiate Competition for Innovation and Entrepreneurship
2016.05	The Ten Pioneers of Innovation and Entrepreneurship in CUG
2015.11	Best Presentation Awards in China National PhD Academic Forum of Surveying and Mapping
2015.06	The Outstanding Volunteer of the 23rd International Conference on Geoinformatics
2014.11	The New Star of GIS in the National College GIS Forum, China
2014.10	National Scholarship for Graduate Students
2013.10	Second Class Prize in the 13th "Challenge Cup" National University Student Curricular Academic Science and Technology Works Competition
2013.12	The Grand Prize in the Graduate Academic Competition of CUG
2013.12	Hi-Target Survey Instruments Company Innovation Scholarship
2013.06	First Class Prize in the 9th "Challenge Cup" Hubei Province College Curricular Academic Science and Technology Works Competition
2013.06	The Ten Outstanding Graduate Student Pacesetter at CUG
2012.12	Spatial Information Outstanding Innovation Scholarship
2012.06	Taihua Company Innovation Scholarship

Selected Professional Experience

2015/10-2017/10	**Team Leader**	Innovation Research Team of Cognitive Navigation at CUG
		The innovation research team of intelligent navigation is mainly focusing on research and development of intelligent indoor positioning and navigation for wearable devices, like smart glasses, smart watches, smart wrists. We are developing a wearnav system based on hybrid indoor positioning technologies including the approaches of Wi-Fi, BLE, PDR, Vision, and Spatial-aided localization.
2012/09-2017/09	**Lab Leader Assistant**	UbiLoc Lab at China University of Geosciences
		The UbiLoc lab (Ubiquitous Location-Aware Computing Lab) founded in 2009. The research areas include indoor positioning, indoor navigation, indoor GIS and Mapping, indoor social network, etc.
2012/09-2013/09	**President**	Software Association of China University of Geosciences
2012/09-2013/09	**Vice President**	Graduate Student Union of Faculty of Information and Engineering

Selected Conferences Attended

2021 The 6Th International Academic Forum for Non-exposed Space Positioning, Navigation and Timing (PNT), Dec 18, 2021, Beijing, China.

2021 Workshop on Intelligent Navigation Technology. June 18-19, 2021, Changsha, China.

2020 The 3rd Interdisciplinary Navigation Symposium (iNAV2020), Oct. 5-7, 2020

2019 Workshop on computational intelligence and intelligent robots, Nov. 16-17, 2019, Huazhong University of Technology, Wuhan, China

2018 IEEE International Conference on Robotics and Automation (ICRA2018), May 21-26, 2018, Brisbane, Australia

2017 China Satellite Navigation Conference (CSNC 2017), May 23-25, 2017, Shanghai, China.

2017 Global Artificial Intelligence Technology Conference (GAITC 2017), May 21, 2017, Beijing, China

2016 The Fourth International Conference on Ubiquitous Positioning, Indoor Navigation and Location-based Service 2016 (IEEE UPINLBS 2016), Nov.3-5, Shanghai, China

2016 China Satellite Navigation Conference (CSNC 2016), May 18-20, 2016, Changsha, China.

2015 International Conference on Ubiquitous Surveying, Mapping and Big Data of Locations, November 6-8, 2015, Wuhan, China.

2015 China National Computer Congress (CNCC 2015), October 22-24, 2015, Hefei, China.

2015 The 23rd International Conference on Geoinformatics (Geoinformatics 2015), June 18-20, 2015, Wuhan China.

2014 ISPRS Geospatial Database and Location Based Services, May 14-16, 2014, Suzhou, China.

2014 China Satellite Navigation Conference (CSNC 2014), May 17-19, 2014, Wuhan, China.

2014 Geospatial Information for Smart City and the Future of Geoinformatics, May 15-16, 2014, Wuhan, China.

Selected Conference Presentations

[1] Fangwen Yu. "**Brain-Inspired 3D Navigation: Progress and Outlook**". 2021 the 6th International Academic Forum for Non-exposed Space Positioning, Navigation and Timing (PNT), Beijing, China.

[2] Fangwen Yu. "**Research Progress on Brain-Inspired 3D Navigation Approach**". Workshop on Intelligent Navigation Technology. June 18-19, 2021, Changsha, China.

[3] Fangwen Yu. **NeuroSLAM: A Brain-Inspired SLAM System For 3D Environments**. The Sixth International Ubiquitous Positioning, Indoor Navigation and Location-Based Services Conference (IEEE UPINLBS 2019), Beijing, China.

[4] Fangwen Yu. **Sensory Landmarks for Indoor Localization**. IEEE UPINLBS 2016, Best Paper Award.

[5] Fangwen Yu. **Approaches and Applications of Continuous Relative Location-Aware Query for Indoor Pedestrians.** China National PhD Academic Forum of Surveying and Mapping, 2015. Best Presentation Award

[6] Fangwen Yu. **Research on Indoor Semantic Location Model for Intelligent Navigation**. ISPRS Geospatial Database and Location Based Services, Workshop of 3D Indoor Modelling and Navigation, 2014.

Membership

- Member of IEEE
- Member of IEEE Robotics and Automation Society (IEEE-RAS)
- Member of IEEE-RAS Technical Committee on Cognitive Robotics
- Member of IEEE-RAS Technical Committee on Neuro-robotics Systems
- Member of Royal Institute of Navigation (RIN)
- Member of China Computer Federation (CCF)
- Member of Chinese Association for Artificial Intelligence (CAAI)
- Member of Chinese Neuroscience Society (CNS)
- Member of Chinese Association of Automation (CAA)

Academic Services

- Guest Editor of the topic on Future Navigation in Satellite Navigation.
- Chair of Brain-inspired Navigation Session of the 7th International Conference on Ubiquitous Positioning, Indoor Navigation and Location-based Services (UPINLBS2022), 3.18-3.19, 2022, Wuhan, China
- Coordinator of the topic on Brain-inspired Navigation and Sensing for Robots in the Frontiers in Neurorobotics.
- Reviewer for ACM Computing Surveys, Robotics: Science and Systems 2024, Biological Cybernetics, Journal of Navigation, Satellite Navigation, Frontiers in Neurorobotics, Frontiers in Neuroscience, Frontier in Comp Neuroscience, Frontier in Robotics and AI, International Joint Conference on Neural Networks (IJNN), IEEE Transactions on Cognitive and Developmental Systems, Journal of Intelligent & Robotic System, International Journal of Social Robotics, etc.
- Member of Brain-inspired Navigation and Advanced Navigation Session of the 10th International Conference on Guidance, Navigation and Control (ICGNC2022), 8.05-8.07, 2022, Harbin, China

Language Skills and Computer Background

- **English level:** full professional proficiency
- **Chinese level**: native speaker
- **Programming Languages**: C++, C, Python, Java, etc. (under ROS, Linux, Windows)
- **Programming Methodologies:** OO Design, Common Design Pattern, RUP
- **Neuromorphic Chip Foundation:** Tianjic, Lynchip programming and usage
- **Robotics:** Clearpath Jackal, Unitree B1, Go1, Z1, AmovLab Drone
- **Databases:** MySQL, PostgreSQL, Oracle
- **Web Technologies:** Apache, Java Servlets, JavaScript, etc.
- **Mathematic Tools:** MATLAB