香港科技大学(广州)
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY (GUANGZHOU)

系统枢纽
SYSTEMS HUB

智能交通学域
INTELLIGENT TRANSPORTATION THRUST

Introduction

Graduate Course INTR-6000P

Week 1 - Lecture 1

Changhao Chen
Assistant Professor
HKUST (GZ)

Instructor

Changhao Chen

- Assistant professor,
- PhD, University of Oxford (2020).

Email: changhaochen@hkust-gz.edu.cn

Experience & Education:

- Assistant Professor, INTR and AI Thrust, The Hong Kong University of Science and Technology (Guangzhou), Jan 2025 - Now
- Lecturer, National University of Defense Technology (NUDT), Dec 2020 – Dec 2024
- Postdoctoral Researcher, University of Oxford, Feb 2020 – Oct 2020
- Ph.D. in Computer Science, University of Oxford, Oct 2016 - Oct 2020
- Master in Control Science and Technology, National University of Defense Technology (NUDT), Sept 2014 – Sept 2016

Instructor

Changhao Chen

- Assistant professor,
- PhD, University of Oxford (2020).

Email: changhaochen@hkust-gz.edu.cn

Research Interests:

3D Scene Perception
System State Estimation
Embodied AI
Efficient Neural Computing

Awards:

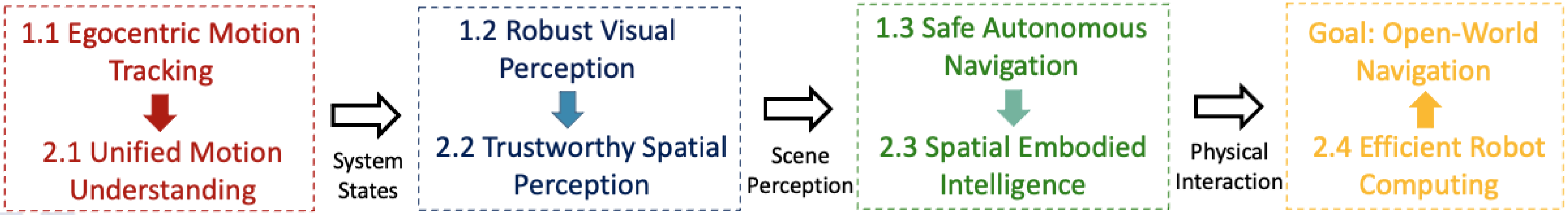
- World's Top 2% Scientists (2024)
- Young Elite Scientist Sponsorship Program, CAST (2022)
- Robotics: Science and Systems Pioneers (2020)

Research Outcomes:

- PI for NSFC General Program and Youth Program
- Published over 50 high-quality papers in the fields of AI, intelligent transportation, and robotics, including top journals such as TITS, TNNLS, TMC, and TIP, as well as top-tier conferences including CVPR, ICCV, AAAI, ECCV, ICRA, IROS, with over 3,200 Google Scholar citations.
- Granted 14 patents, including international PCT patents, and patents from China, the US, Europe, and Australia, including one successfully commercialized in the UK.

Our Research

- HKUST (GZ) PEAK-Lab is a research group dedicated to embodied AI and autonomous systems.
- Traditional robotic algorithms often depend on meticulously crafted physical and geometric models, which may struggle to the ever-changing complexities of the open world.
- Our mission is to bring AI into the physical open world by enabling machines to understand general motion, perceive 3D scenes, and actively navigate and interact with their surroundings.



Homepage: changhao-chen.github.io/

PEAK Lab

Perception, Embodiment, Autonomy, Kinematics

What is an intelligent vehicle

Self-driving Vehicles

An intelligent vehicle is a vehicle equipped with advanced sensors, computing systems, and algorithms that allow it to perceive its environment, make decisions, and assist or even replace the human driver.

What is an intelligent vehicle

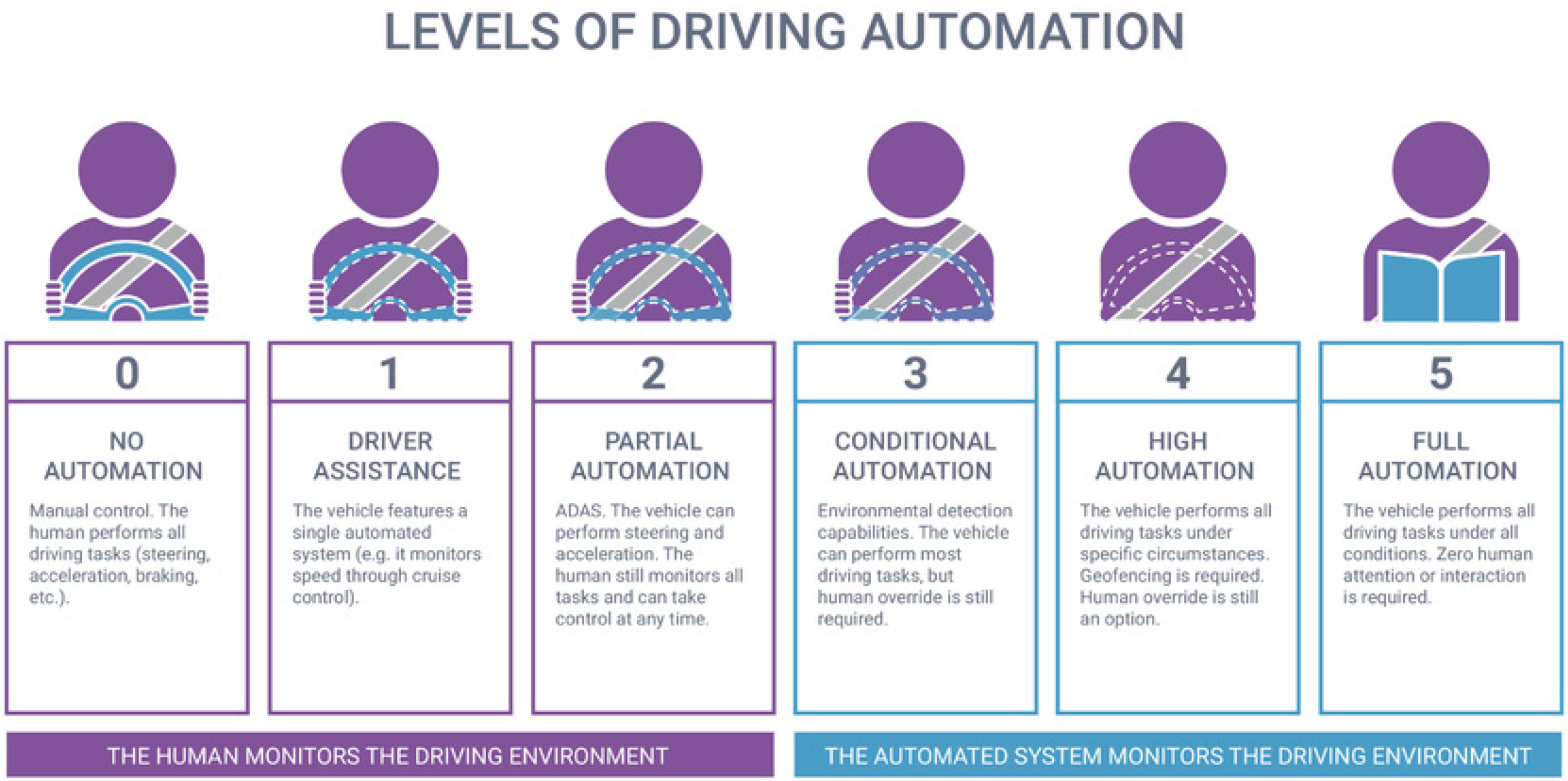
Trucks & Intelligent Port


Delivery Robots


Drones


Underwater Vehicles

Why navigation matters for autonomy and safety



- Navigation = “knowing where you are and where you’re going”
- Without reliable navigation → autonomy fails

From GPS-based to vision-based navigation

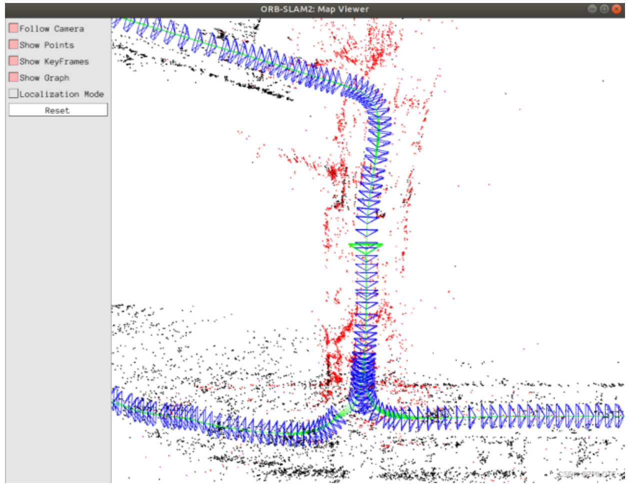
- Perception is important
- Early reliance on GPS + IMU (limited indoors, urban canyons, tunnels)
- Addition of LiDAR and radar for mapping
- Shift to vision-based navigation → affordable, rich semantic infomation
- Today: Vision is central to most autonomous driving stacks

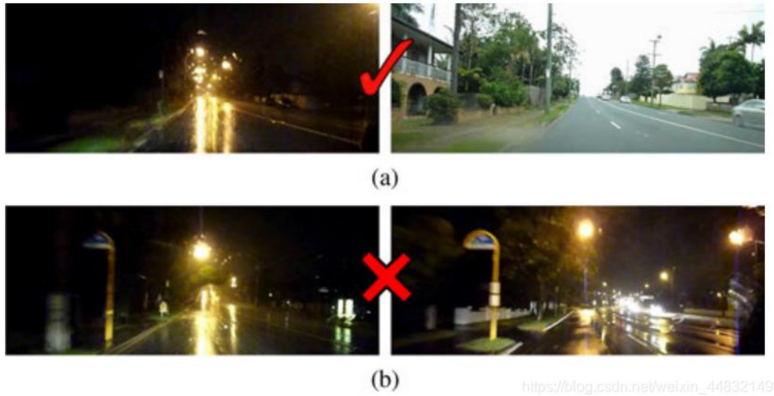
Key Ability - Perception

Object Detection and Tracking

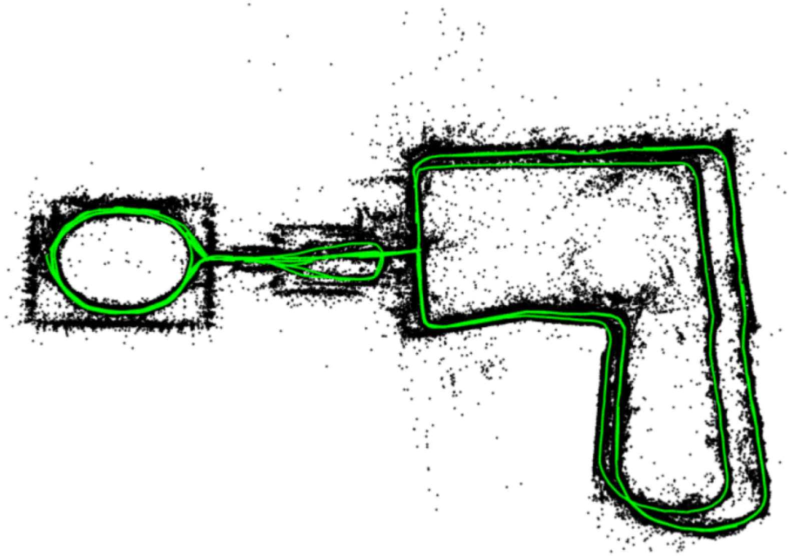
Semantic Understanding

Key Ability – Visual Localization and Mapping



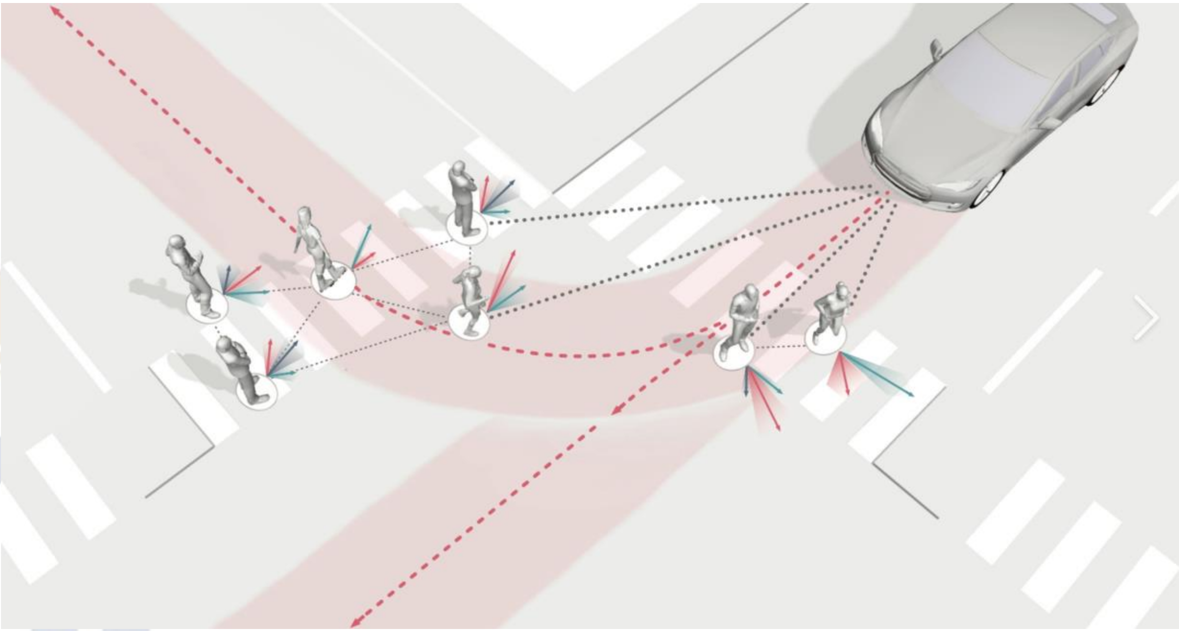


Localization- Place Recognition

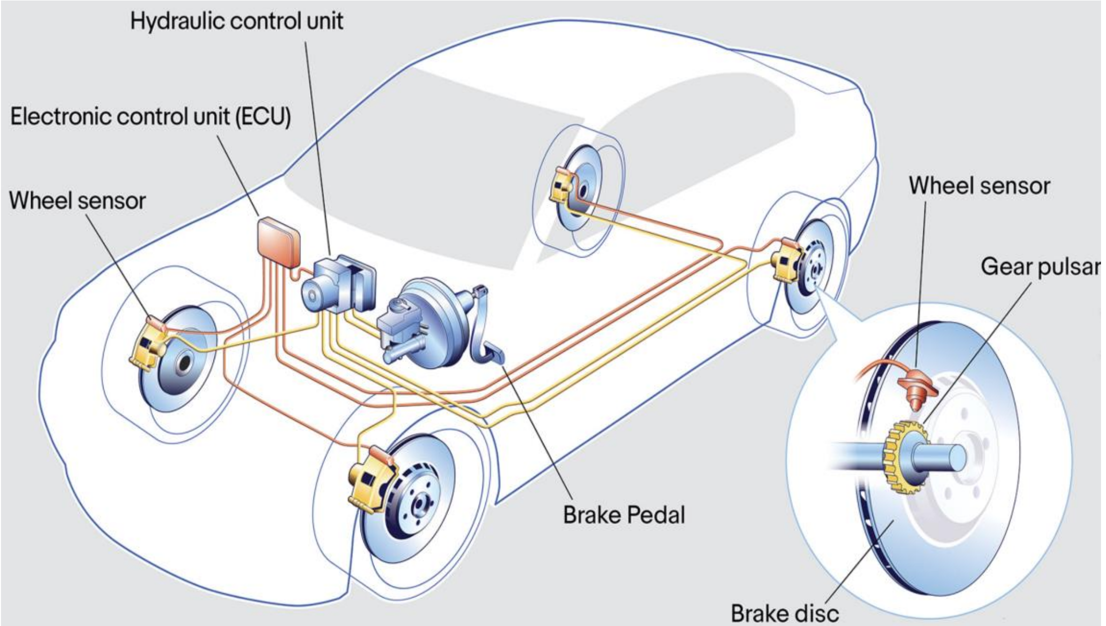


Mapping

Key Ability - Planning and Control



Trajectory Planning



Vehicle Motion Control

Key Ability - End-to-end Self-Driving

End-to-end Self-Driving :

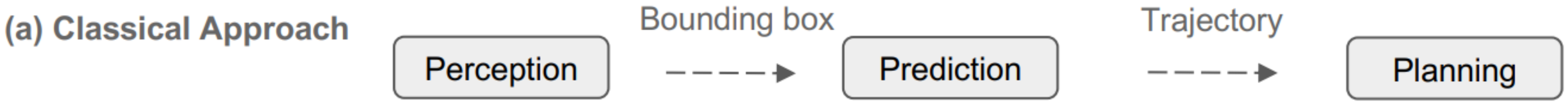
Simplicity in combining perception, prediction, and planning

Optimization of system and intermediate representations

Computational efficiency through shared backbones

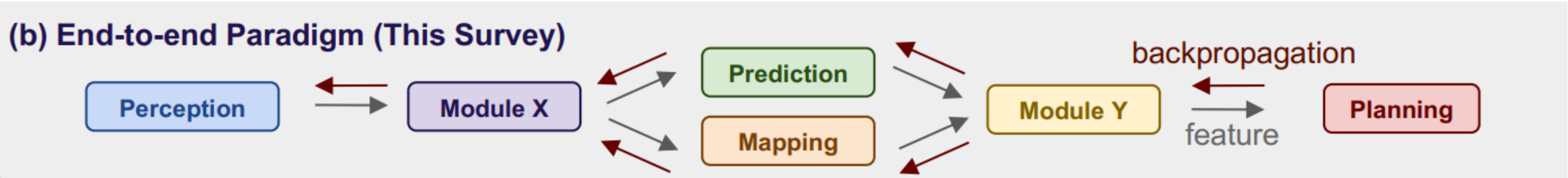
Data-driven optimization via resource scaling

Traditional Modular Navigation:



vs.

End-to-End Navigation:

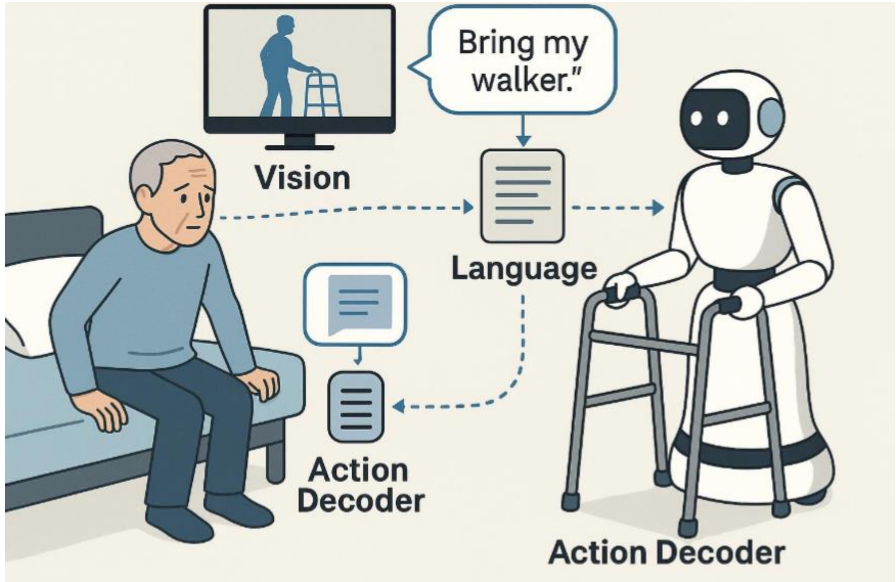


Key Ability - Embodied AI

VLA models jointly process visual inputs, interpret natural language, and generate executable actions in dynamic environments.

VLA models enable robots to jointly perceive, understand language, and act, overcoming the fragmentation of earlier approaches and marking a major step toward adaptive, generalizable, and intelligent embodied agents.

Visual-Language Navigation: an autonomous agent must navigate through a complex, previously unseen, 3D environment by following natural language instructions.



Course Roadmap

What you will learn:

- Background knowledge about Intelligent Vehicles and Visual Navigation
- 3D vision foundations
- Visual Localization and Mapping
- Sensor fusion and Vehicle Control
- AI for vehicle navigation

Expectations: hands-on projects, case studies, discussions

Research frontiers & open questions

INTR 6000P - Visual Navigation for Intelligent Vehicles

Week	Lecture	Date	Topics	
1	1	Tuesday, Sep 2	Introduction	Introduction
1	2	Tuesday, Sep 2	Visual Navigation System Overview	
2	3	Tuesday, Sep 9	3D Motion Model	3D Vision Foundations
2	4	Tuesday, Sep 9	Lie Groups	
3	5	Tuesday, Sep 16	Camera Model	
3	6	Tuesday, Sep 16	Feature Detection & Description	
4	7	Tuesday, Sep 23	Visual Pose Estimation	Visual Localization and Mapping
4	8	Tuesday, Sep 23	Feature-Based Visual Odometry	
5	9	Sunday, Sep 28	Direct Visual Odometry	
5	10	Sunday, Sep 28	Place Recognition	
6	11	Tuesday, Sep 30	Filtering and State Estimation	
6	12	Tuesday, Sep 30	Non-Linear Optimization	
7	13	Tuesday, Oct 14	Scene Reprensentation	
7	14	Tuesday, Oct 14	Mapping	
8	15	Tuesday, Oct 21	Inertial Integration	Multisensor Fusion & Vehicle Control
8	16	Tuesday, Oct 21	Visual-Inertial Navigation	
9	17	Tuesday, Oct 28	Point Cloud Processing	
9	18	Tuesday, Oct 28	LiDAR-Visual Navigation	
10	19	Tuesday, Nov 4	Trajectory Planning	
10	20	Tuesday, Nov 4	Vehicle Motion Control	
11	21	Tuesday, Nov 11	Enhancing Visual SLAM with Deep Learning	AI for Vehicle Navigation
11	22	Tuesday, Nov 11		
12	23	Tuesday, Nov 18	Embodied Navigation	
12	24	Tuesday, Nov 18	End-to-End Self-Driving	
13	25	Tuesday, Nov 25	Project Presentation	
13	26	Tuesday, Nov 25		

Grading

Course Assessment Breakdown:

- Final Project (55%):

Implementation of a SLAM System and evaluation in challenging vehicle navigation scenes
Final Presentation

- Reading & Report (30%)

Paper Reading
Report Submission

- Course Tests (15%)

Scan QR Code
Three Tests (5% each)

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Tools

Tools we will use:

1. ROS
2. Pytorch
3. OpenCV

Programming Language:
C/C++ and Python

PyTorch

OpenCV

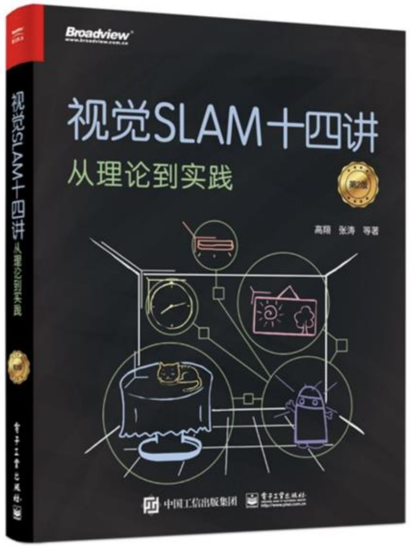
TextBooks

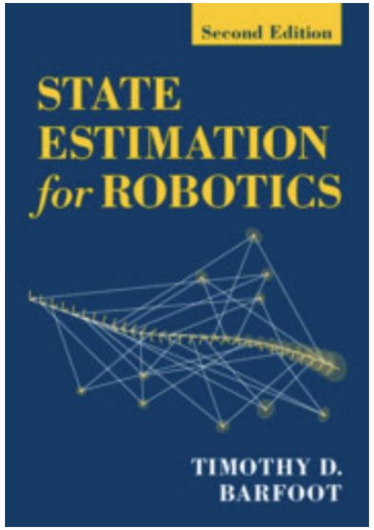
1. Xiang Gao, Tao Zhang, Fourteen Lectures on Visual SLAM: From Theory to Practice, Electronic Industry Press, 2019.

2. Timothy Barfoot. State Estimation for Robotics. Cambridge University Press.

3. Sebastian Thrun, Wolfram Burgard, and Dieter Fox, Probabilistic Robotics, MIT Press, 2005.

4. Richard Hartley and Andrew Zisserman, Multiple View Geometry in Computer Vision, Cambridge University Press, 2004.





Important Sources

Journals:

- IEEE Transactions on Robotics
- The International Journal of Robotics Research
- IEEE Robotics and Automation Letters
- Journal of Field Robotics
- Science Robotics

Conferences:

- Robotics: Science and Systems
- IEEE International Conference on Robotics and Automation
- IEEE/RSJ International Conference on Intelligent Robots and Systems
- Computer Vision and Pattern Recognition
- International Conference on Computer Vision
- Neural Information Processing Systems

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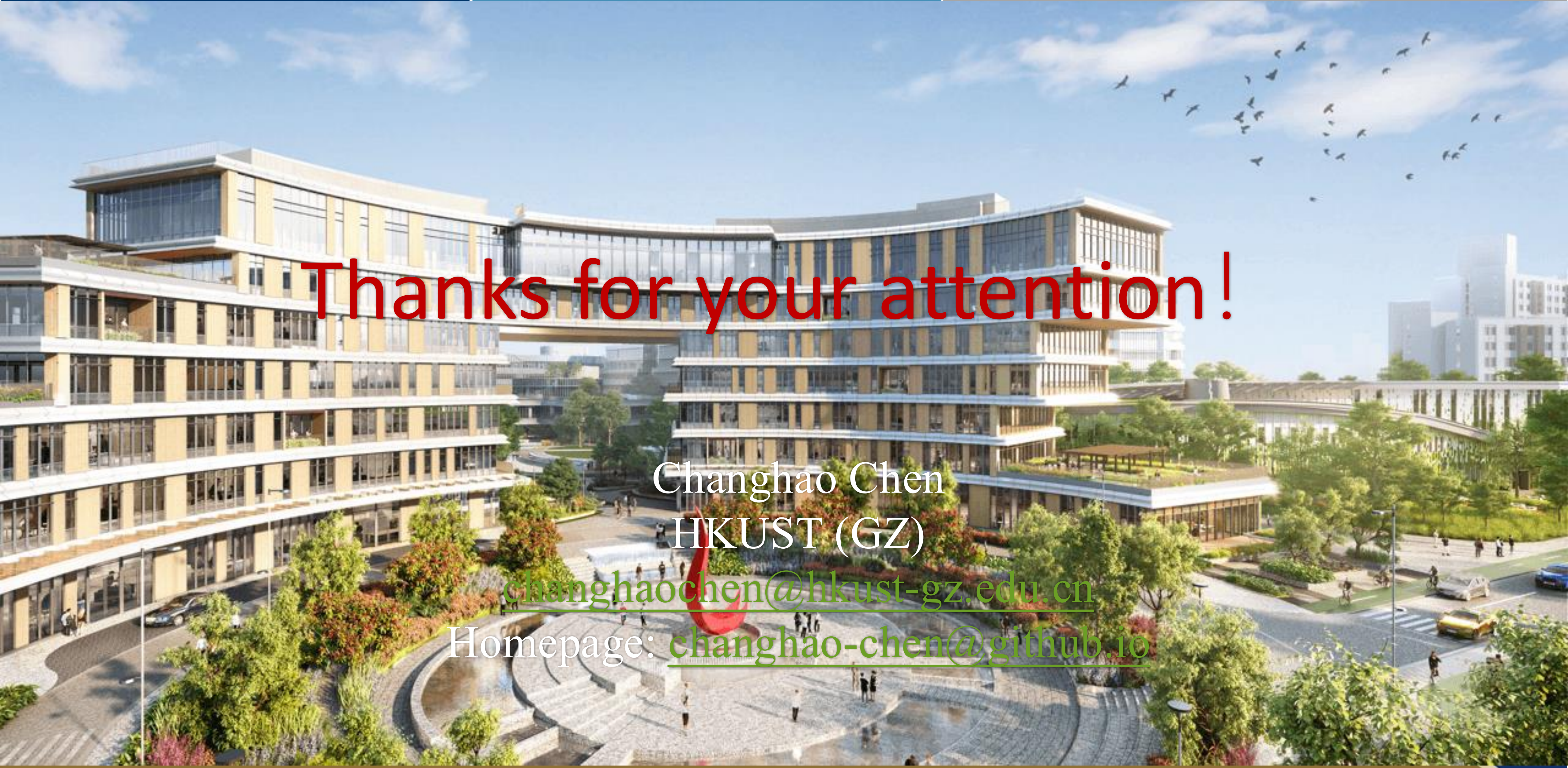

Thanks for your attention！

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