



香港科技大學
THE HONG KONG
UNIVERSITY OF SCIENCE
AND TECHNOLOGY



2023 Shenzhen IC Summit

Enabling Technologies for Multi-Robot Human Collaboration

实现多机器人与人協同合作的科技

C. Patrick Yue 俞捷

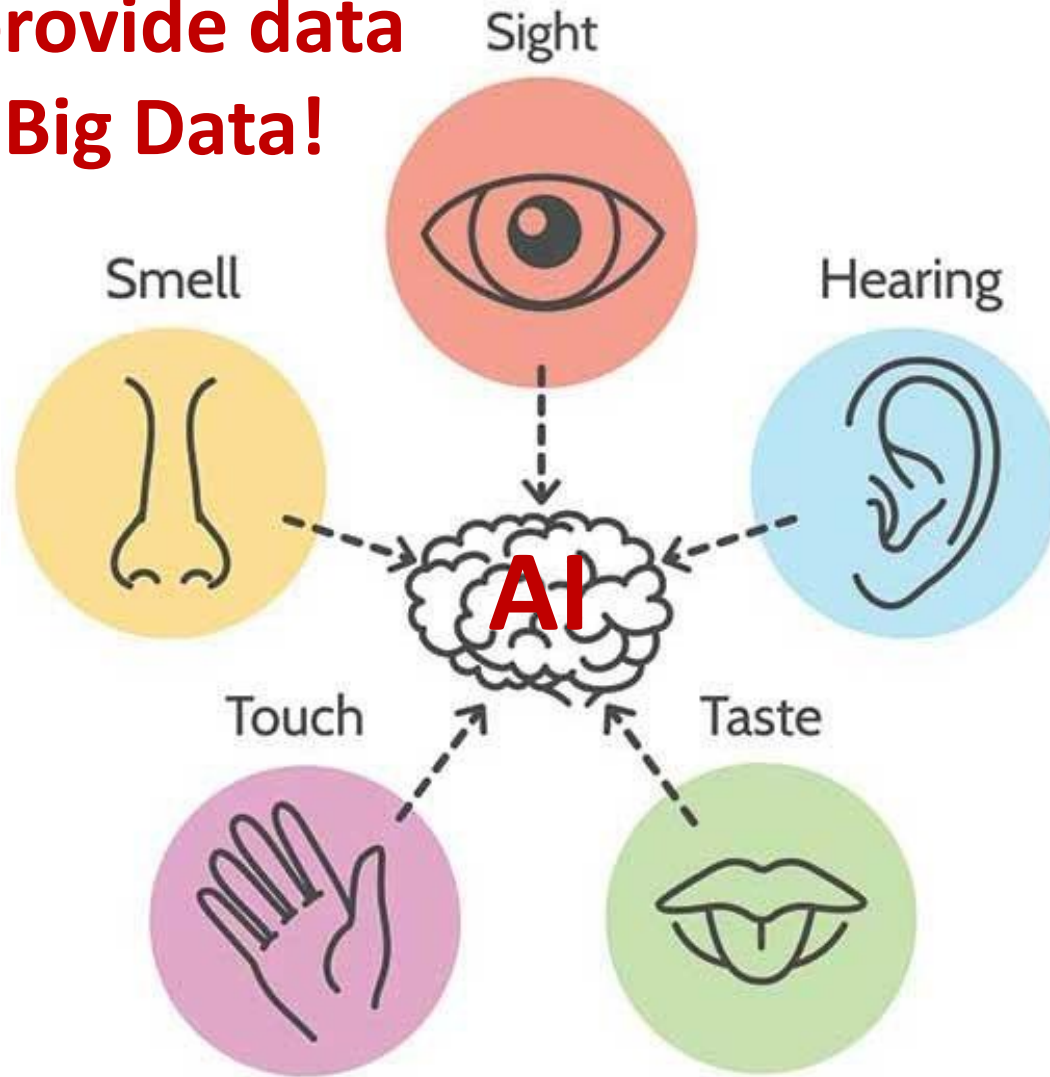
**Integrated Circuit Design Center (ICDC) & Optical Wireless Lab (OWL)
Department of Electronic and Computer Engineering (ECE)
The Hong Kong University of Science and Technology (HKUST)**

What is MRH Collaboration?

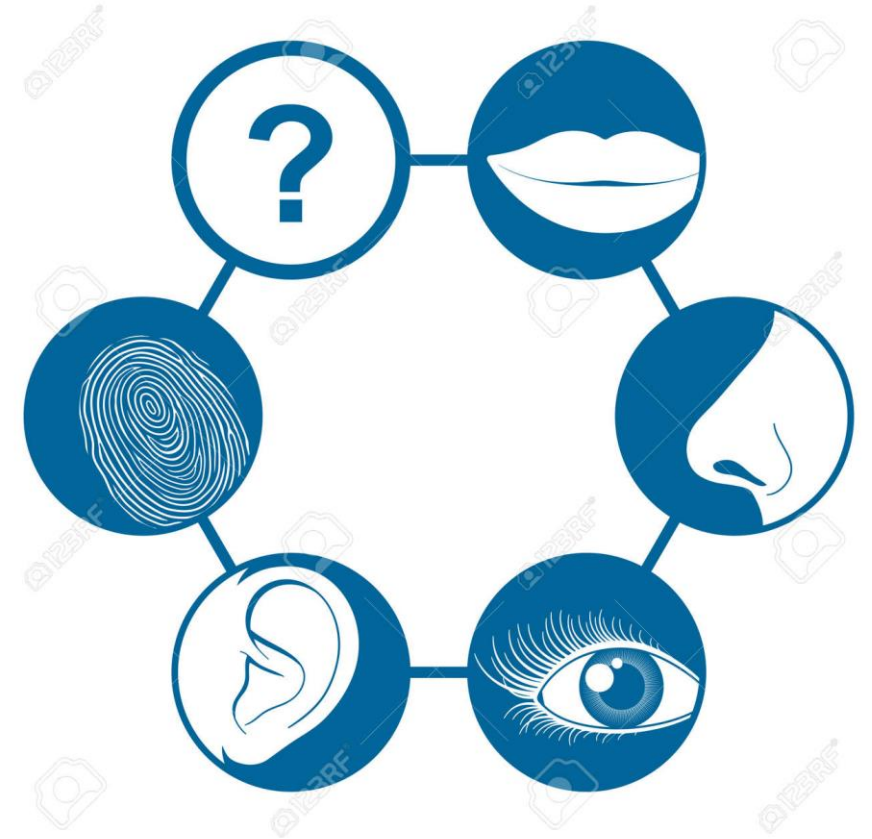


Smart Robots Empowered with AI and Senses

Sensors provide data
Lots of Big Data!



The 6th sense is missing



Some Suggested that 6th Sense is Equilibrium...

6 SENSES



HEARING



VISION



SMELL



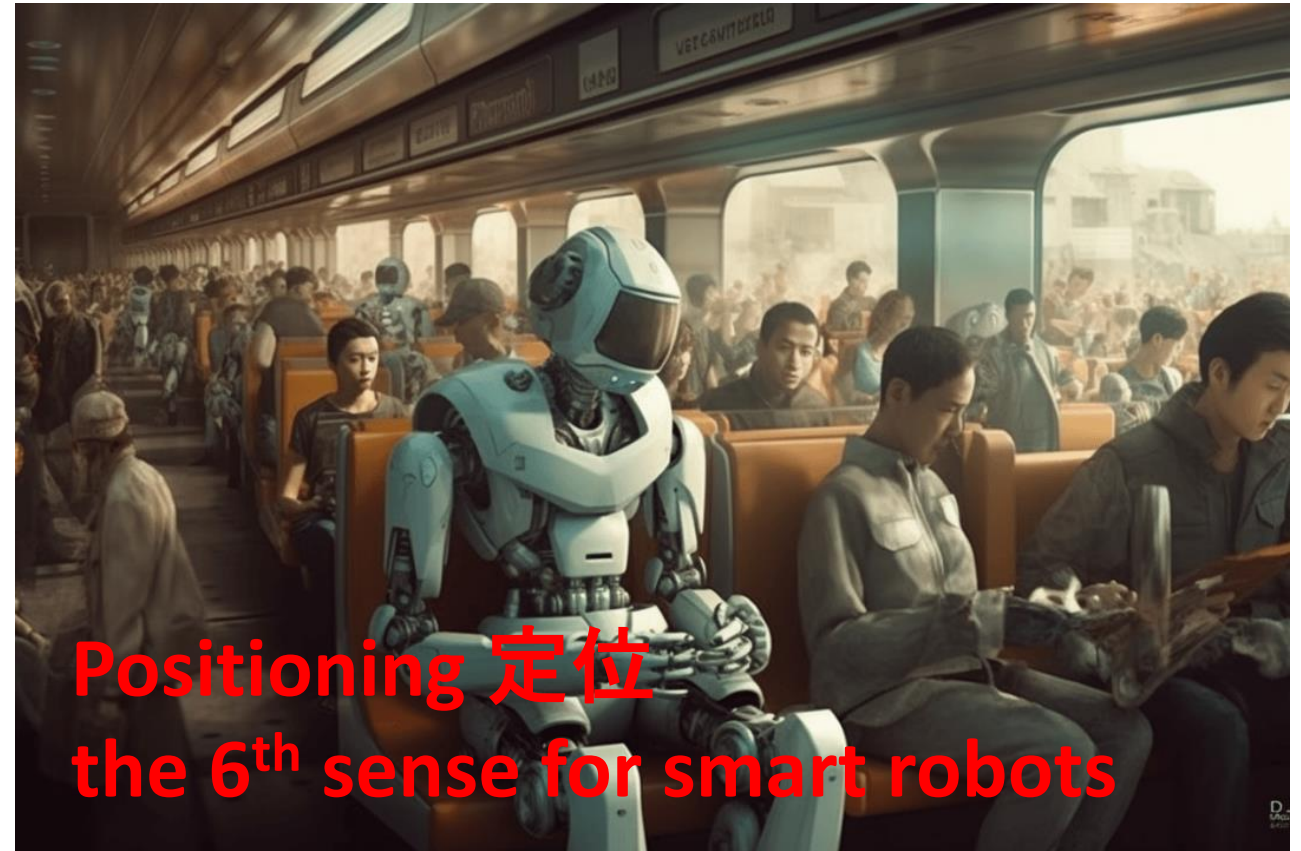
TASTE



TOUCH

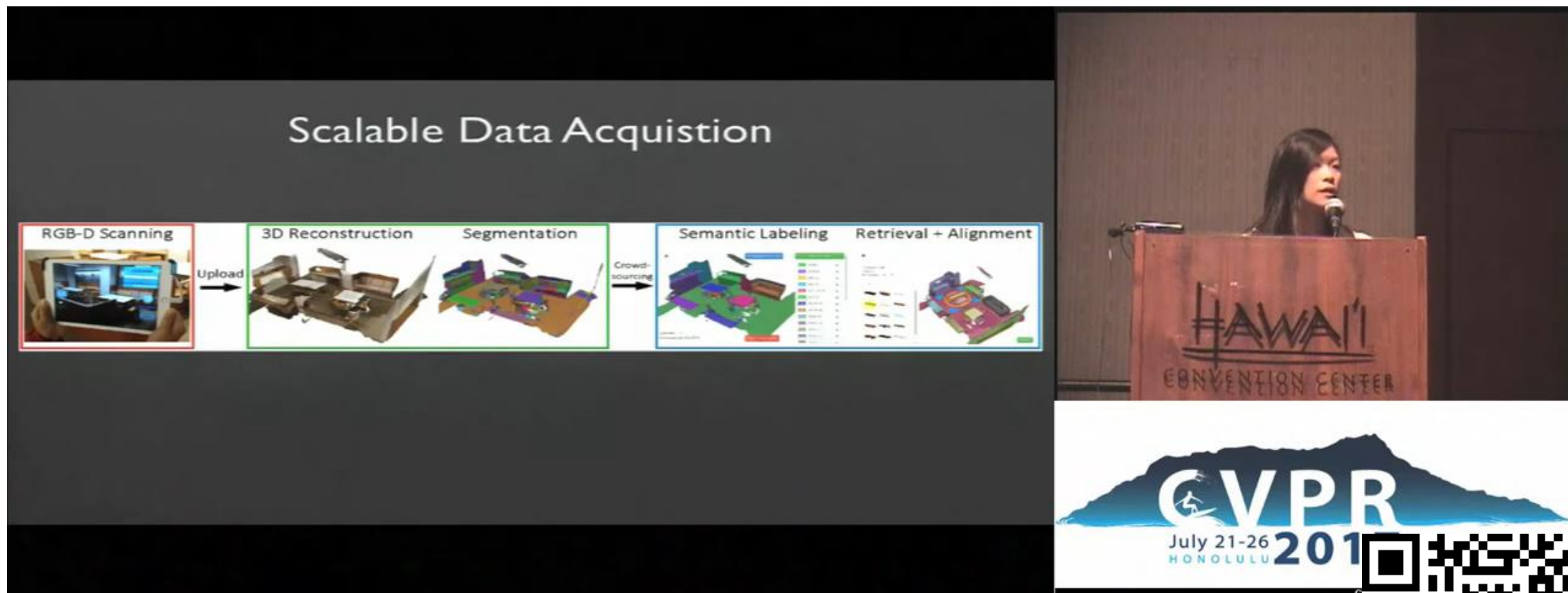


EQUILIBRIUM



Positioning 定位
the 6th sense for smart robots

The 1st Sense – Vision

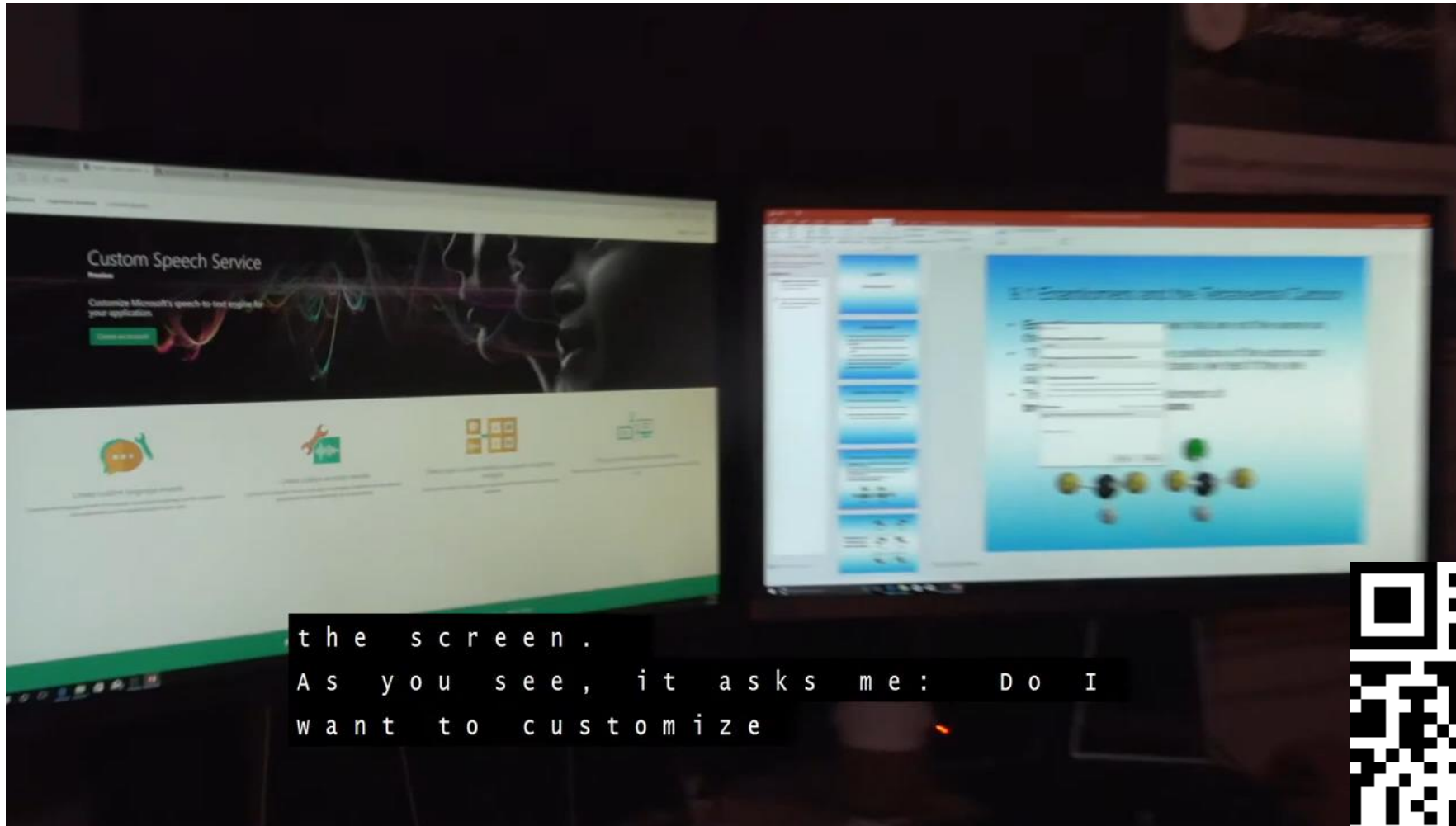


https://www.bilibili.com/video/BV17E411Y7mC/?spm_id_from=333.337

Dai, A. *et al.*, "ScanNet: Richly-annotated 3D Reconstructions of Indoor Scenes," 2017 CVPR.



The 2nd Sense – Speech (Speak and Hear)



<https://www.youtube.com/watch?v=80CPeMLJMEw>



The 4th Sense – Taste



□ <https://www.youtube.com/watch?v=P-V3EqQEuyQ>

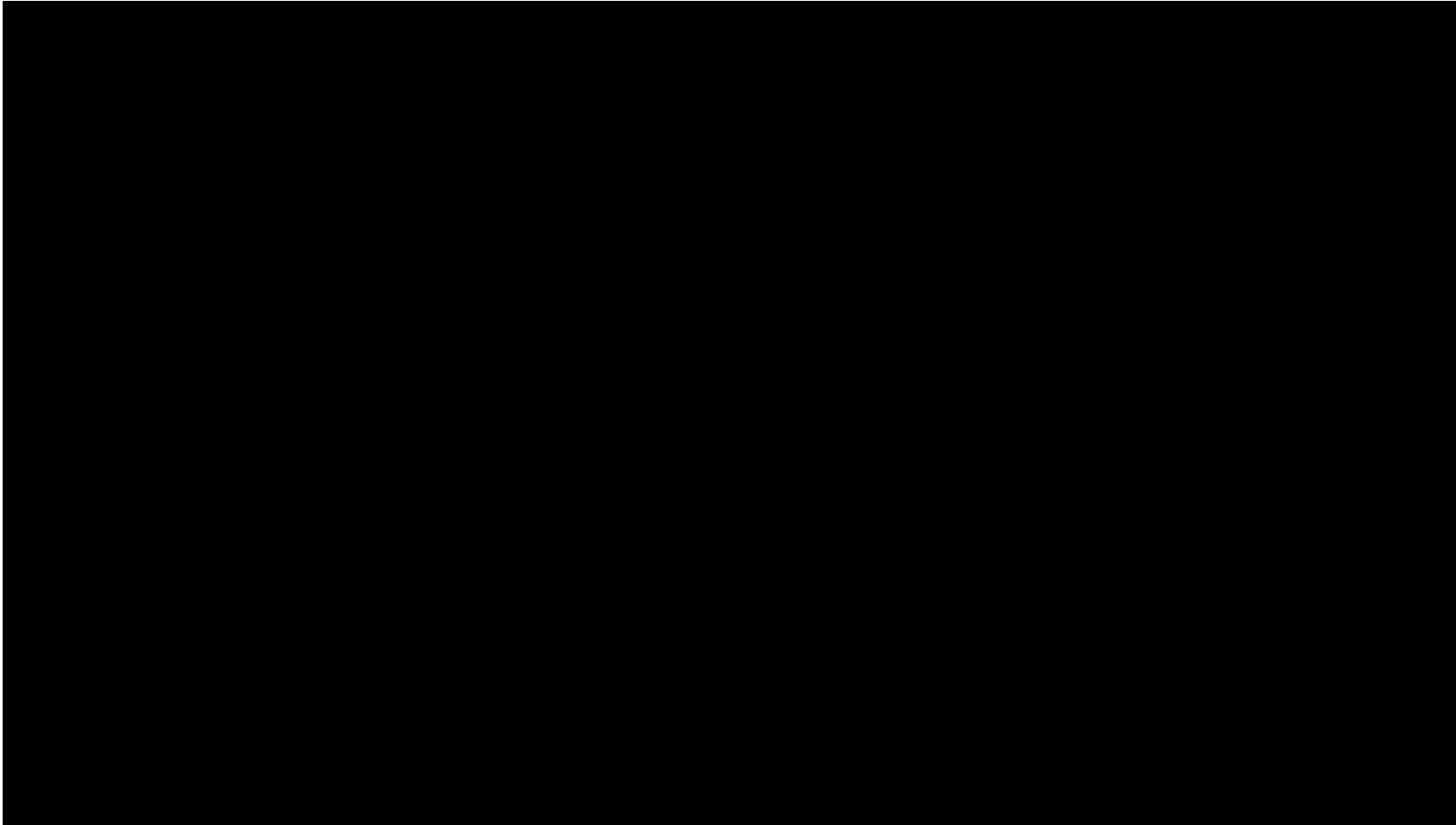


The Fifth Sense - Touching



□ https://www.bilibili.com/video/BV1M4411j7wm/?spm_id_from=333.337

The Sixth Sense - Positioning

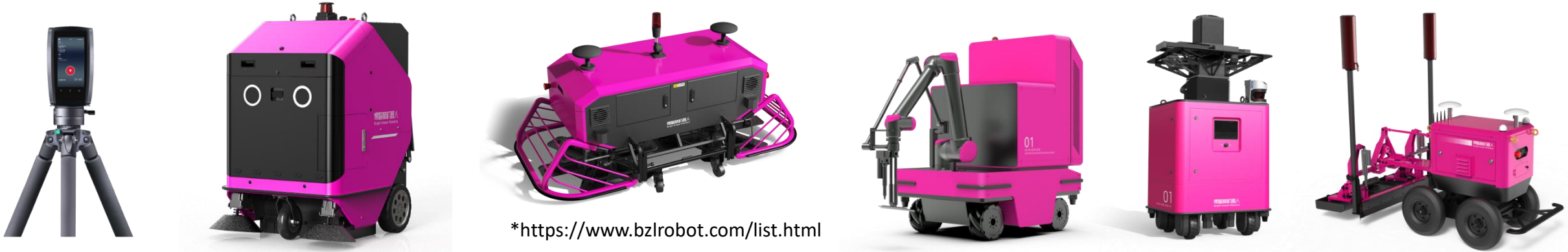


□ <https://www.youtube.com/watch?v=JjalvBHqC94&t=111s%E2%80%8B>



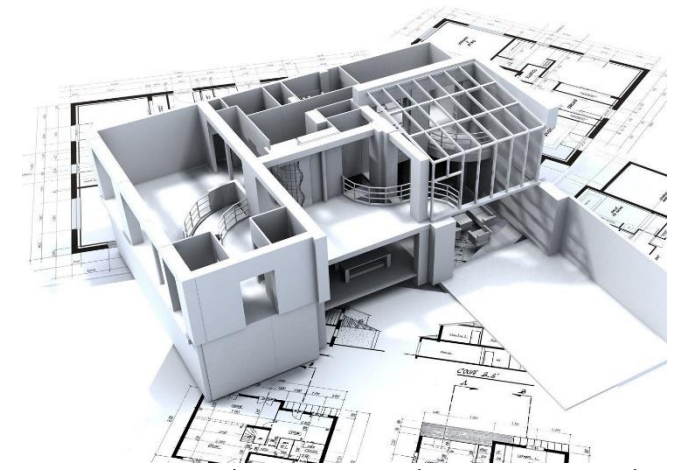
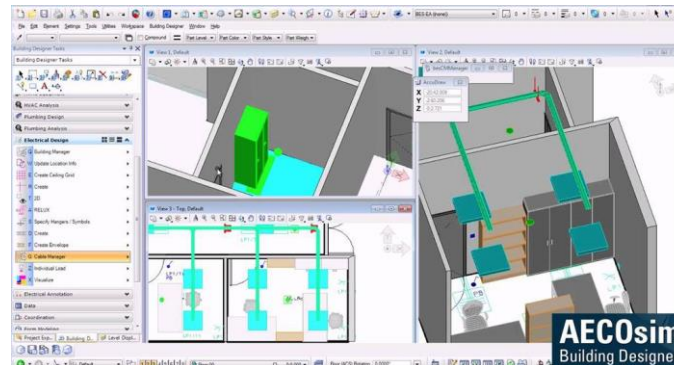
Application-Specific Smart Robots

- ❑ **Robot + AI:** a new flashpoint for the development of the construction industry *



*<https://www.bzlrobot.com/list.html>

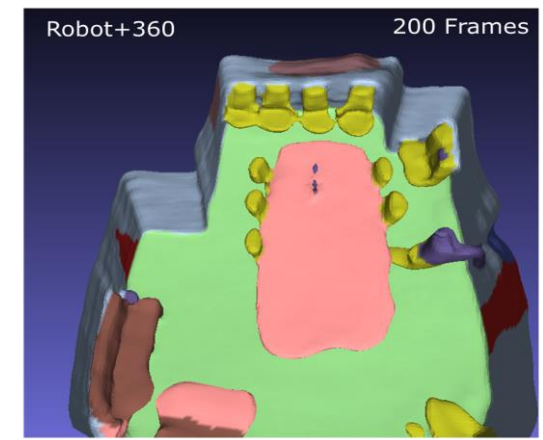
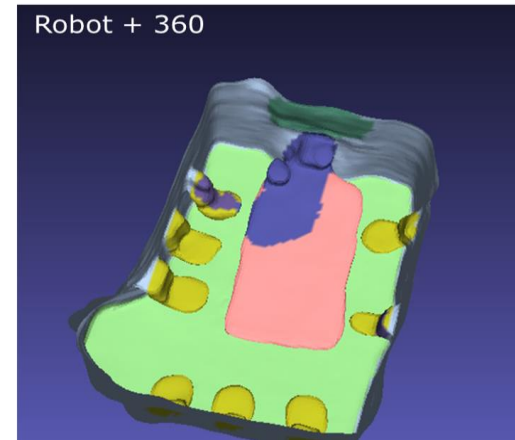
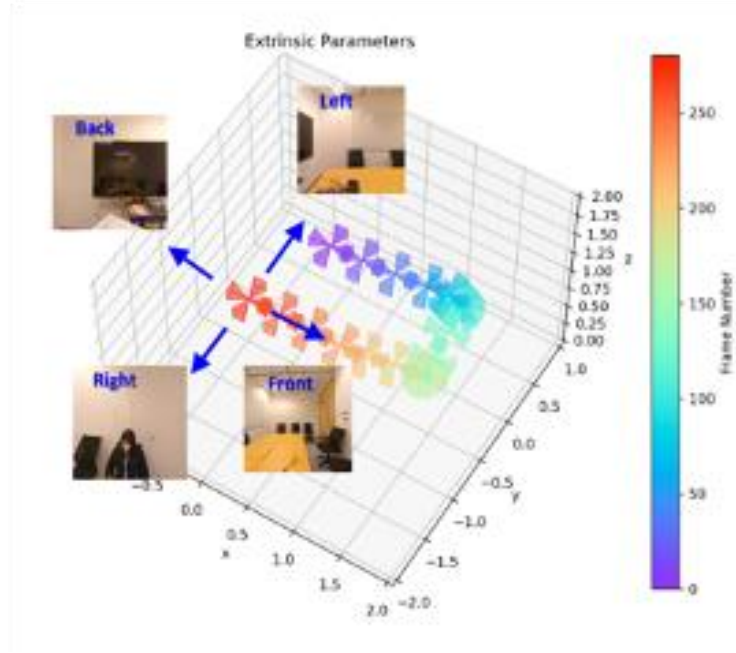
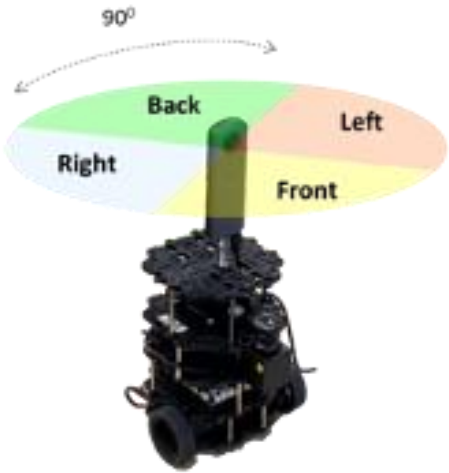
- ❑ **BIM:** the basis for efficient, fast, and autonomous intelligent operations
- ❑ **The future market demand and scale are huge:** reach an estimated \$9 billion by 2025 with a CAGR of 9% to 11% from 2019 to 2025 *



*<https://--ResearchAndMarkets.comwww.businesswire.com/news/home/20210412005399/en/Global-Building-Information-Modeling-Market-2021-2025-Trends-Forecasts-and-Competitive-Analysis->

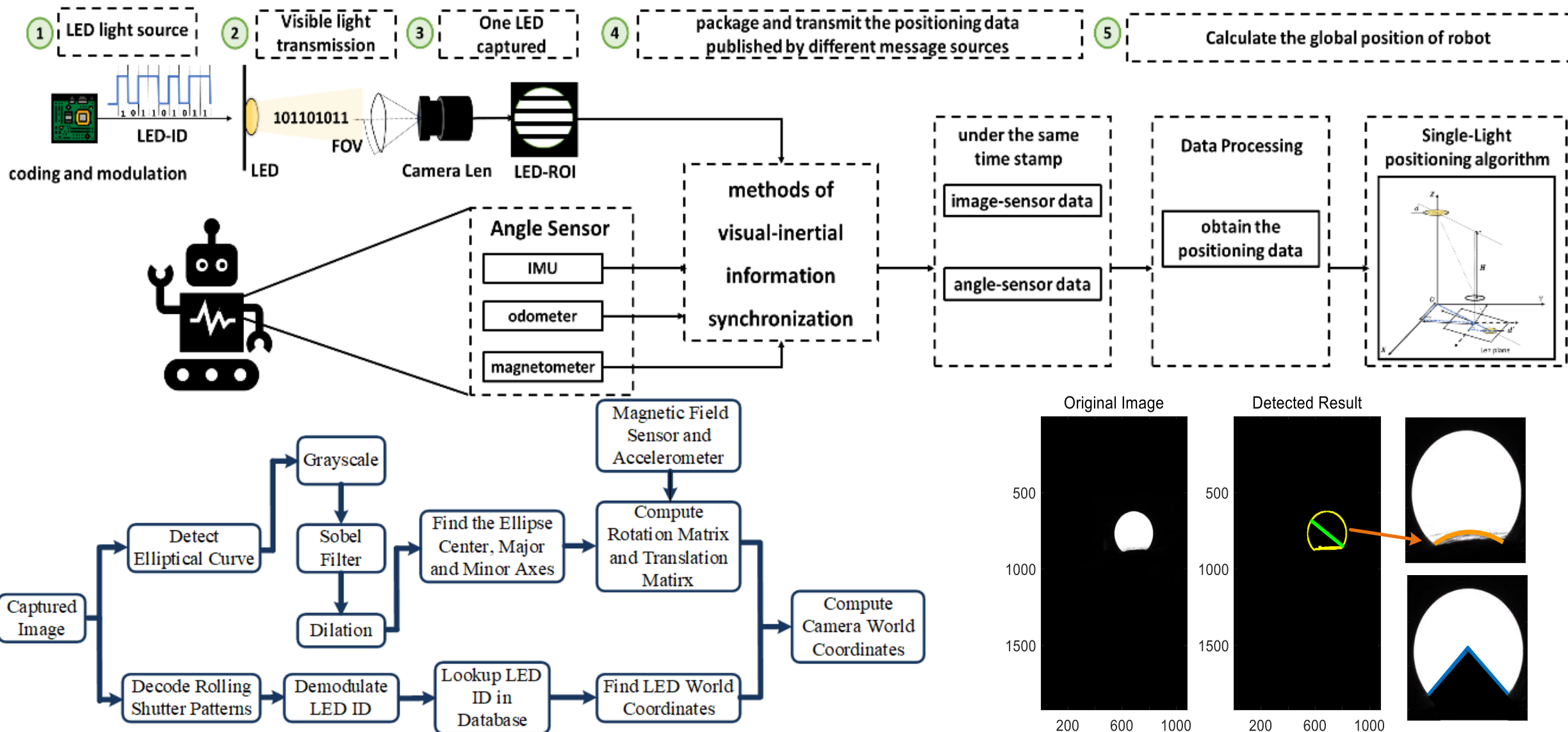
Our Smart Robot Enabling Technologies

1. Positioning: VLP 2. Path planning: RL 3. 3D scene: CDRNet & 360 Camera

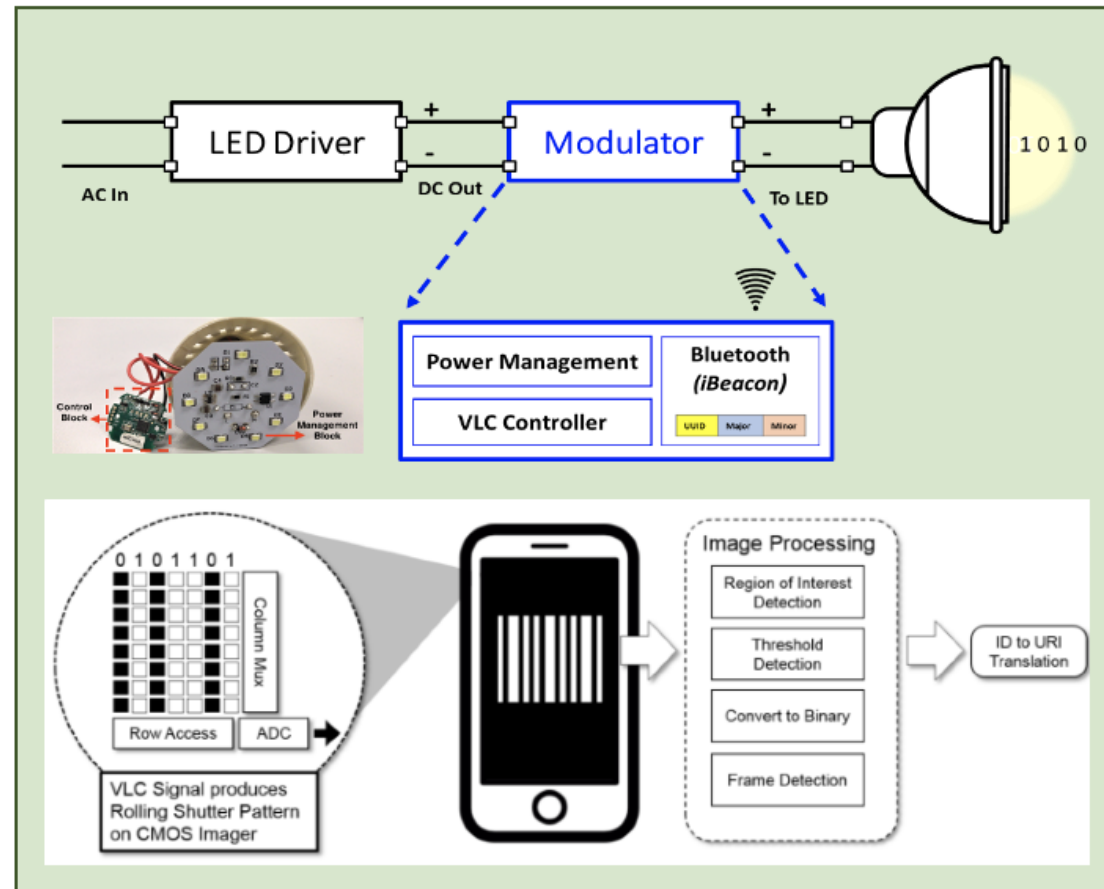
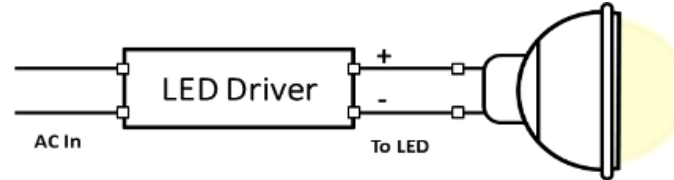


- Visualization of perspective views and the corresponding pose using VLP
- 3D reconstructed model using CDRNet with input images captured using a 360 camera mounted on the robot
- Reinforcement learning for multi-robot path planning and collaborative task

Visible Light Positioning (VLP) for Robot



Enabling VLP in Ordinary LED Lighting



Demo Video for VLP Robotics



Presentation Number: M1B.8

Presentation Time: 5 AM - 7 AM PDT (UTC-07:00), June 7, 2021

High Precision Indoor Robot Localization Using VLC Enabled Smart Lighting

Yiru Wang¹, Weipeng Guan¹, Babar Hussain^{1,2}, C. Patrick Yue^{1,2}

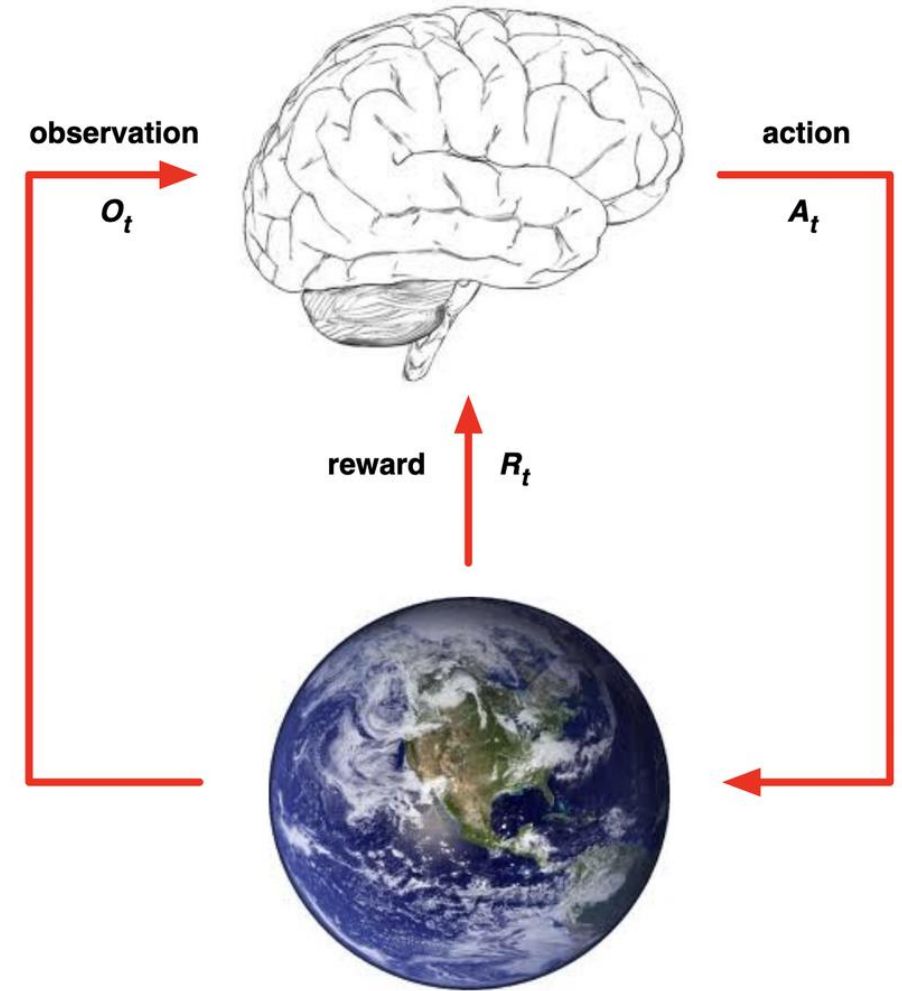
¹ Optical Wireless Lab, IC Design Center, ECE Department, The Hong Kong University of Science and Technology, Hong Kong, S.A.R, China

² LiPHY Communications Limited, Hong Kong, S.A.R, China



Reinforcement Learning (RL)

- ❑ An approach where an agent learns to make optimal decisions by interacting with an environment through trial and error
- ❑ Enables adaptive and versatile behavior across diverse tasks and domains
- ❑ Advantages
 - Ability to learn from experience and adapt to changing environments
 - Can handle complex decision-making problems
 - Offers potential for breakthroughs in various domains such as autonomous systems



Results on Optimizing MARL

- ❑ **Scenario: Multi-agent path finding**
 - Warehouse robotics
 - Multi-robot exploration in hazardous areas
- ❑ **Experiment on optimizing Field-of-View (FOV)**
 - FOV impacts agents' perception, navigation, opportunity awareness and communication in MARL
 - FOV affects coordination and communication through overlapping views
- ❑ **Tested the performance in metrics such as success rate, number of communications, etc.**
 - FOV size does not always correlate with improved performance; increasing it may weaken performance
 - Smaller FOV sizes can be more effective as performance does not decrease proportionally with FOV size

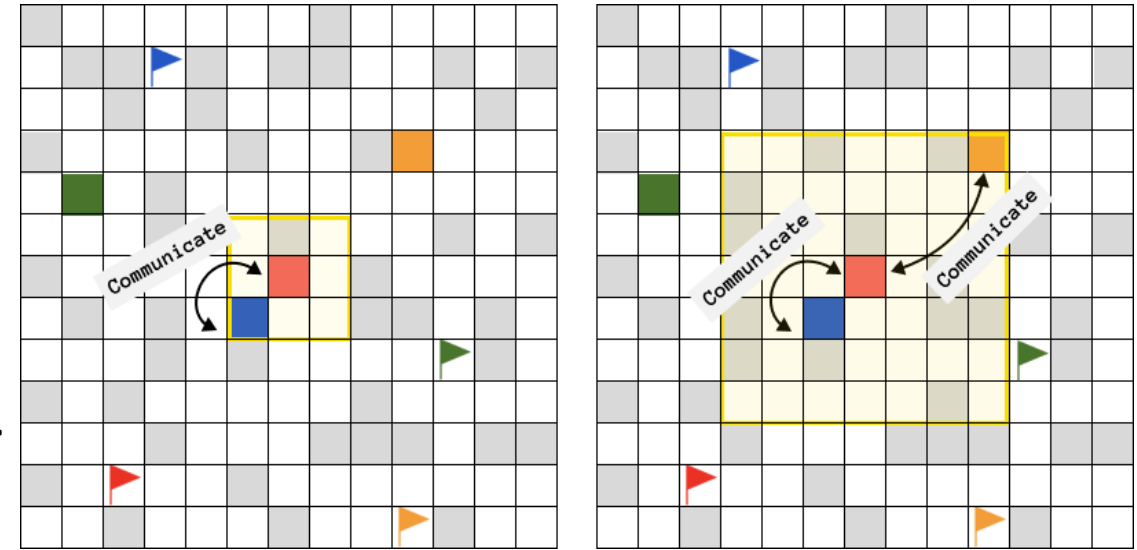
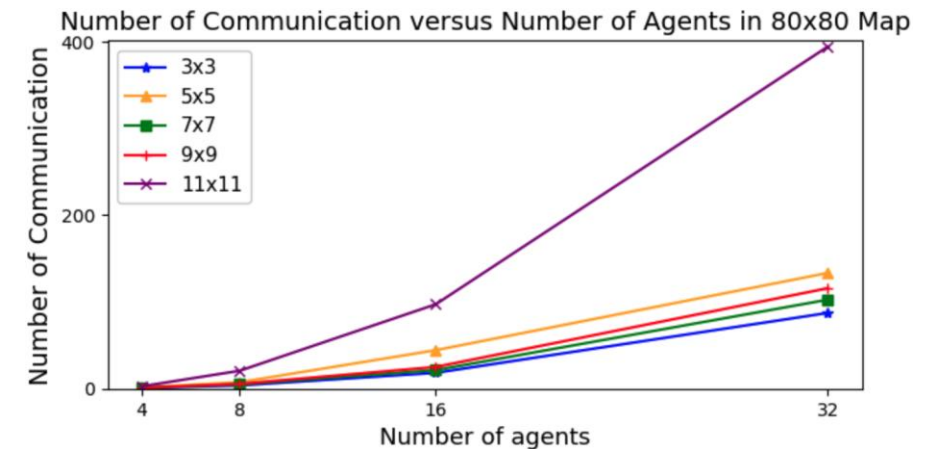
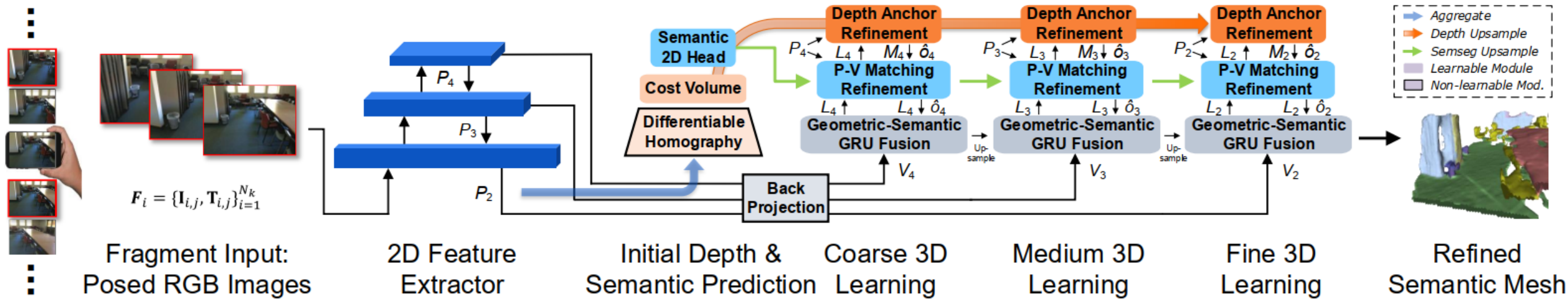


Illustration of 3x3 FOV (left) and 7x7 FOV (right)

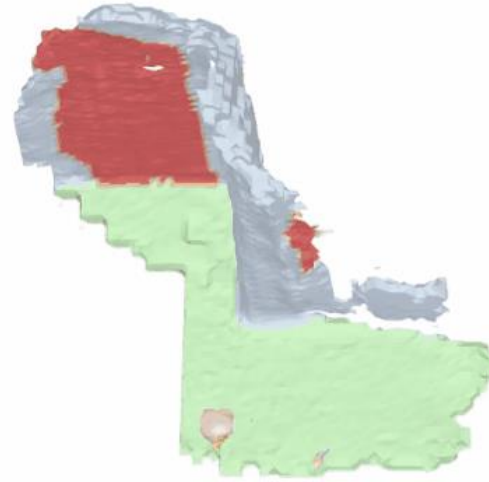
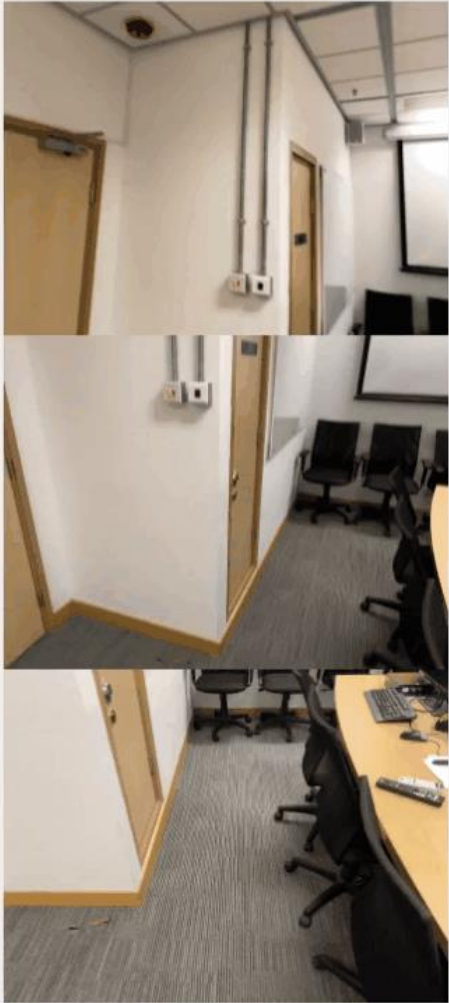


Proposed 3D Perception Pipeline: CDRNet



- ❑ Sparse 3D convolution to improve efficiency
- ❑ Temporal: Using gated recurrent units (GRU) to infer a local truncated signed distance field (TSDF) volume and merge into global features
- ❑ Spatial: 2D explicit inference as a prior knowledge to refine the 3D feature

Real-Time 3D Perception Using CDRNet



See [video](#)

FPS: 158, Fragmented Mesh Rate: 2.38/sec

Market Driven=> Application-Specific => Power Awareness

- ❑ The demand for AI algorithm computing power has surged, and the energy consumption of hardware systems may lead to "Demand exceeds Supply"
 - The amount of algorithm calculations doubles every 3-4 months, and the hardware computing power doubles every 18-24 months
 - The domestic advanced technology is stuck, and it is urgent to break through the limitations of advanced technology blockade on intelligent computing energy efficiency

Computing power requirements

- Doubling every 3-4 months on average

US CHIP Act

- Ban the sale of 14nm and more advanced process circuit design tools and chip manufacturing equipment to China
- The domestic mature technology is 14-28nm, which is two to three generations behind.

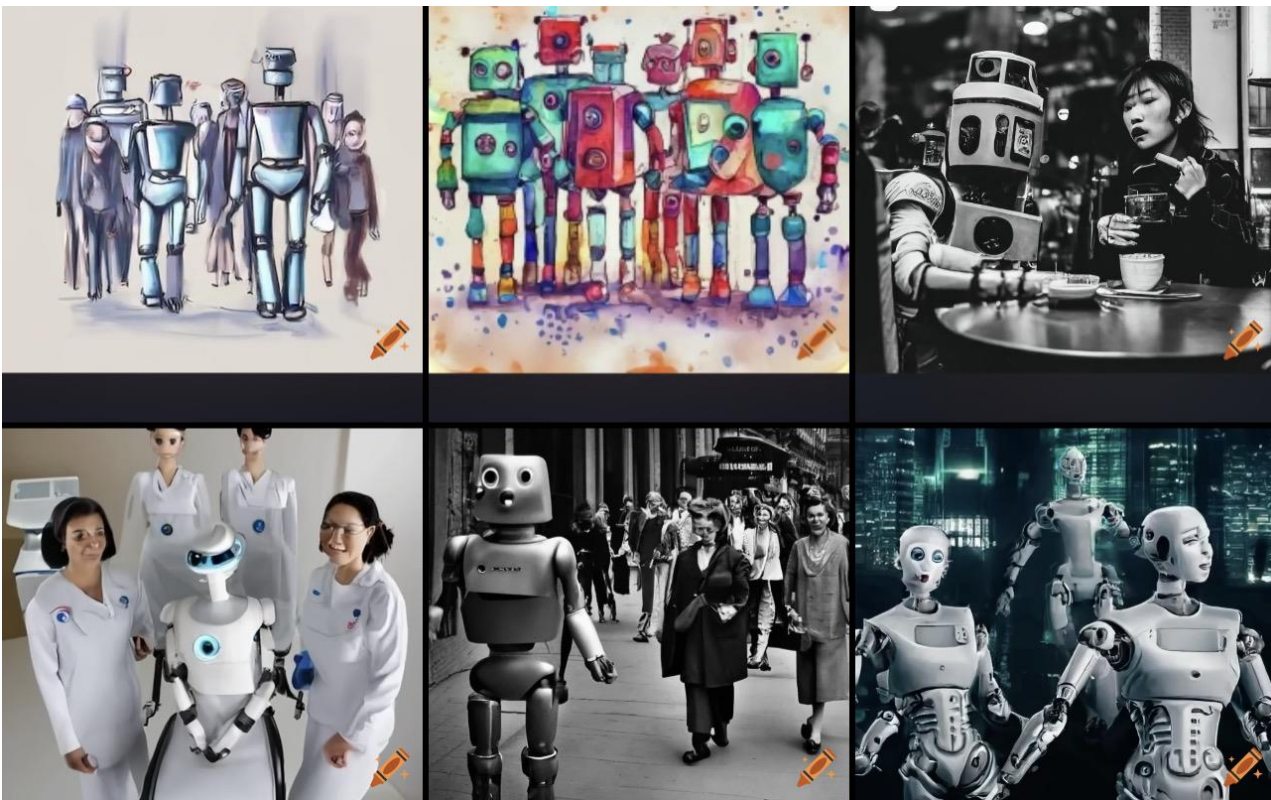
Moore's Law

- Computing power doubles every 18-24 months

"14th Five-Year Plan" National Informatization Plan

- Accelerate research on key integrated circuit technologies, promote innovation in computing chips, storage chips, etc., and accelerate the development of integrated circuit design tools

谢谢!!



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