Status of International Robotics
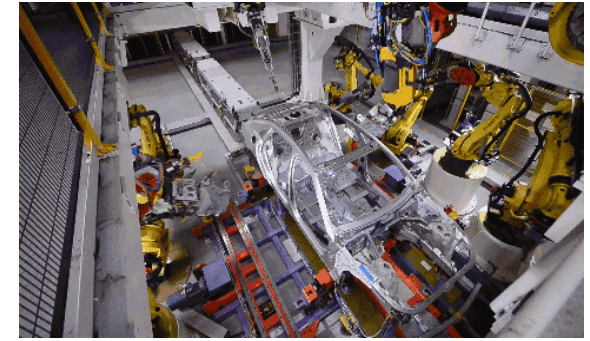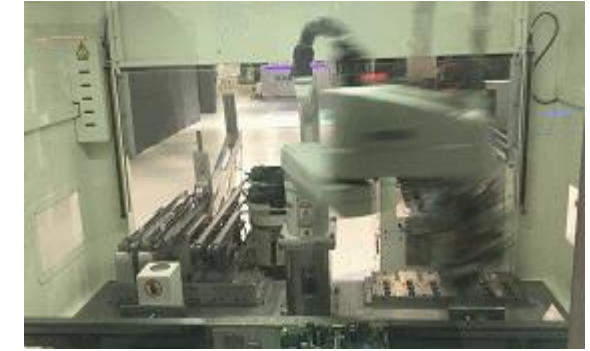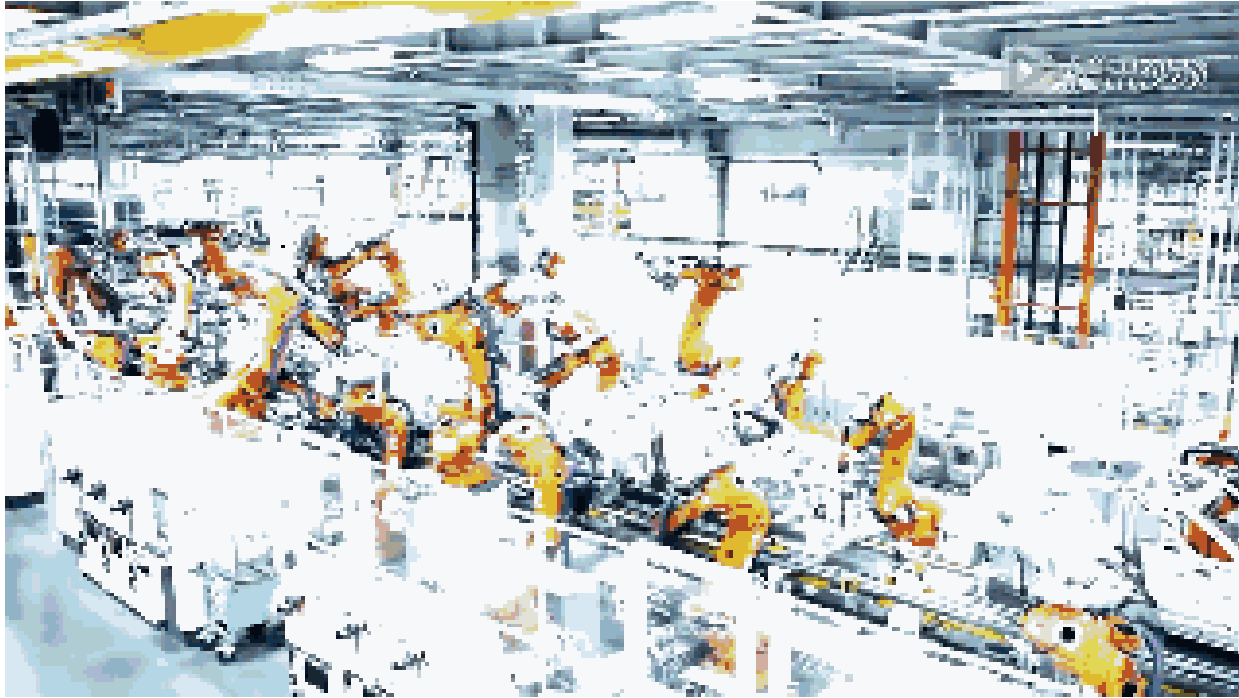
Industrial Robots, Special Robots, Service Robots

Industrial robots

Multi robot collaboration/human-machine integration

South Korea

Robot density in the manufacturing industry 2021
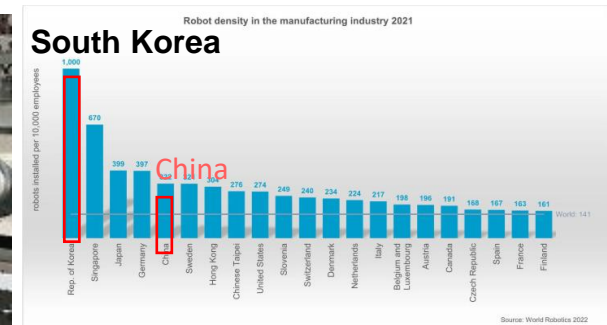
China

Number of robots/10k workers： South Korea: 1000 people, Singapore: 670 people, Japan: 399 people, Germany: 397 people, China: 322 people, United States: 277 people

Special robots

DaVinci minimally invasive surgical robot

High speed, high inertia, dynamic stability control → Microscopic, fine, and agile operation

Service Robots
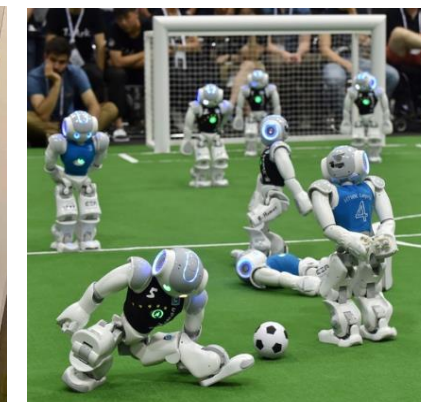
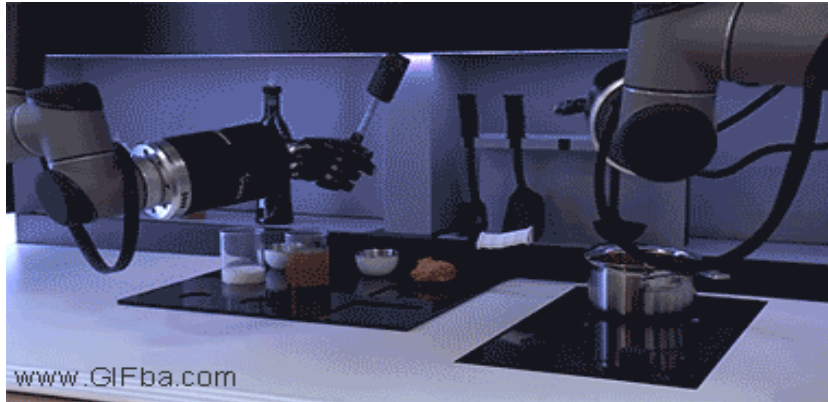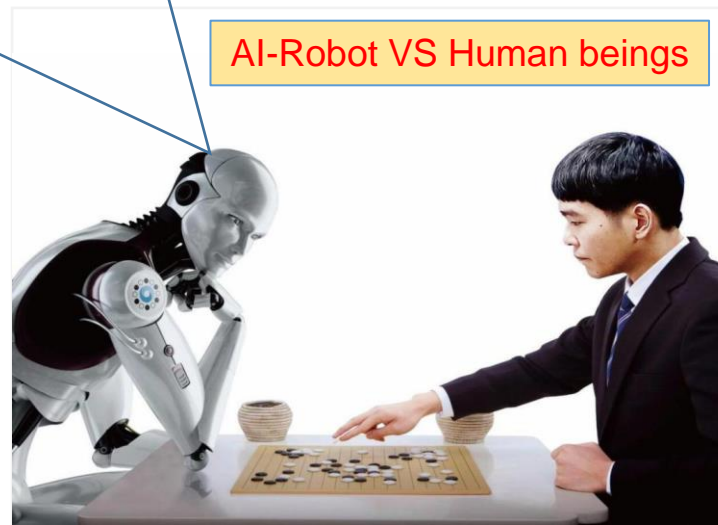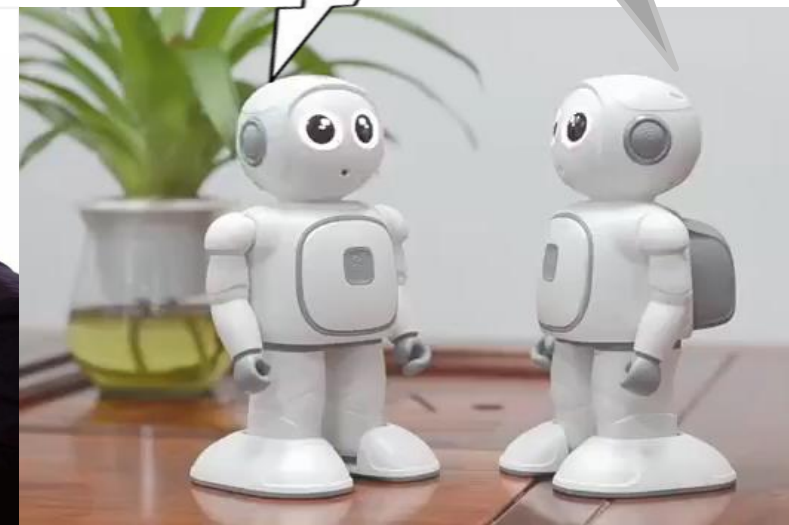Before **AlphaGo** faced Lee Sedol, the Google DeepMind team first trained the "AlphaGo" neural network with nearly **30 million moves** played by humans, allowing it to learn how to predict how a human professional player will land. Let AlphaGo play against itself, thus creating a massive new game book.

AI vs AI (Chat GPT)
Cloud Knowledge Base

AI-Robot VS Human beings

机器手就开始做了
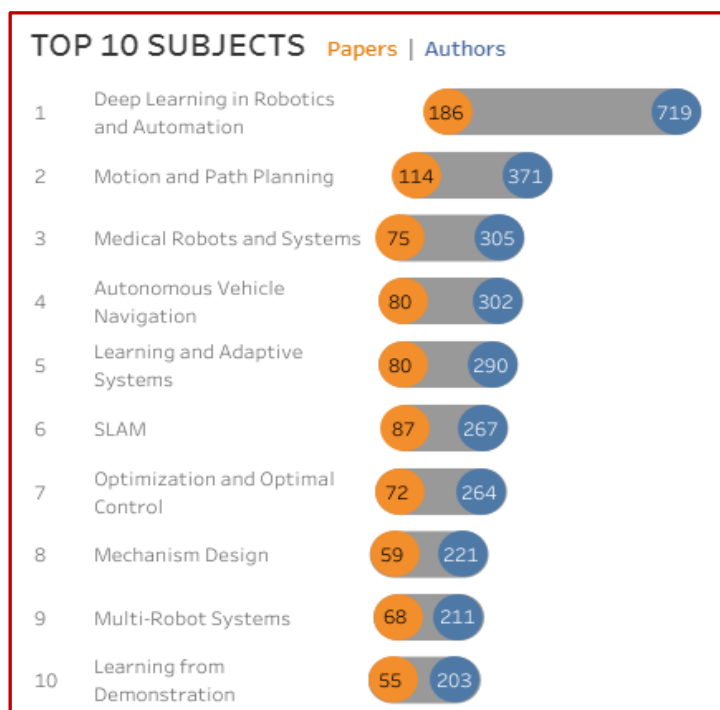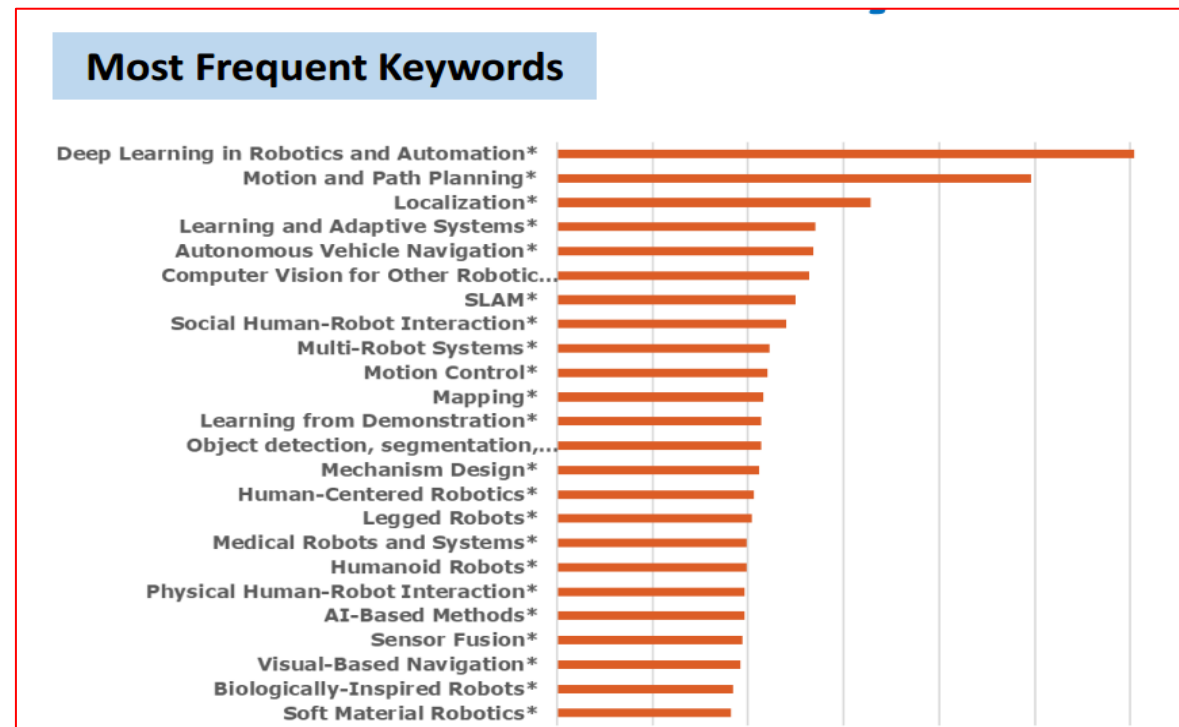
☐ **Advanced technologies:** deep learning and neural networks, autonomous navigation and positioning, perception and cognition, flexible robots and soft robots, collaborative robots and human-machine collaboration, multi robot systems and collaboration, human-machine interaction and social robots, autonomous decision-making and planning

☐ **Research direction:** Autonomy, Intelligence, Integration, Collaboration

ICRA2021 Hot Words

IROS2020 Hot Words

TOP 10 SUBJECTS   Papers | Authors

		Papers	Authors
1	Deep Learning in Robotics and Automation	186	719
2	Motion and Path Planning	114	371
3	Medical Robots and Systems	75	305
4	Autonomous Vehicle Navigation	80	302
5	Learning and Adaptive Systems	80	290
6	SLAM	87	267
7	Optimization and Optimal Control	72	264
8	Mechanism Design	59	221
9	Multi-Robot Systems	68	211
10	Learning from Demonstration	55	203

Most Frequent Keywords

Deep Learning in Robotics and Automation*
Motion and Path Planning*
Localization*
Learning and Adaptive Systems*
Autonomous Vehicle Navigation*
Computer Vision for Other Robotic...
SLAM*
Social Human-Robot Interaction*
Multi-Robot Systems*
Motion Control*
Mapping*
Learning from Demonstration*
Object detection, segmentation,...
Mechanism Design*
Human-Centered Robotics*
Legged Robots*
Medical Robots and Systems*
Humanoid Robots*
Physical Human-Robot Interaction*
AI-Based Methods*
Sensor Fusion*
Visual-Based Navigation*
Biologically-Inspired Robots*
Soft Material Robotics*

CONTENT

1. What kind of robots are needed for agriculture

2. Field robot status and its developing trends

3. Greenhouse robot status and its developing trends

4. Key technologies of Agricultural robot
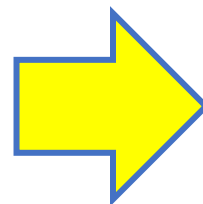
5. Research on Agricultural Robots at SJTU

Harmful

Drone Spraying

Too tired

Unmanned driving

Milking robot

Unwillingt to do

Transplanting robot

Inefficient

Labour shortage

Picking robot

ABUNDANT ROBOTICS USES A SELF-DRIVING MACHINE THAT CAN IDENTIFY FRUIT, DECIDE IF IT'S READY FOR HARVEST,

Harsh scene
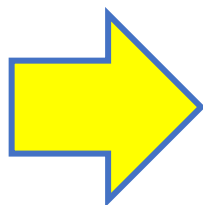
Sea cucumber fishing robot
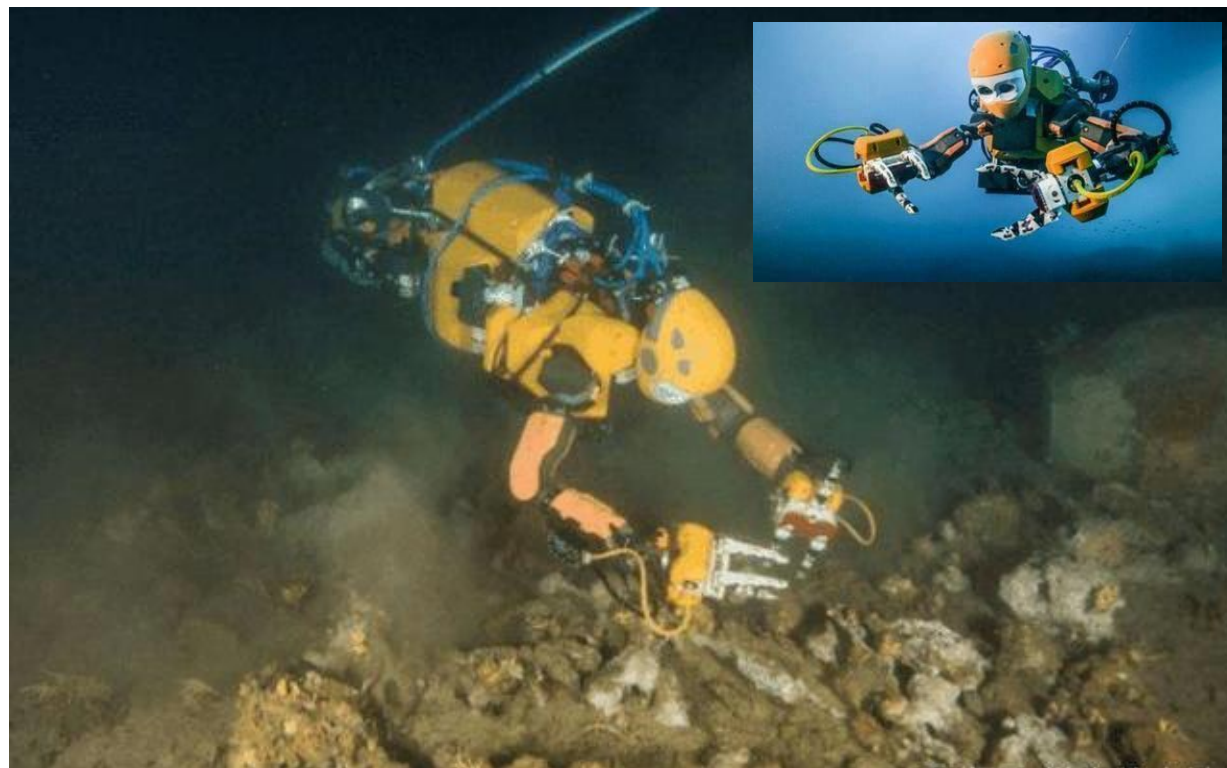
Shanghai sweet agricultural robot
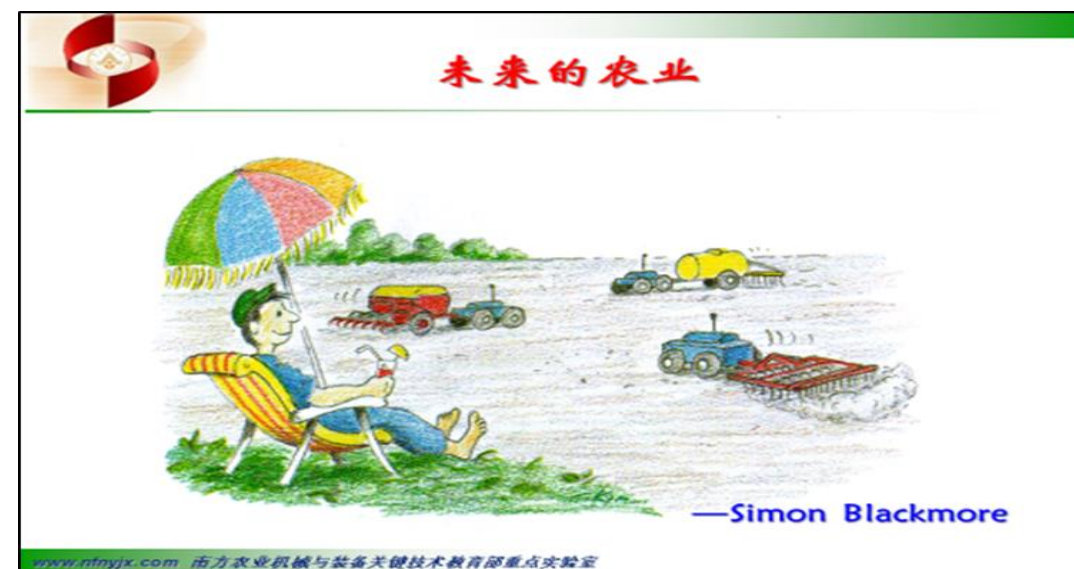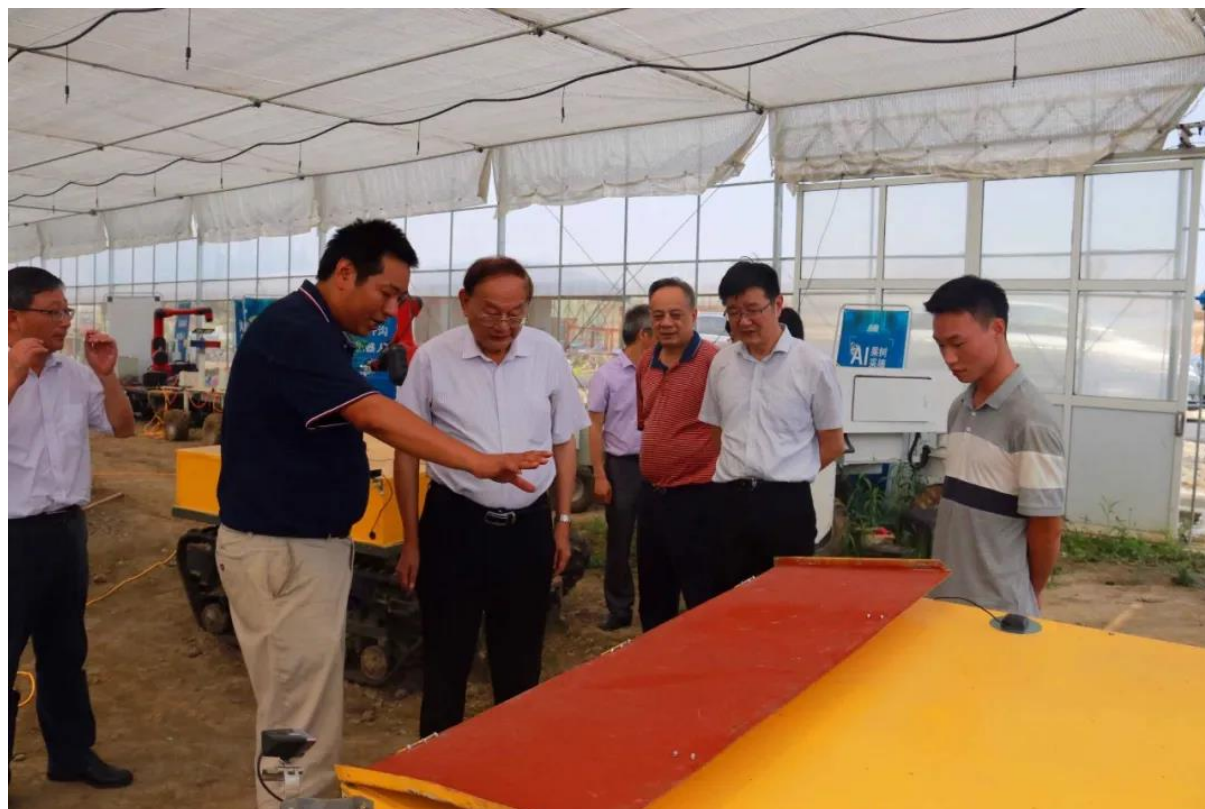
—Simon Blackmore

—Simon Blackmore

1. What kind of robots are needed for agriculture

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Lemken Krone launched unmanned tractors

Norwegian Kverneland Group

Seeding robot

Diverse agricultural robots
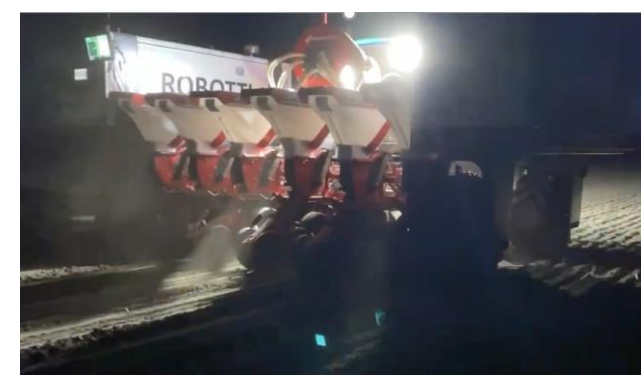
French Weeding robot: Dino

DETECTION OF THE PLANTS USING DEEP-LEARNING

IN-ROW WEEDING

French vineyard robot: Pruning robot

Spanish agricultural robot manufacturer Agrobot:
24-arm strawberry harvesting robot

Diverse agricultural robots

Germany 1100 hp NEXAT modular farm machine

University of Sydney - solar charging, four-wheel steering, four-wheel drive RIPPA

Carbon Robotics Laser Automated Weeding Robot (Seattle)

Second Generation Ted #European Winery Vineyard Robot

Diverse agricultural robots

Dutch Steketee Weeding Robot

室内的理想照明条件不会被外部光线干扰
no external light is allowed to interfere with the ideal lighting conditions inside

Ztractor Compact Smart Tractor   California

NVIDIA Jetson Edge AI Platform Performs Computer Vision Tasks

Fully Autonomous Agricultural Robotic System from AgXeed, Netherlands

John deere

Autonomous tractor robot work platform

https://www.deere.com

http://www.sohu.com/a/134009698_691441

✓ **Autonomous tractor**

✓ Illumination & weather conditions independent

✓ Work 7x24

- **Automated steering system**
- Radar and vision measurement system
- Monitoring system
- Remote control system

WASHINGTON STATE UNIVERSITY

Prof. Qin ZHANG

✓ Precision, site-specific Irrigation control of an apple orchard
✓ Bandit Cub: a self-propelled harvest assist and platform machine

✓ Intelligent Irrigation Control System for Apple Orchards - Precise Control and Water Saving
✓ Self-propelled harvesting assist platforms - for a wide range of orchards in different field conditions

http://cpaas.wsu.edu

Queensland University of Technology 🇦🇺

"AgBot II" :

✓ A new generation of crop and weed management machinery

✓ Navigate through a field, apply fertilizer, detect and classify weeds

✓ Kill weeds either mechanically or chemically

✓ Success rate in weed detection and classification above 90%

Christopher McCool

Tristan Perez

Owen Bawden

AgBot II

https://research.qut.edu.au/
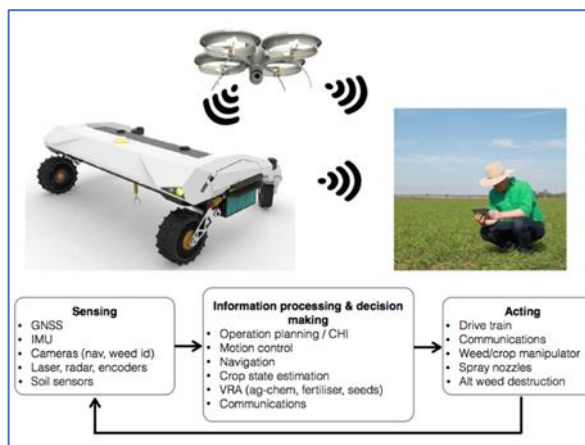
x3 Edit: X. Liu

Faculty of Agriculture

HOKKAIDO UNIVERSITY

Noboru Noguchi

✓ Teamwork of Ag Robots

✓ Based on wireless communication

✓ Advanced task management system

✓ Low cost

Robot farming system using multiple robot tractors

Edit: X. Liu

YANMAR

https://www.agr.hokudai.ac.jp

Prof. LUO Xiwen, CAE academician

Xinjiang Academy of Agriculture

Prof. CHEN Xuegeng, CAE academician

Autonomous cotton filming planter

Realize the mechanization of the whole cotton production:
- ☐ Developed new machines ranging from ploughing to cotton stalks returning to the field.
- ☐ The area of cotton mechanized planting and management mode has reached 38.29 million mu.
- ☐ Formed a four-in-one mechanization technology system for the whole cotton production.
- ☐ Solved the management problem of fork weeding

- ✓ Precise single hole sowing
- ✓ Save labour force enormously
- ✓ Complete multi-process simultaneously

UN GEONOW 2024
首届联合国地信周

Prof. ZHAO Chunjiang, CAE academician

Prof. FANG Xianfa

✓ Solve the problem of heavy human workload & low work efficiency

✓ Integrated operation

http://www.caams.org.cn/

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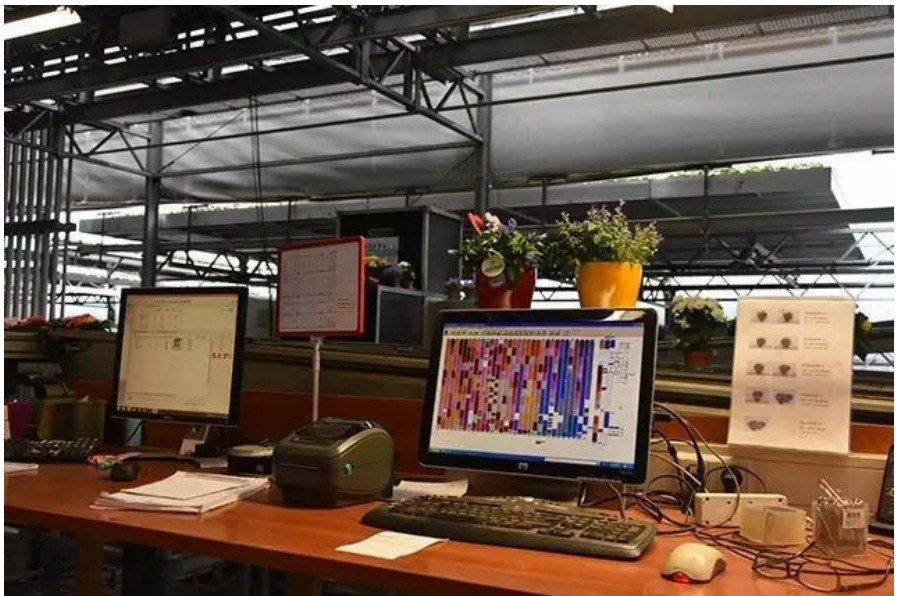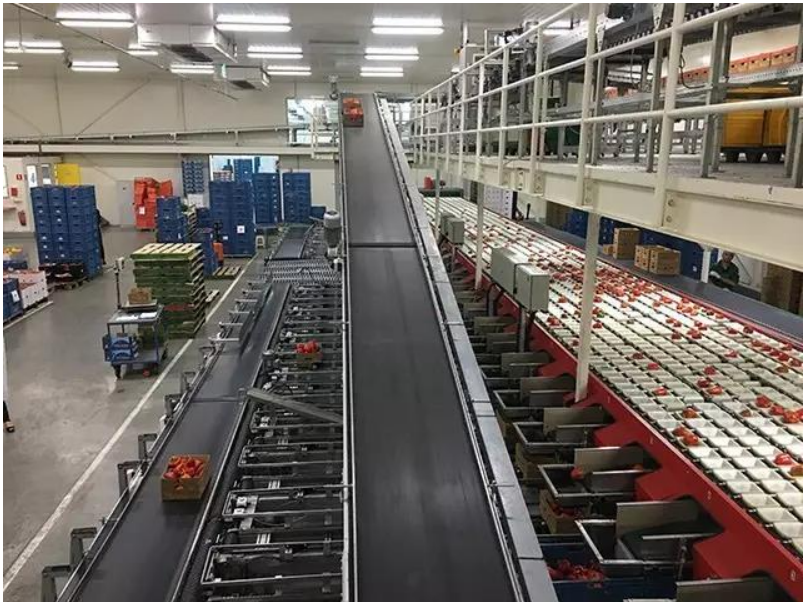
- ✓ Plant growth monitoring robot
- ✓ Greenhouse logistics truck
- ✓ Automatic spray robot

https://berghortimotive.com/nl/

Plant growth monitoring robot

Automatic spray robot

Greenhouse logistics truck

- ✓ Fruit harvesting robotics
- ✓ Agricultural logistics robot
- ✓ Agricultural machine vision system

https://www.ffrobotics.com/

Field Plant Phenotyping Robot

✓ Plant Phenotyping

✓ Environmental Stress

✓ Plant Growth Monitoring

✓ Individual to Group Analysis

http://phenospex.com/
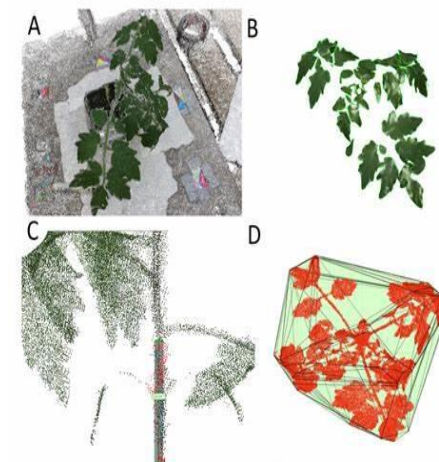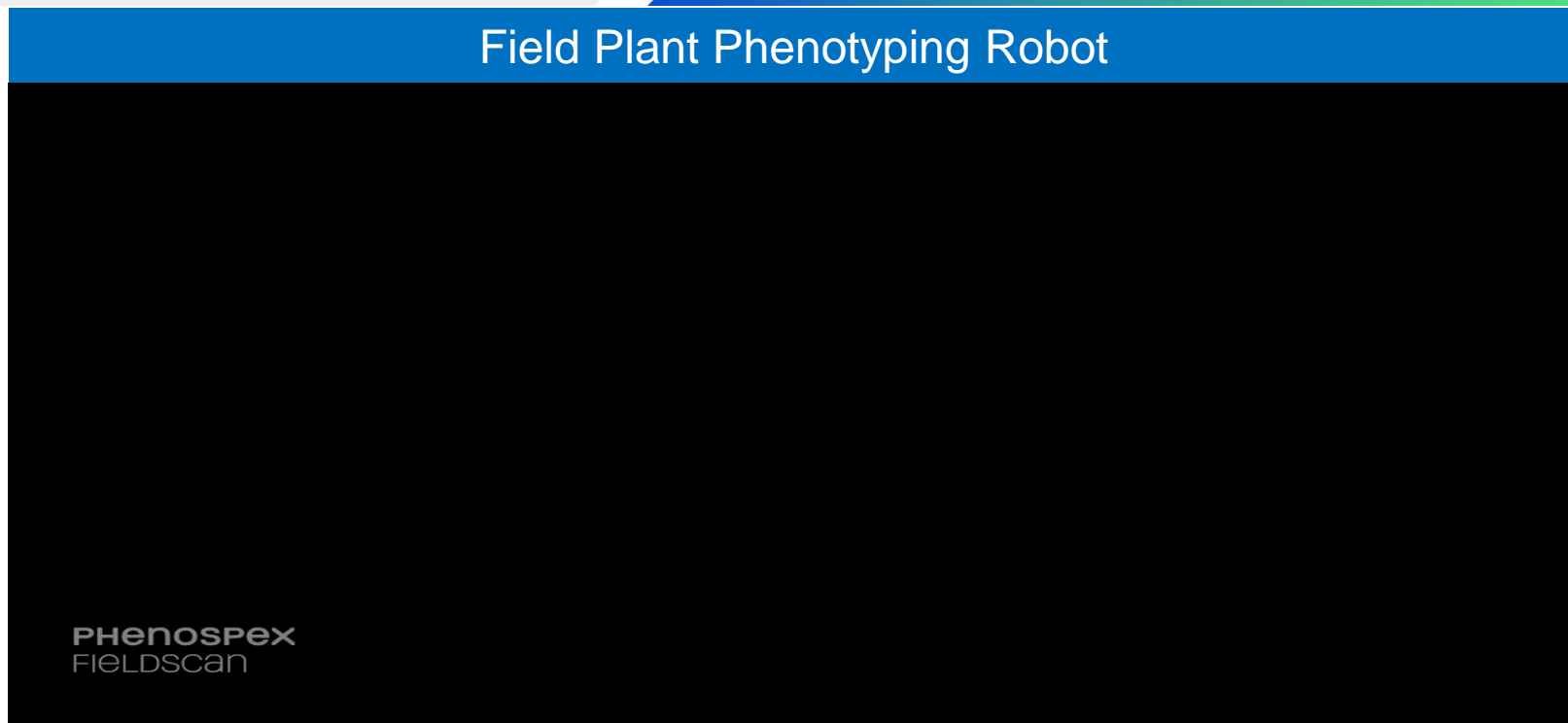
Prof. LI Wei

- ✓ Tomato harvesting robot
- ✓ Cucumber harvesting robot
- ✓ Rail suspension transfer car
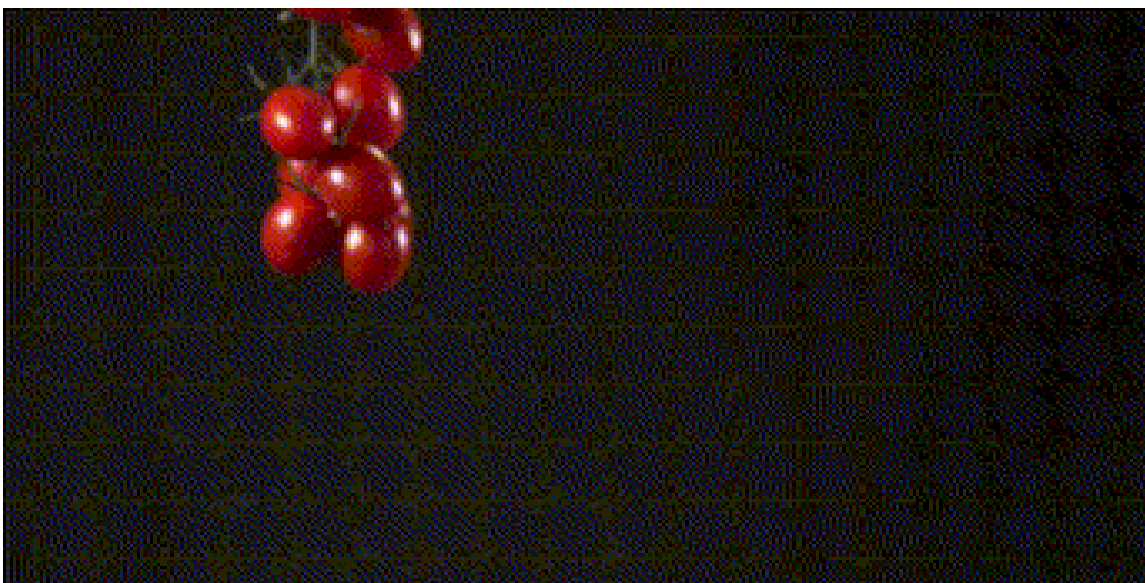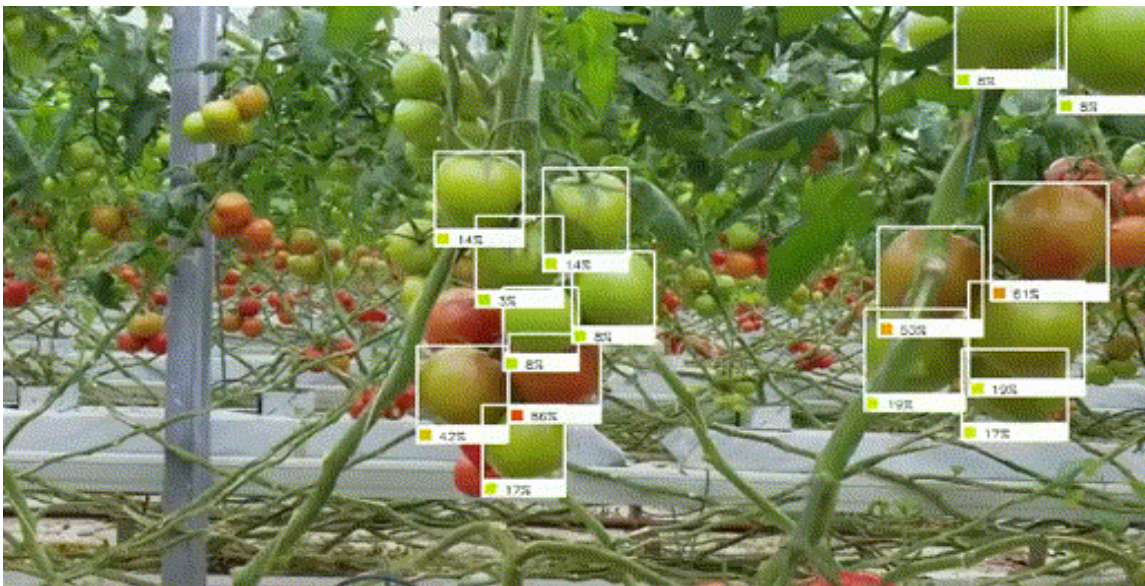- ✓ Fruit grading production line
- ✓ Facility logistics robot
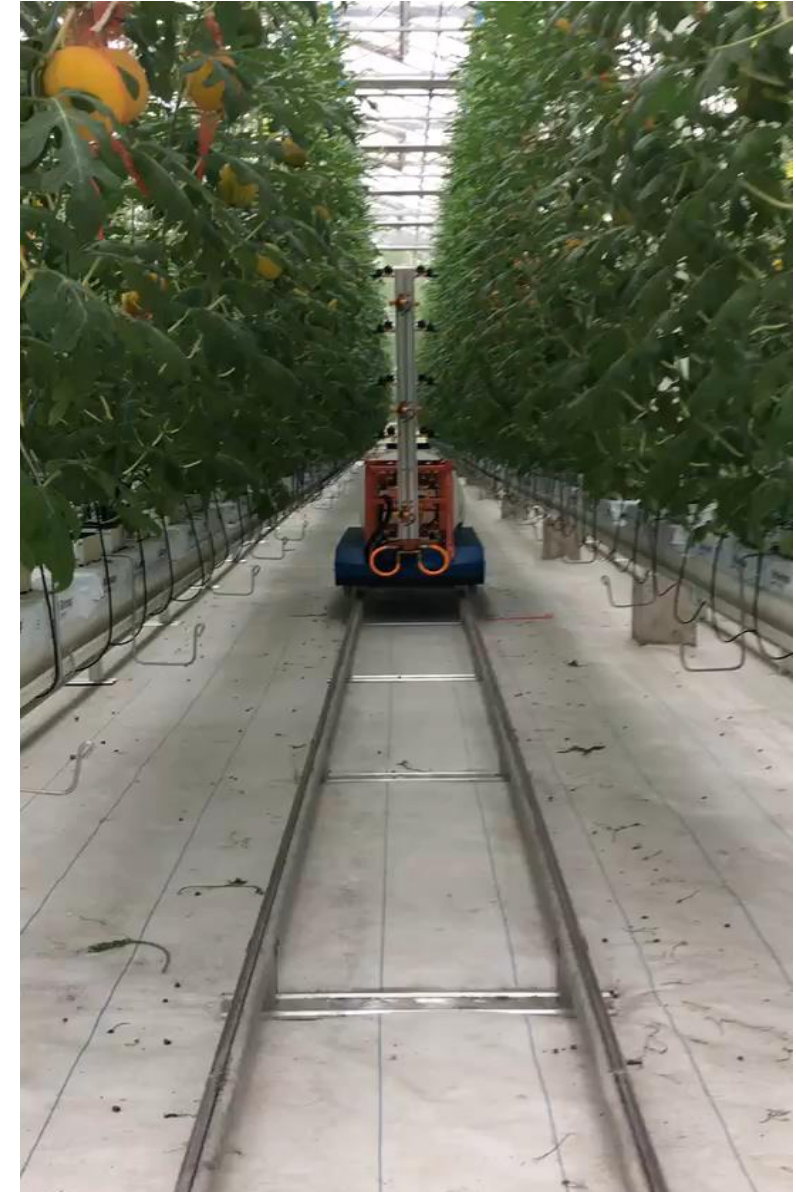
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Agricultural robot system (Agribots)

$$\frac{\text{Robots}}{\text{noumenon}} \;+\; \frac{\text{Sensing+Decision+Control}}{\text{Intelligence}} \;+\; \frac{\text{BigData+Cloud-AI+IOT}}{\text{System}} \;=\; \text{Agribots}$$

Definition of Agricultural Robots ——It refers to multi-degree-of-freedom autonomous operational equipment with perception, decision-making, control, and execution capabilities used in agricultural production, which mainly includes information perception systems, decision and control systems, operation execution mechanisms, and autonomous mobile platforms. That is, "eyes, brain, hands, and feet".

Liu C., Transactions of the Chinese Society for Agricultural Machinery. 2022.53 (7): 1-22

Agricultural Robot System Architecture

Decisions in the cloud

Databases

AI

repository

model library

Intelligence in the terminal
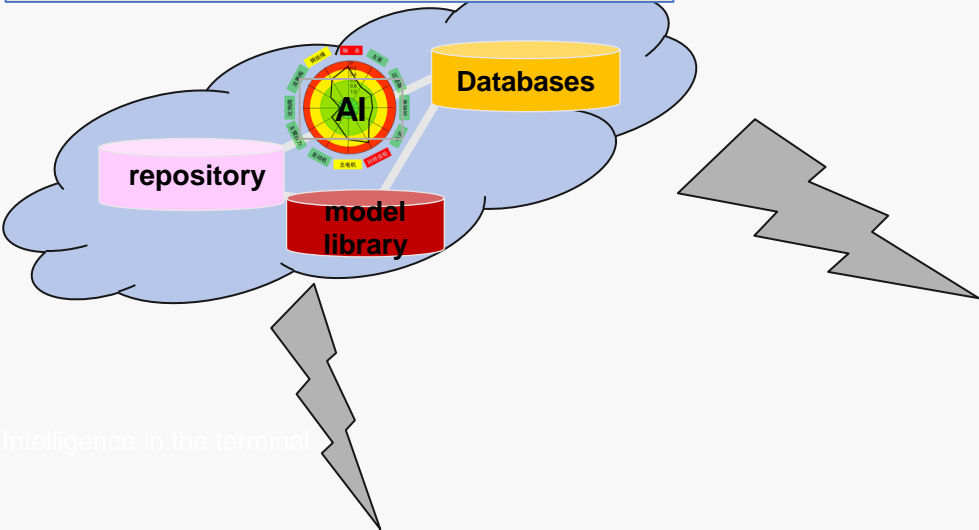
Intelligence in the terminal

Control on the screen

无人驾驶
洋马版
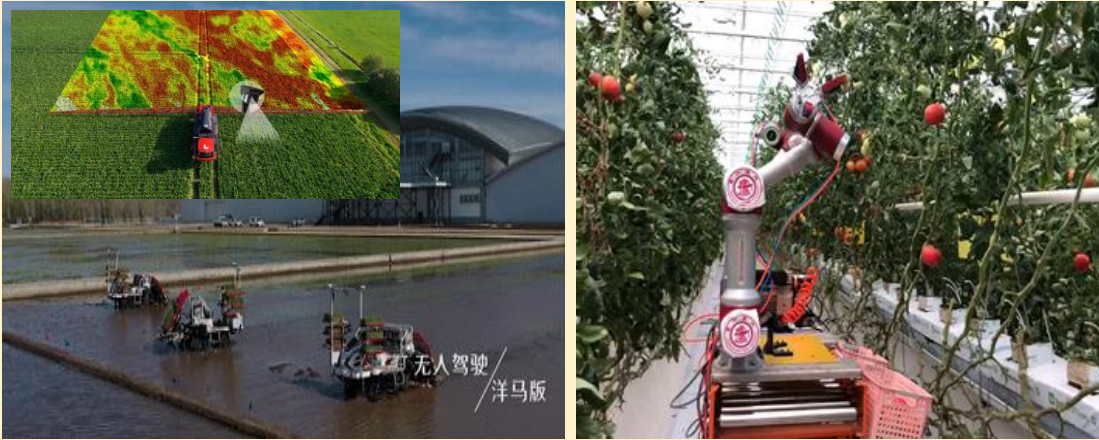
APP

管 控 A P P   作 业 调 度 与 运 行 管 理 A P P   预 报 A P P

Agribots key technologies

"Eye"
Intelligent perception

- Biological Object Information Acquisition
- Operation environment information acquisition
- Machine ontology information acquisition
- Feature extraction
- Multi-source hetero-geneous data fusion

……

"Brain"
Decision control

- Variable prescription decision
- Generation of harvesting strategy
- Knowledge graph construction
- Machine learning model
- Agri-ROS Operating system

……

"Hand"
Dexterous operate

- Dexterous hand design
- Robot arm design
- Motion/dynamics planning
- Task teaching learning
- Hybrid control of force and position

……

"Foot"
autonomous movement

- Map construction
- Position navigation
- Path planning
- Autonomous walking
- Dynamic obstacle avoidance

……

Agricultural robot system integration

- Robot ontology design
- Design of robot intelligent control system
- Edge-end-cloud collaboration
- IoT+Big data+AI

……

1. Intelligent sensing technology ('Eyes')
Sensing & Perception

Sensor device

- Machine vision/radar
- Multi/High Spectrum
- Water/Nutrients
- Taste sensors
- RF/Gas
- Velocity/acceleration
- Tactile/Force
- GNSS/IMU
- UWB/beacons
- ......

Feature extraction

- data transformation
- Calibration Compensation
- wildcard removal
- data filtering
- Data denoising
- data fault tolerance
- modal analysis
- time-frequency analysis
- Data downgrading
- ......

Information fusion

- Weighted/Kalman
- Wavelet/K-T transform
- neural network
- manifold learning
- PCT
- Bayesian estimate
- D-S reasoning
- divisor diagram
- fuzzy reasoning
- ......

"Eye"

Intelligent Sensing

"Brain"

Wisdom

decision-

making

Control platform

- Communication system
- Human-machine interactive system
- Multi-fieldbus
- Underlying Hardware driver
- System Software Library
- Controller Hardware

...

Algorithmic tools

- Environmental reconstruction
- Motion control
- Task coordination and optimisation
- Deep learning
- Knowledge representation and reasoning
- Migration of knowledge
- knowledge graph construction

...

Job decisions

- Operational control and assessment
- Job path trajectory planning
- Positioning Navigation Autonomous Driving
- Variable Prescription and Control
- Task generation and planning
- Harvesting strategies and control
- O&M scheduling

...

Agri-ROS operating system

Arms & End-effectors

"Arm"

Dexterous

operate

Arm design

| Mechanical arm configuration synthesis |
| Rigid-flexible coupled arm design |
| Electro-mechanical-hydraulic-pneumatic hybrid actuation |
| Underactuated robotic hand design |
| Flexible end effector |
| Eye-in-hand configuration design |
| Integrated sensing and grasping design |
| Wearable exoskeleton |

……

Job planning

| Kinematic planning |
| Dynamic planning |
| Multi-arm task planning |
| End-effector pose planning |
| Task teaching interaction |
| Hand-eye coordination planning |
| Path trajectory planning |
| Real-time collision avoidance planning |

……

Job control

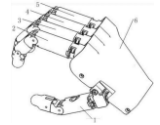| Optimal working posture estimation |
| Active compliance adjustment |
| Dynamic visual servoing |
| Force/position hybrid control |
| Trajectory tracking control |
| Active disturbance rejection control |
| Admittance/impedance control |
| Operational skill reinforcement learning |

……

Mobile platforms

Positioning navigation

Autonomous movement

"Foot"

Autonomous movement

Mobile platforms
Modular lightweight design
High ground clearance stability design
Wheel-leg composite design
Drive optimization power distribution
Walking state perception
Walking-operating speed matching
Load-sensitive control
SoC technology
......

Positioning navigation
Field satellite positioning
Underwater sonar positioning
Optical/magnetic/acoustic hybrid positioning
Laser/vision/radar positioning
Environment map construction
Path tracking navigation
Crop row navigation
SLAM navigation
......

Autonomous movement
Wheel-leg ground contour following cooperation
Walking stability control
Autonomous obstacle avoidance and negotiation
Path trajectory tracking control
Mobile behavior scheduling and monitoring
Eye-hand-foot coordination control
Operational area task management
Multi-agent queue control
......

Autonomous mobile platform

At this stage, China's agricultural unmanned

Future agricultural machinery unmanned program

BeiDou Navigation+Microwave Radar+
Vehicle-mounted Industrial Controller

BeiDou Navigation

Vehicle-mounted
Industrial Controller

Microwave Radar

High cost, complex systems and poor reliability

GPS/BDS+ Vision/LiDAR …+ AI chip

GPS

controller +AI chip

Vision/LiDAR

Strong computing power, high integration and high cost performance

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Prof. LIU Cheng-liang

Research Interests

✓ Intelligent control of agricultural machinery
✓ Agricultural robots

Application scenarios

✓ Smart fields
✓ smart orchards
✓ smart facilities

Unmanned rice live streaming machine

Cotton picking machine control system

Rice field weeding robot

Variable fertilization rotary tiller seeder

Smart Orchard Spray Robot

Smart facility complete set of robots

Dual arm coordinated picking robot

Agricultural Machinery AI Chip Module

Smart Agriculture Control Platform

First Intelligent Yield Measuring System

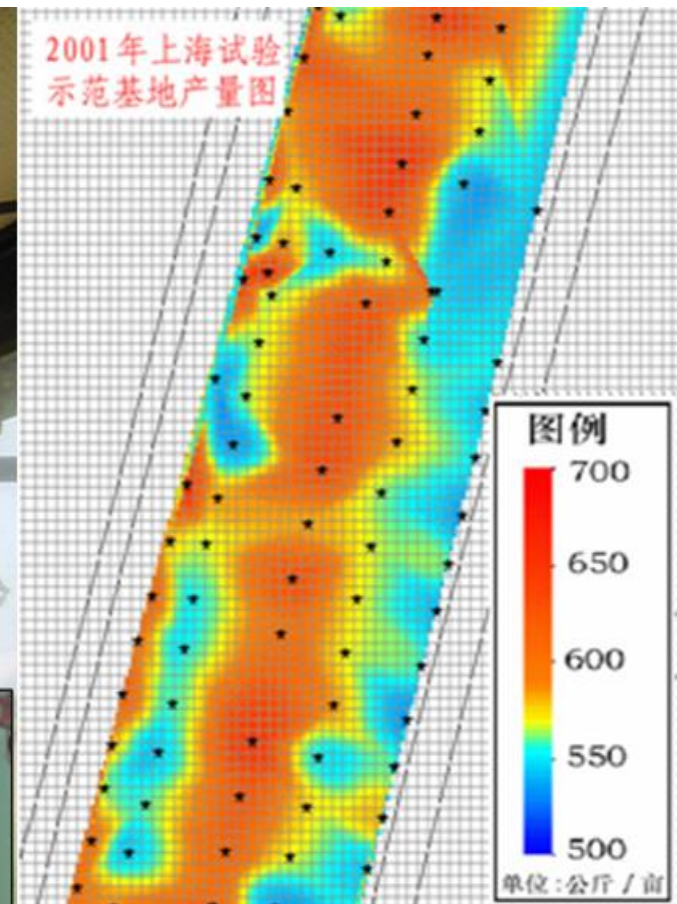## First Intelligent Yield Measuring System for Combines by SJTU

First Yield Mapping 2001

Unmanned rice seeder

Shanghai Songjiang Unmanned Farm

Edit: X. Liu

Multi machine collaboration

Unmanned Farm on Chongming Island, Shanghai

■ Key technologies:

✓ **Control system:** unmanned driving controller based on AI chip;

✓ **Integrated navigation:** Beidou+vision+radar, recognition and obstacle avoidance;

✓ **Path planning:** toolization of homework path planning software;

✓ **Tracking error:** less than 2.5cm.

Rice field weeding robot

Promotion and application in Yexie Town, Songjiang District, Shanghai

Operation Experiment in Zhuangxing Town, Fengxian District, Shanghai

■ Key technologies:

✓ **Control system:** unmanned driving controller based on AI chip;

✓ **Integrated navigation:** Beidou+vision+radar+INS;

✓ **Path planning:** automatic homework path planning software tool;

✓ **Four wheel drive:** four-wheel steering, coordinated control;

Weed removal rate>90%; Less than 5% of seedlings are damaged 5 acres per hour

Cotton picker unmanned driving system

■ **Core technologies:** power load adaptive energy consumption control, dynamic stability control, precise operation control **-- The first domestic cotton picking machine control system**

■ **Key technologies:**

Production measurement sensor system	Automatic Matching System	Energy consumption control system	Intelligent control system	上海交大基于ISO-BUS 的自主控制系统

Collaborated with Shanghai University Chinese Academy of Agricultural Machinery

Robotic equipment for facility agriculture

■ Key technologies

✓ Robotization of the whole process of cultivation - planting - management – harvesting

✓ Indoor centimeter-level high-precision positioning

✓ Multi-machine cooperative operation technology with cloud brain control
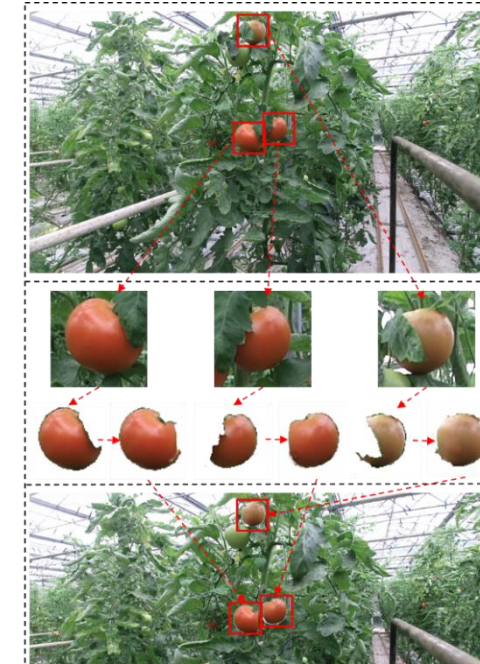
Smart facility agriculture - Series equipment

Dual arm vegetable and fruit picking robot
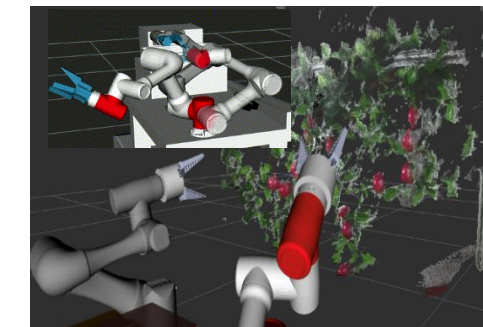
■ Key technologies

- ✓ Fruit localization, ripeness recognition
- ✓ AGV autonomous localization, navigation and obstacle avoidance
- ✓ Hands coordinated gripping operation control

Eye-occluded target recognition localization

Hand Flexibility Low Loss End Rapid Prototyping

Arm Reinforcement Learning Obstacle Avoidance Planning

Dual-arm cooperative anthropomorphic job control

Smart Orchard - Targeted spraying robot

Henan Sanmenxia *Wave Agricultural Base

Single-side nozzle spray ring segmentation

■ Key technologies

- ✓ AI chip-based driverless controller
- ✓ BDS+Vision/IMU/Odometer combination navigation
- ✓ Canopy Density Point Cloud Recognition;
- ✓ Variable precision target spraying

THANK YOU