amtc
Advanced Manufacturing Technology Center
先进制造技术中心

5G 和人工智能助力制造业转型升级

February 4, 2021

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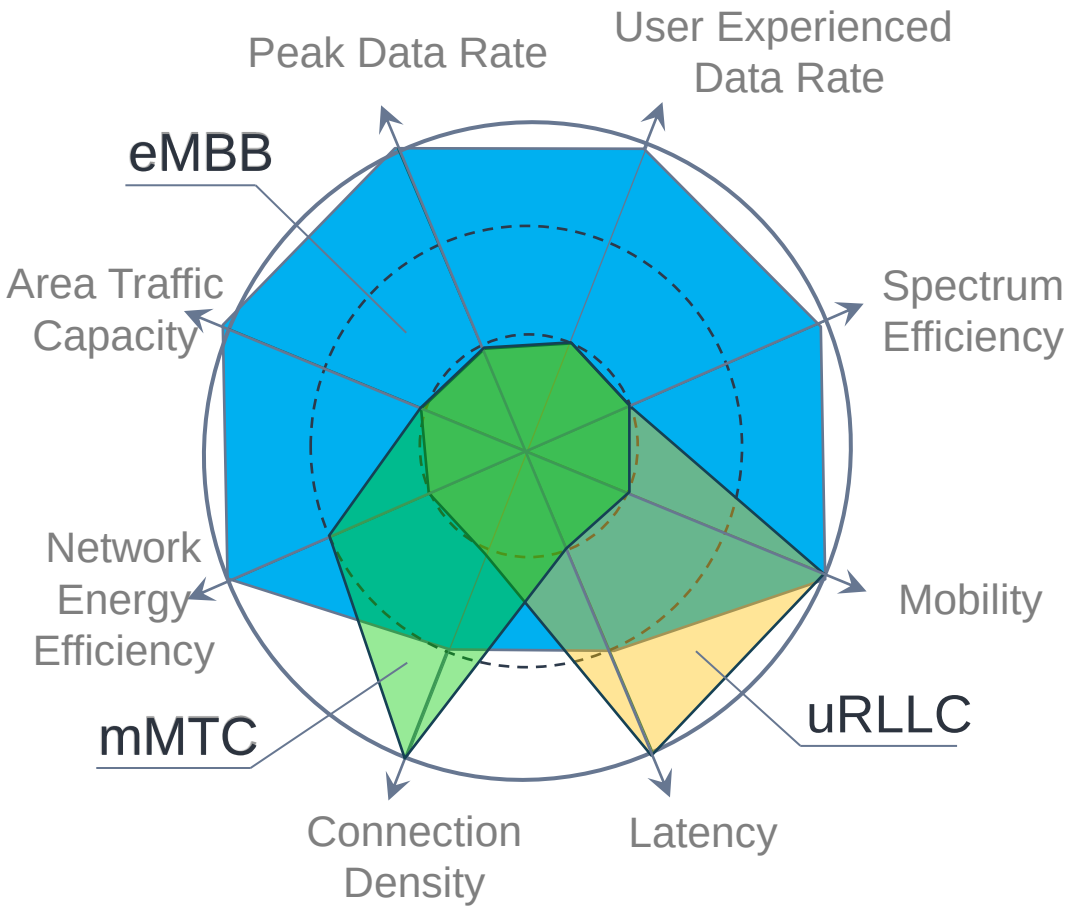
1. WHAT'S 5G

Introduction



From international mobile telecommunications (IMT)

- Requirement for bandwidth at least 100 MHz
- Bandwidths up to 1 GHz are required for higher frequencies (above 6 GHz)
- 1 million devices per km2
- Downlink peak data rate of 20 Gb/s
- Uplink peak data rate of 10 Gb/s
- Target downlink "user experienced data rate" of 100 Mb/s
- Target uplink "user experienced data rate" of 50 Mb/s

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无线通信技术

名称	WIFI	Bluetooth	ZigBee	5G
速率	11-54Mbps	1Mbps	100Kbps	3-10Gbps
距离	20-200m	20-200m	2-20m	Anywhere
频段	2.4GHz	2.4GHz	2.4GHz	3.4GHz-3.6GHz、 4.8GHz-5.0GHz (China)
安全性	Low	High	Middle	High
成本	$25	$2-5	$5	<$30
用途	PC, Entertainment	Automotive, Industrial, Medical	Wireless sensing	Networking of all things

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工业物联网(IIoT)

Introduction

	Peripheral connectivity	Local (home) networking	Wide area networking
Typical range	<30 ft.	<300 ft.	Outdoor (miles)
Content distribution Focus on high data rates Energy consumption secondary	Bluetooth®	Wi Fi .11ah: HaLow IEEE 802. llax	GSM Lte 5G LTE Cat-M NB-IoT GPRS
Sense and control Low energy/long battery life Data rate is secondary	Bluetooth® SMART	ZigBee	
Proprietary solutions	ANT	Sub-GHz enocean®	LoRa SIGFOX INGENU
Typical applications	Personal appliances (wristband, smartwatch, step counter, keyboard, mouse, pointer, etc.)	Indoor networks (internet, email, phone, security, energy management, smart home monitoring, etc.)	Outdoor networks (smartphone, internet, city, industry 4.0, agriculture, smart logistics, etc.)

EtherNet/IP™ ΣΔ PROFINET® PROFIBUS® EtherCAT® Technology Group sercos ETHERNET POWERLINK EnDat 2.2 BiSS INTERFACE

- Wireless technology: 6% of the market, a rapid growth of 32%. For wireless technology, WLAN is the most popular, followed by Bluetooth.
- Industrial Ethernet: 46% of the market, the growth rate is accelerating, the growth rate is 22%.
- Fieldbus: 48% of the market, and the growth rate is slowing (2017: 4%, 2016: 7%).

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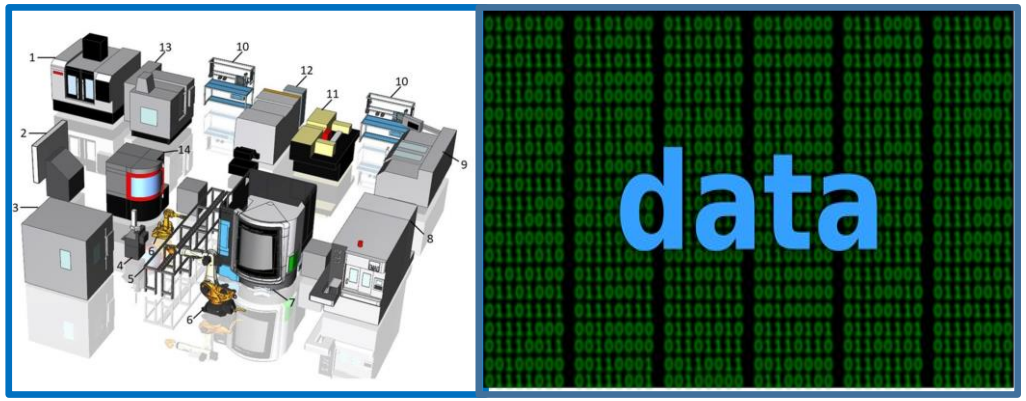
OPTIMIZATION FOR INDUSTRY

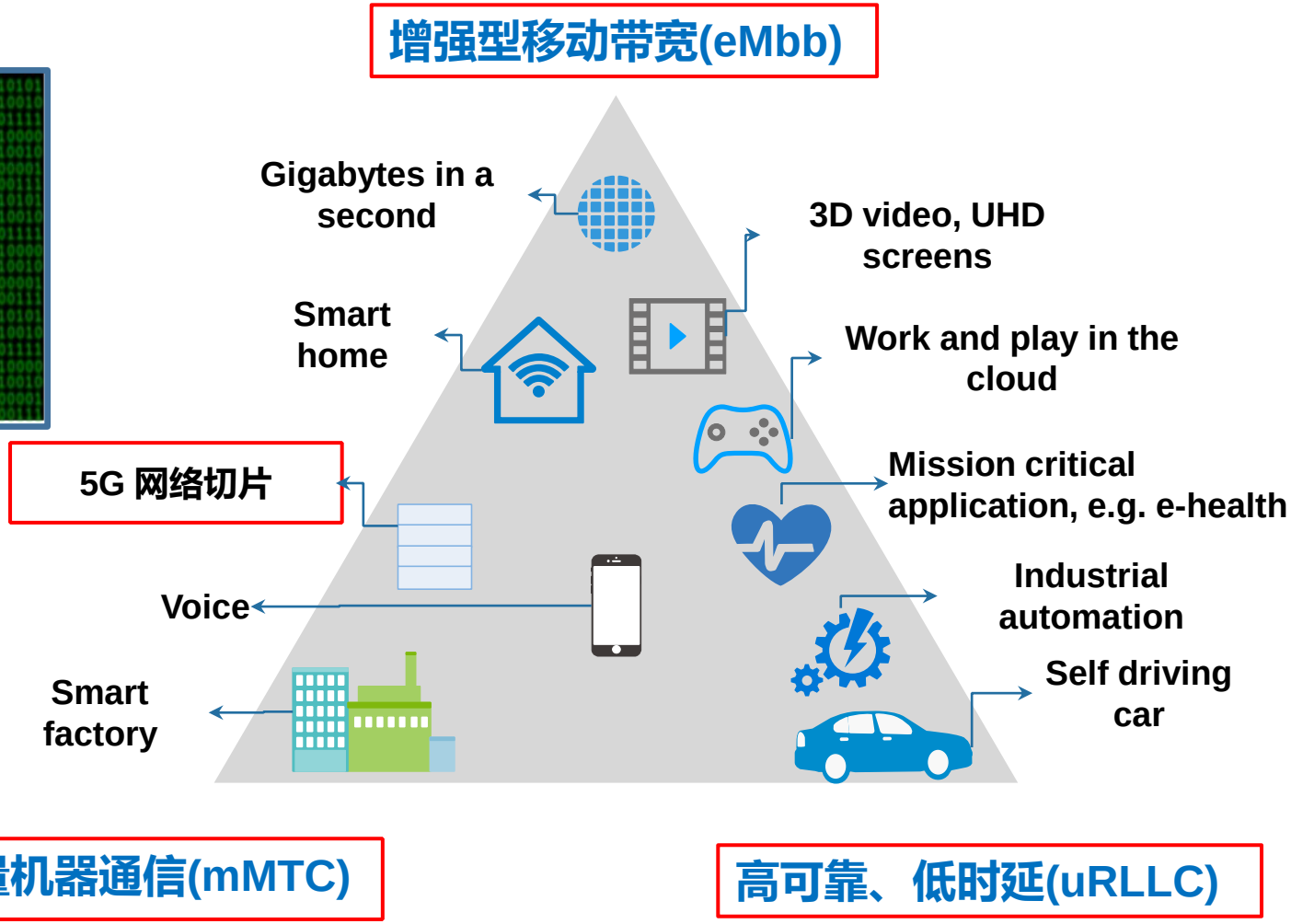
Motivation

Production



工业加工数据量越来越大

需要一种可靠的数据传输方式



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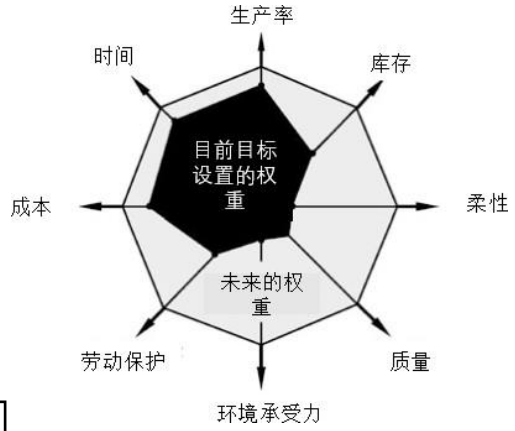
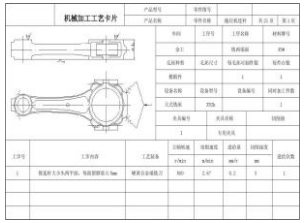
2. AI在制造中的应用



AI
人工智能技术



Domain
具体工艺技术

智能制造
过程支撑
技术

Big data/Block chain
大数据/区块链及关联的运营模式

C/E: Cloud/Edge computing
云/边缘计算

AI定义：？？？ 对人类思考和活动的模仿

工业AI智能等级：

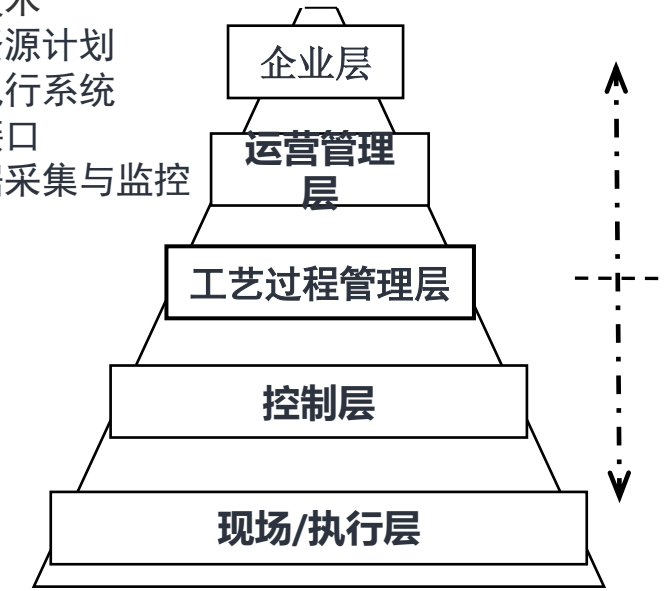
- 独立解决问题的能力
- 自主程度、问题的复杂程度
- 解决问题方法的有效性等

IT/OT支持系统　信息技术/（运营）操作技术

ERP
MES
HMI, SCADA
PLC
传感器 执行器

ERP：企业资源计划
MES：制造执行系统
HMI：人机接口
SCADA：数据采集与监控

层级结构



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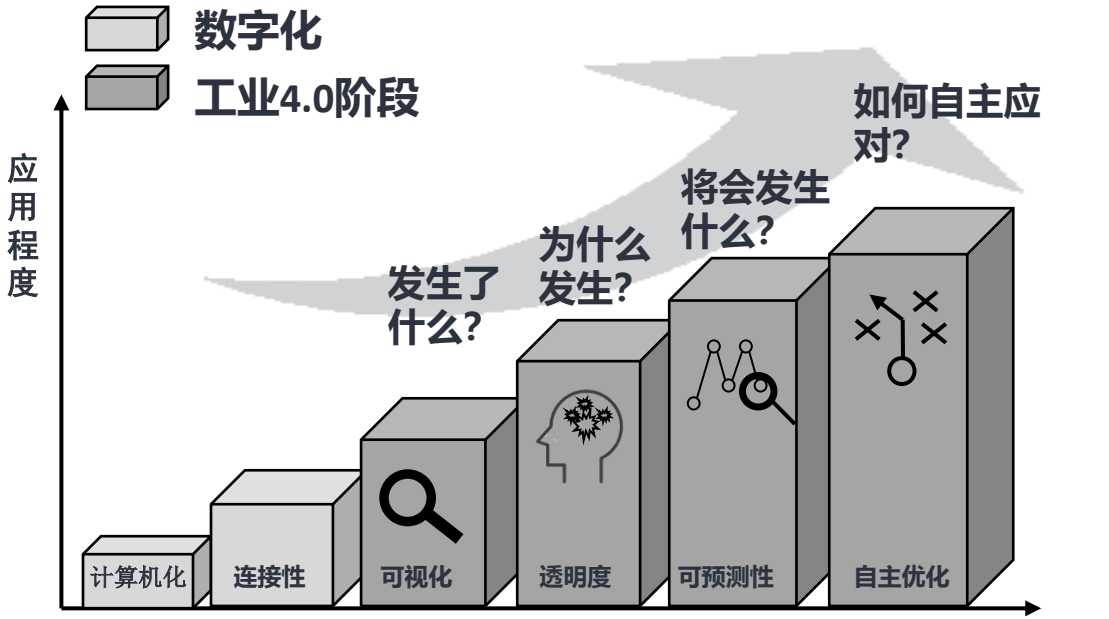
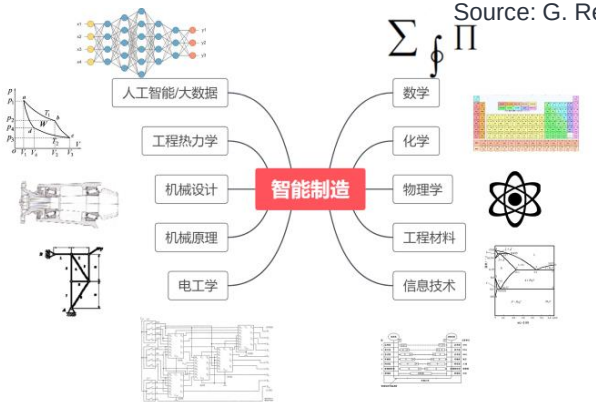
AI在制造中的应用阶段



Source: G. Reinhart. Handbuch Industrie 4.0. HANSER



AI解决问题的方式及顺序：

- 检测（Detection），例：质量检测
- 聚类（Clustering），例：识别工作条件和评估健康状况
- 分类（Classification），例：估计故障模式或类型
- 预测（Prediction），例：设备运行风险预测
- 优化（Optimization），例：工艺以及生产调度
- 泛化能力（Generalization Ability），例：模型能很好地适用于“新样本”
- 创造能力（Creation Ability）是人类智能的基本特征，也是对人工智能的挑战。例：将熟悉的想法重新组合、探索概念空间的潜力、通过变革。

前一个问题的结果是后一个问题的前提

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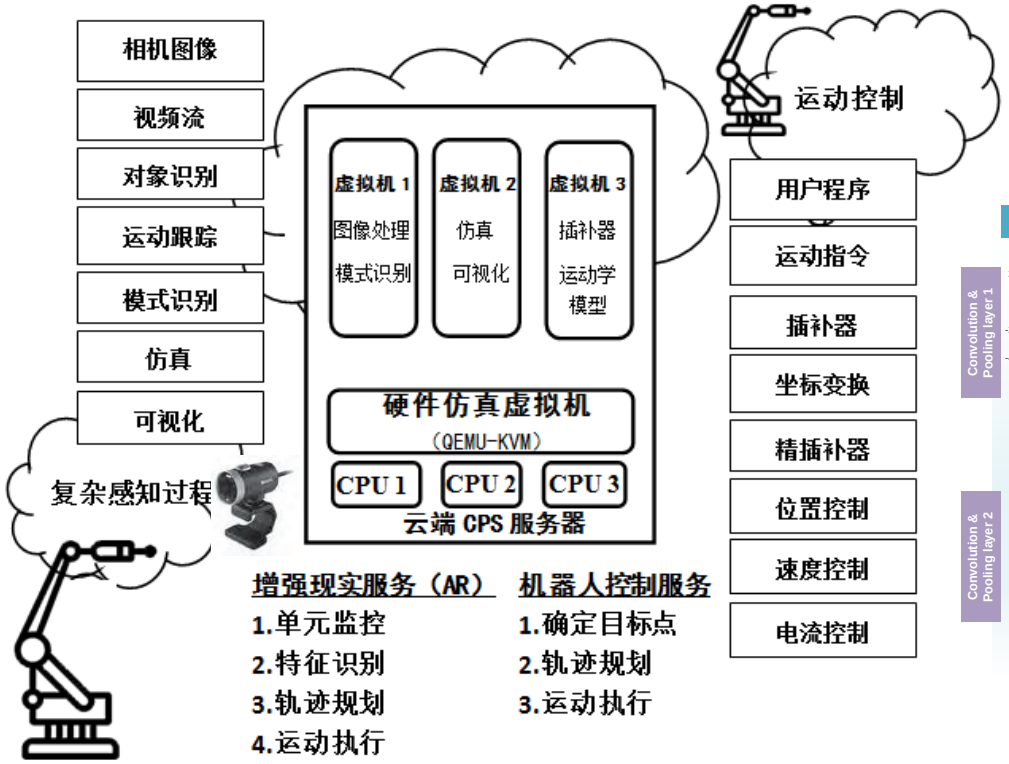
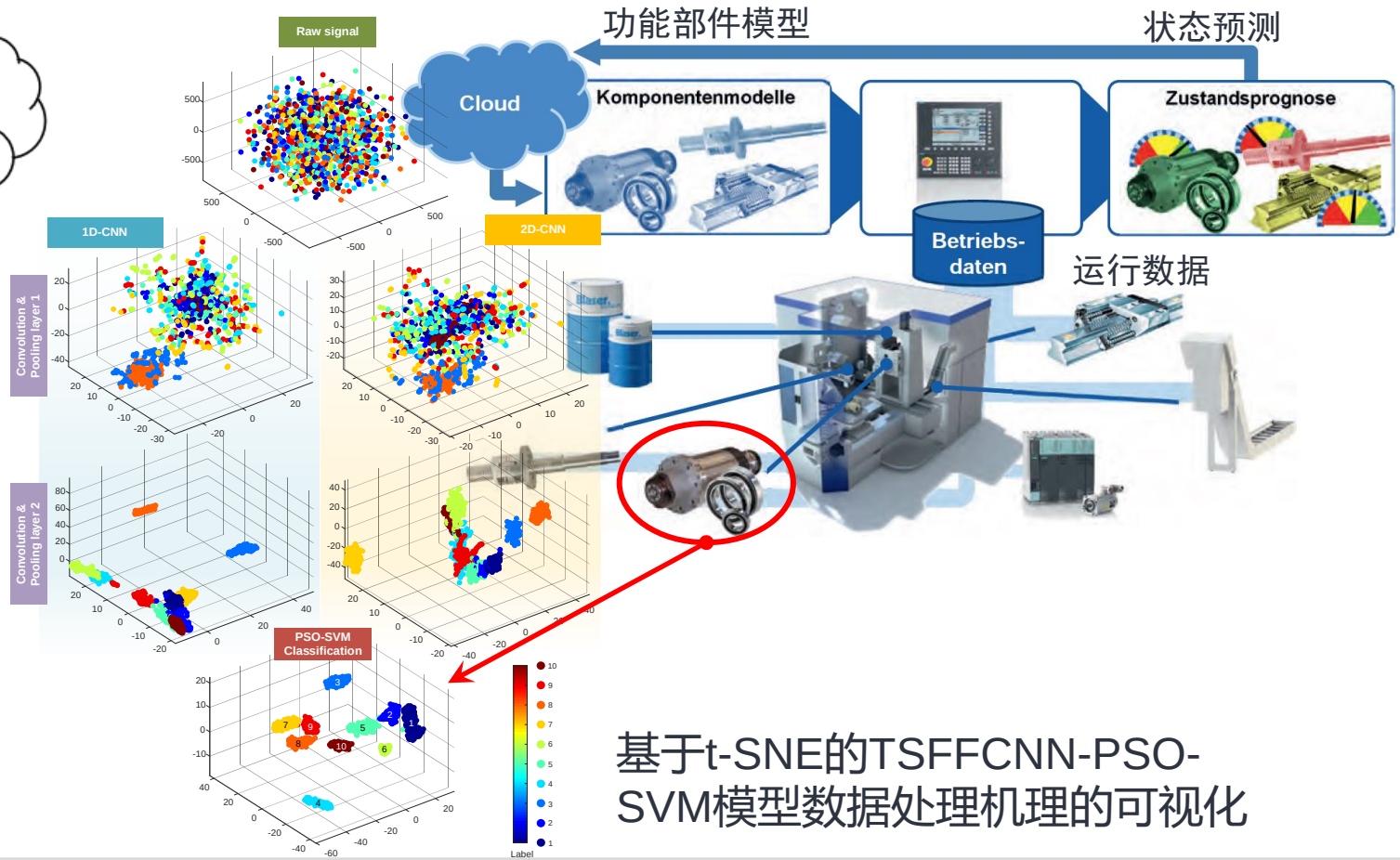
AI在制造中的应用

基于服务的云端的自动化加工过程管理
-面向制造过程的运动控制和图像处理CPS示例



Source: G. Reinhart. Handbuch Industrie 4.0. HANSER

自主监控机床



基于t-SNE的TSFFCNN-PSO-SVM模型数据处理机理的可视化

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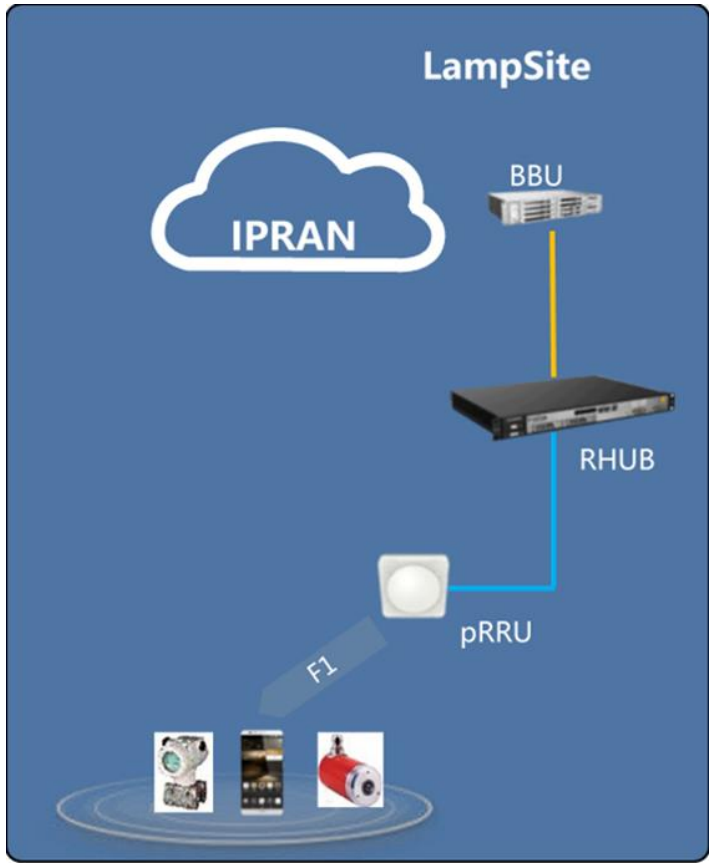
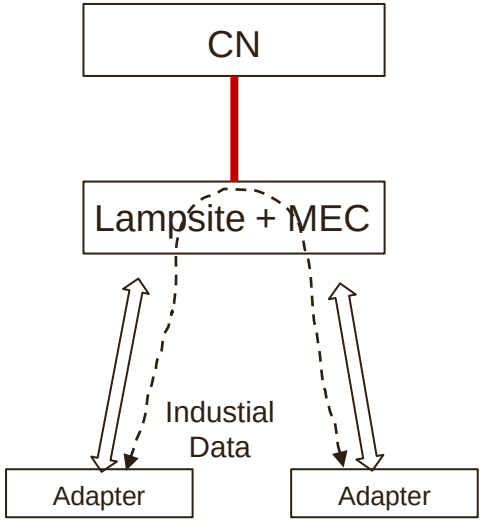
3. AMTC 5G/AI测试床

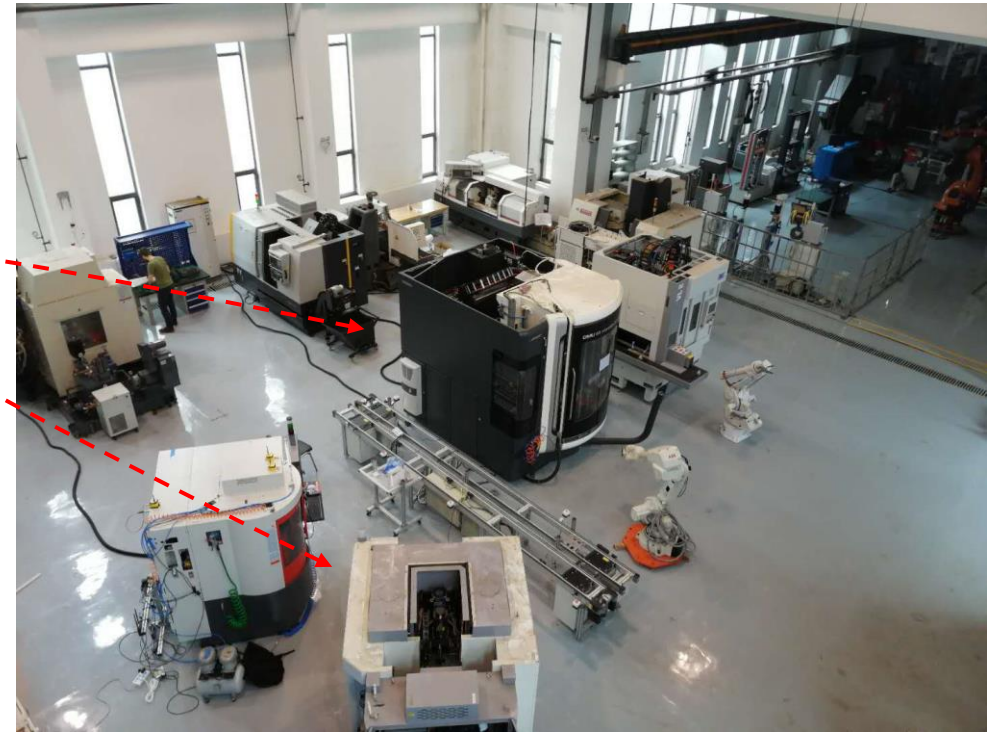
Local Area Network



Lampsite + SVA

基站





- 数据本地路由;
- 海量数据传输保障;
- 多平台支持;
- 多协议融合转换。

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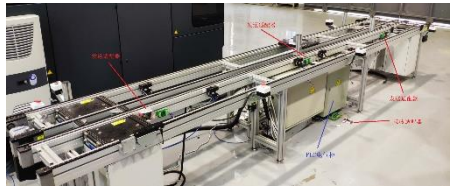
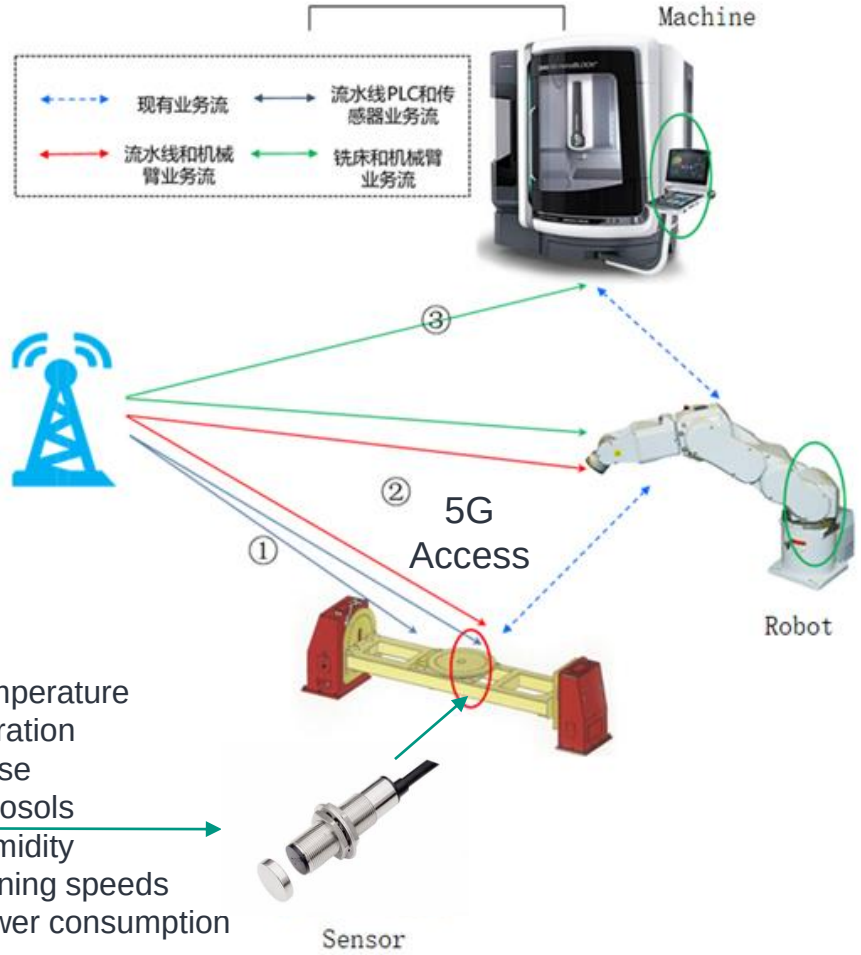
AMTC 5G/AI测试床

Plan implementation

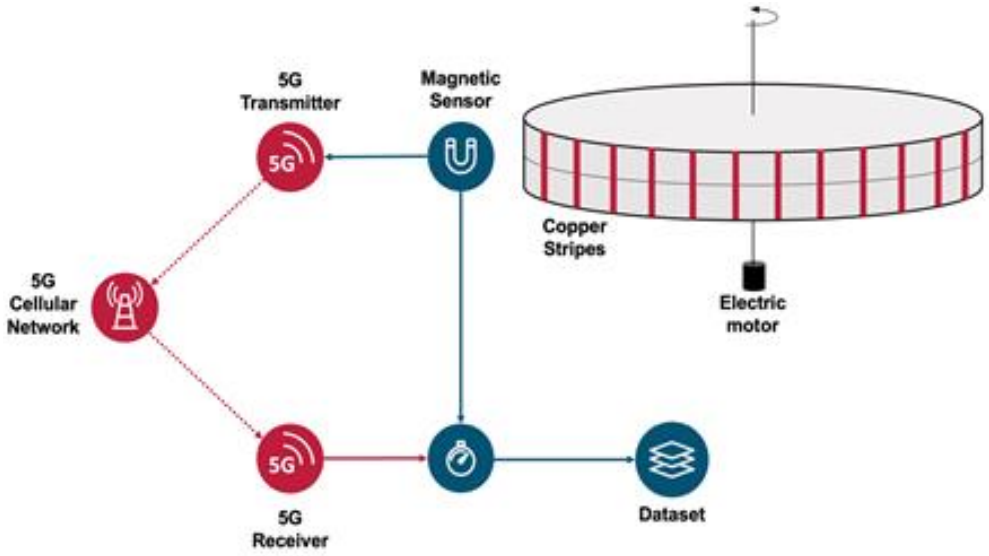




Temperature
Vibration
Noise
Aerosols
Humidity
Turning speeds
Power consumption
Etc.

5G测试床案例: 人-机-料 协同

人、机器人，传感器和传送带之间通过5G网络进行无线通信，5G网络提供底层传输保障，可以实现大数据量的实时传输。上层应用功能不变，大大降低布线的成本，有利于工业生产的快速升级。



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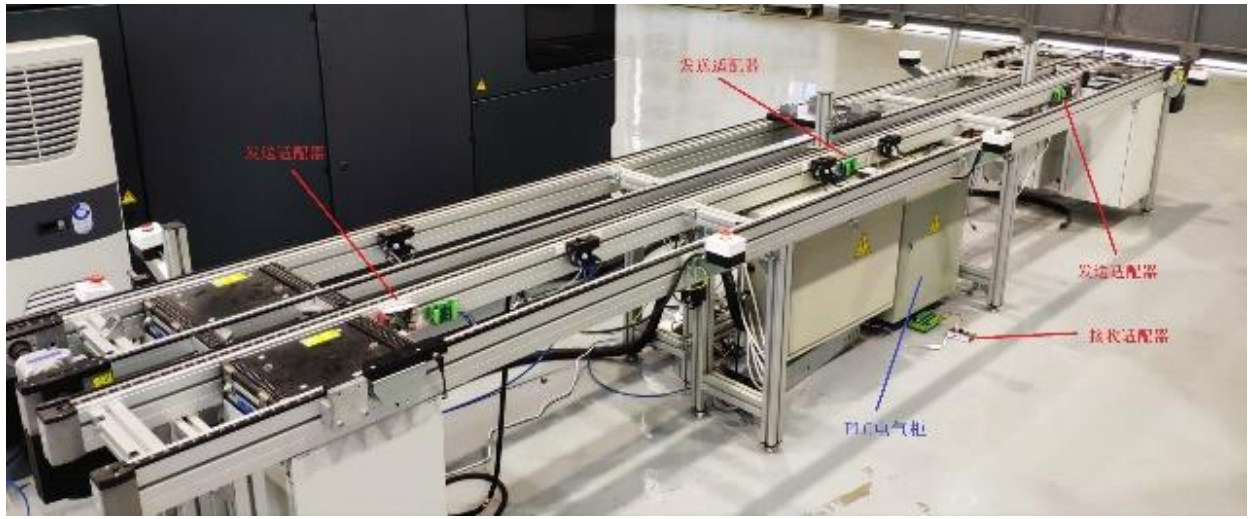
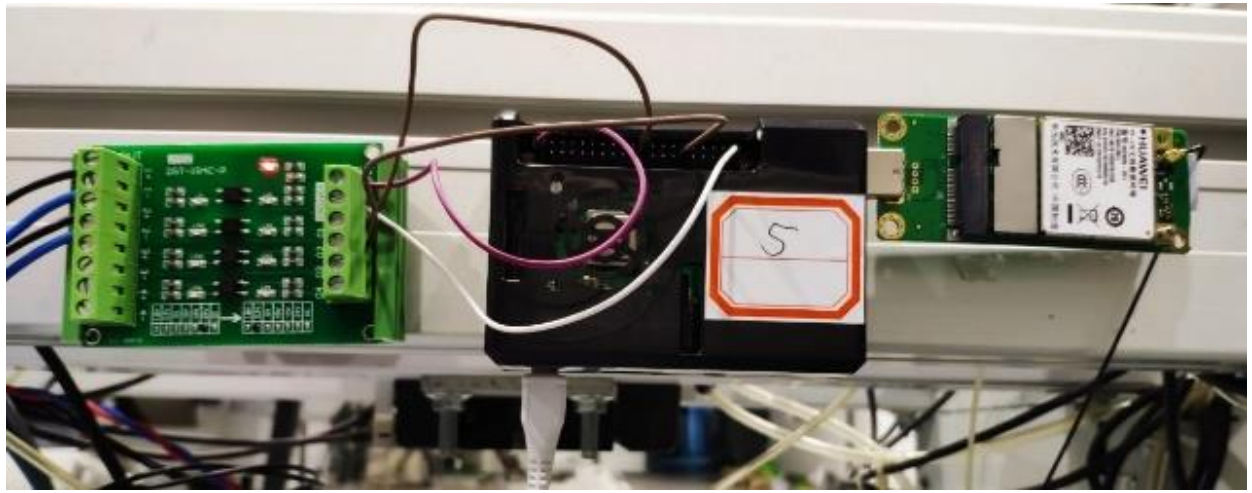
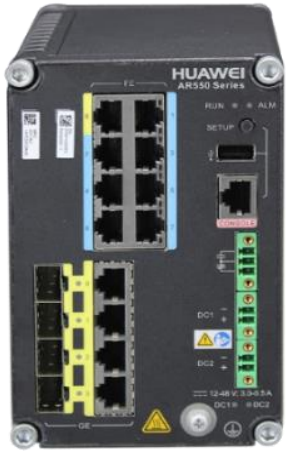
AMTC 5G/AI测试床

5G网络接入适配器





TSN switch



- 适配器可以支持Top 7（Ethernet/IP, Profinet, Ethercat,Powerlink, Modbus-TCP,TSN,Sercos）的工业通信协议和USB/网线通信方式的转换，支持存量工业设备接入蜂窝网络。
- 5G与TSN融合来提高数据在边缘测的处理速度。

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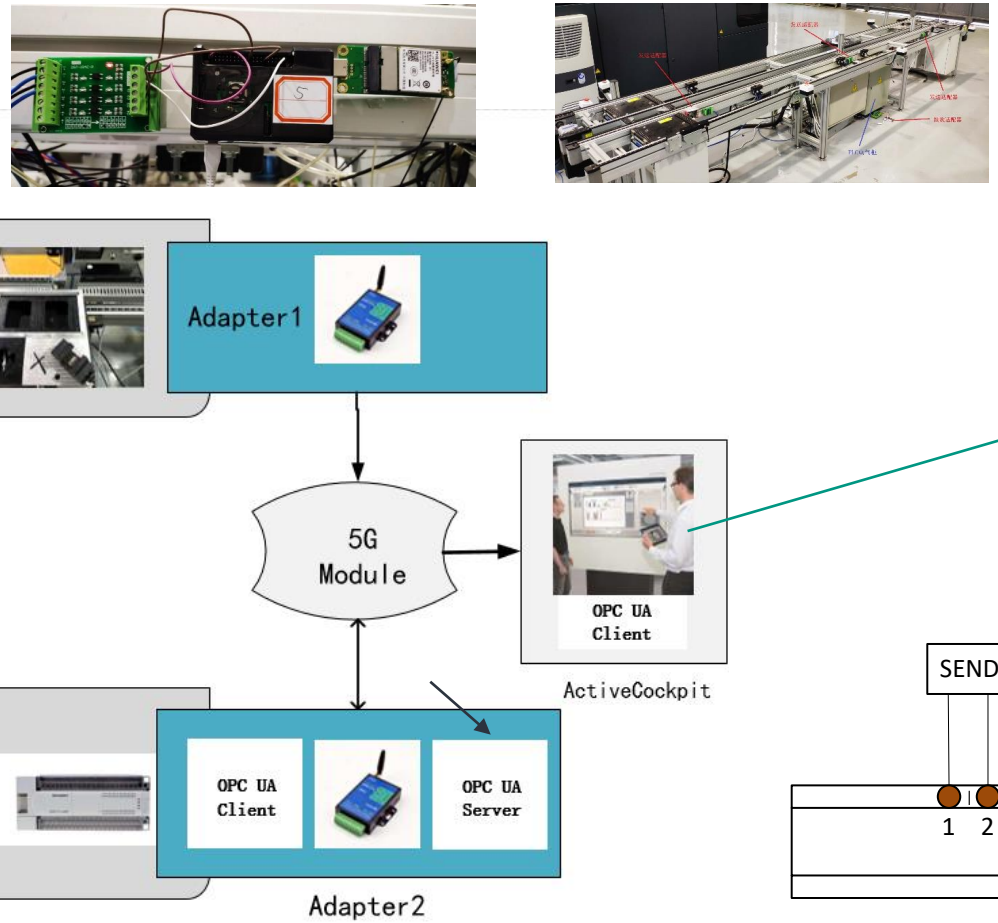
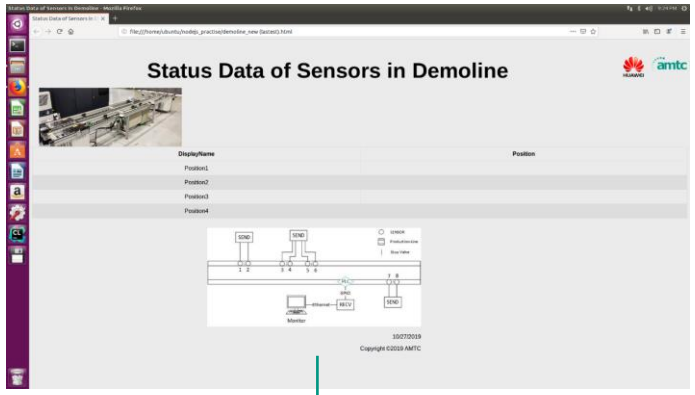
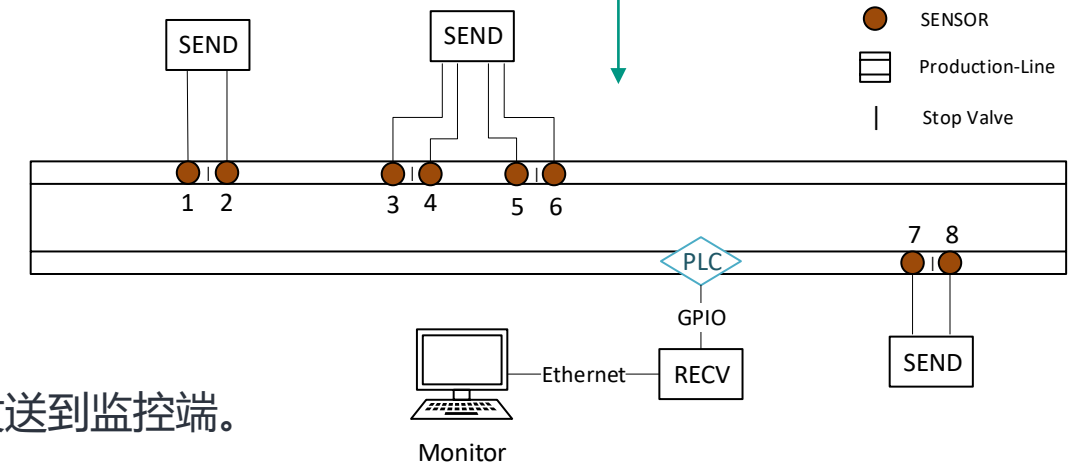
5G & OPC UA 融合

5G and OPC







PLC收集传感器数据，通过OPC UA协议进行封装，并通过5G网络发送到监控端。

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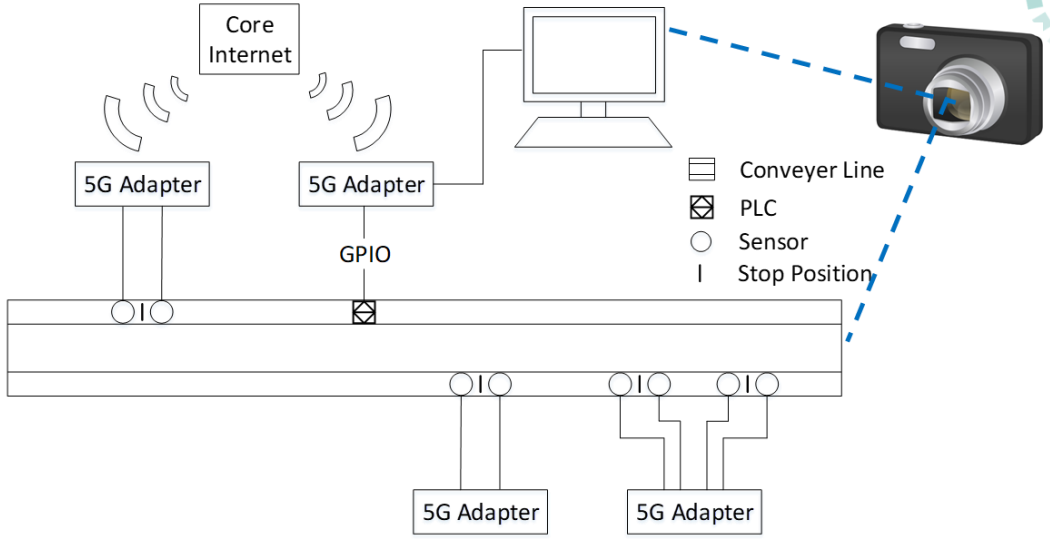
AMTC 5G/AI测试床

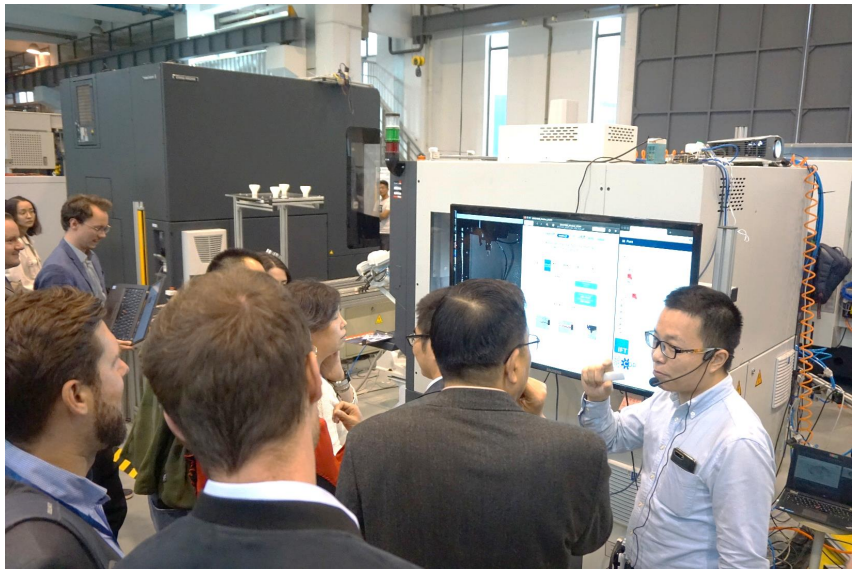
机器视觉与5G场景

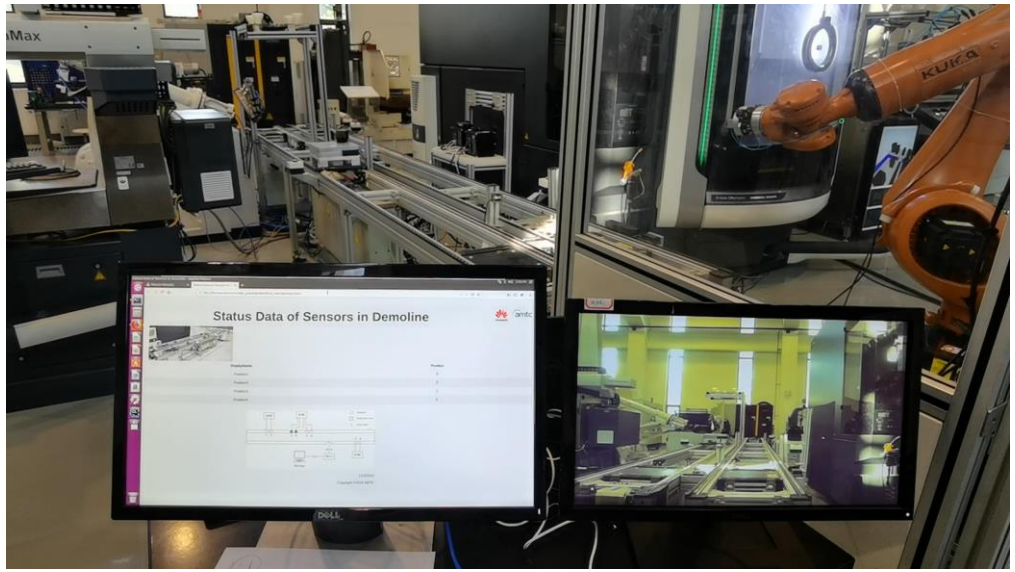
5G发送图像数据

机器视觉

- 车间导航
- 刀具特征和状态识别
- 产品质量管控







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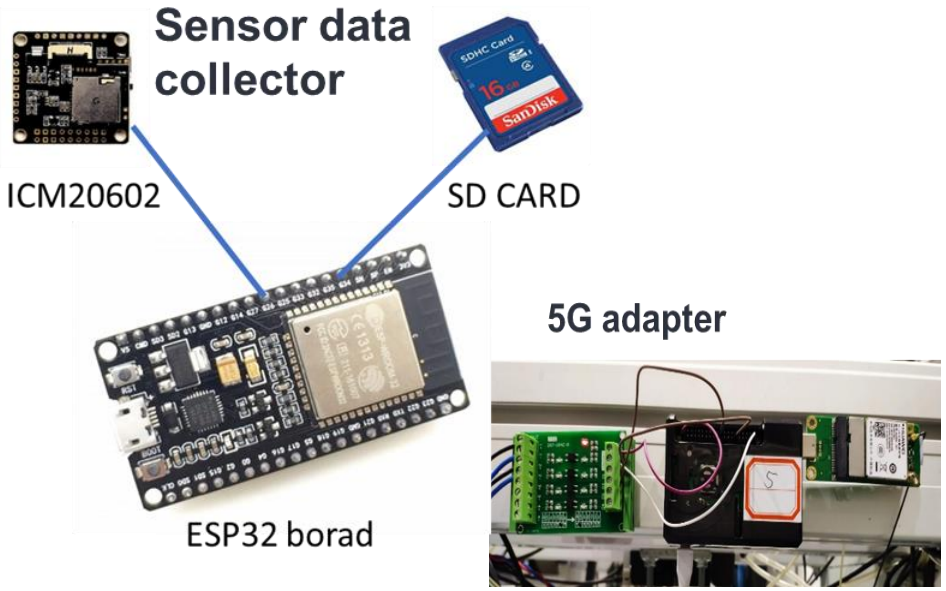
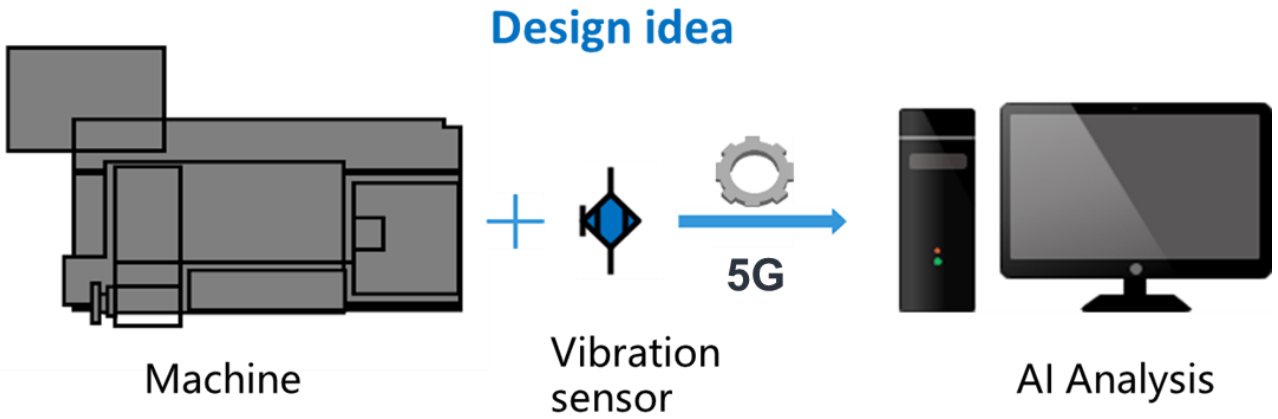
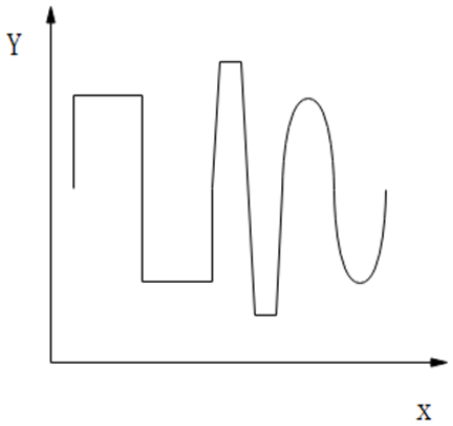
5G和AI

机器学习与5G场景，预测性维护

5G发送传感器数据
机器学习
- 预测性维护
- 机床状态监测







Examples

Machine learning

- Machine status monitor
- Predictive maintenance

轴承寿命预测
机床状态监测的即插即用装置

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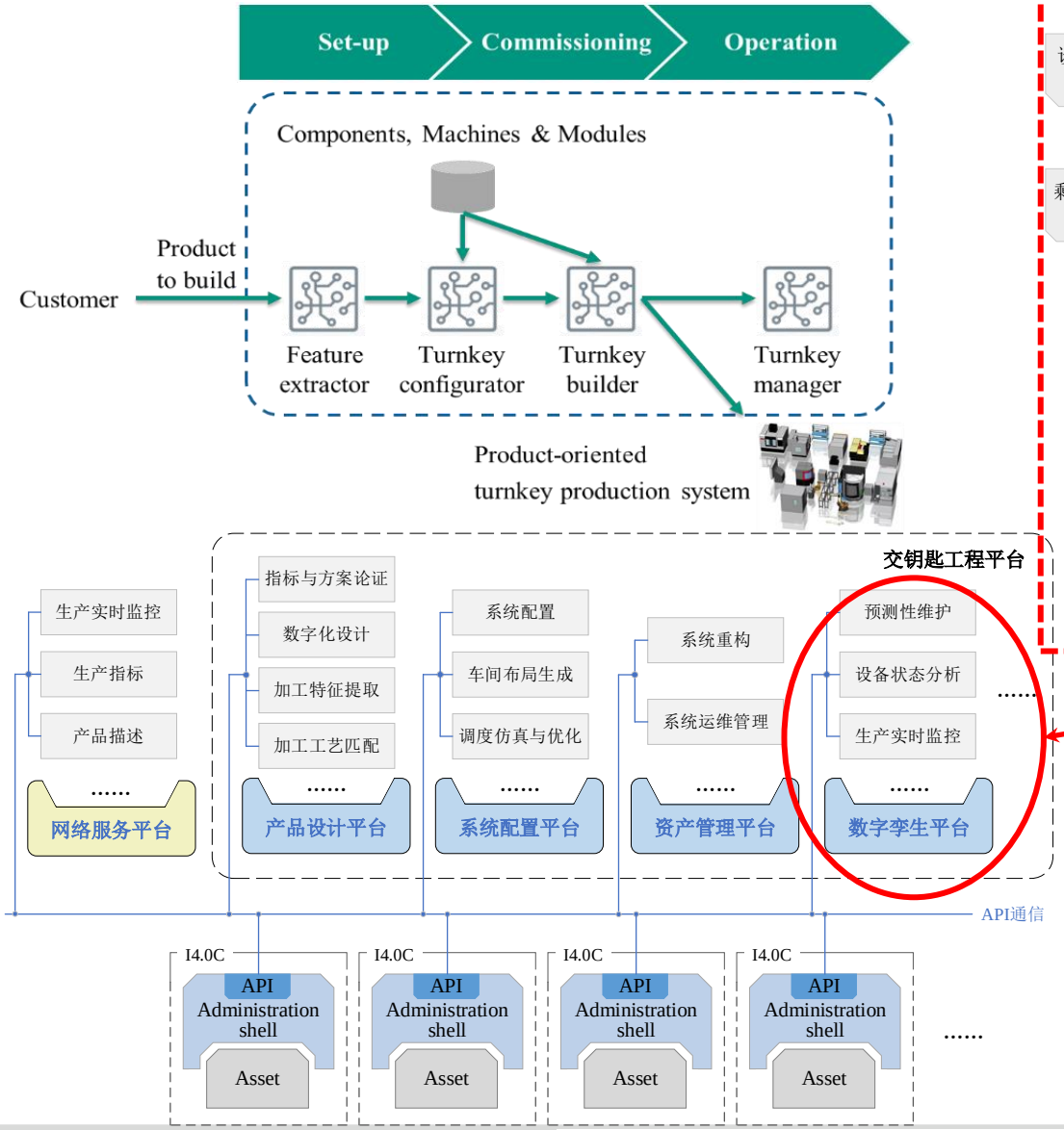
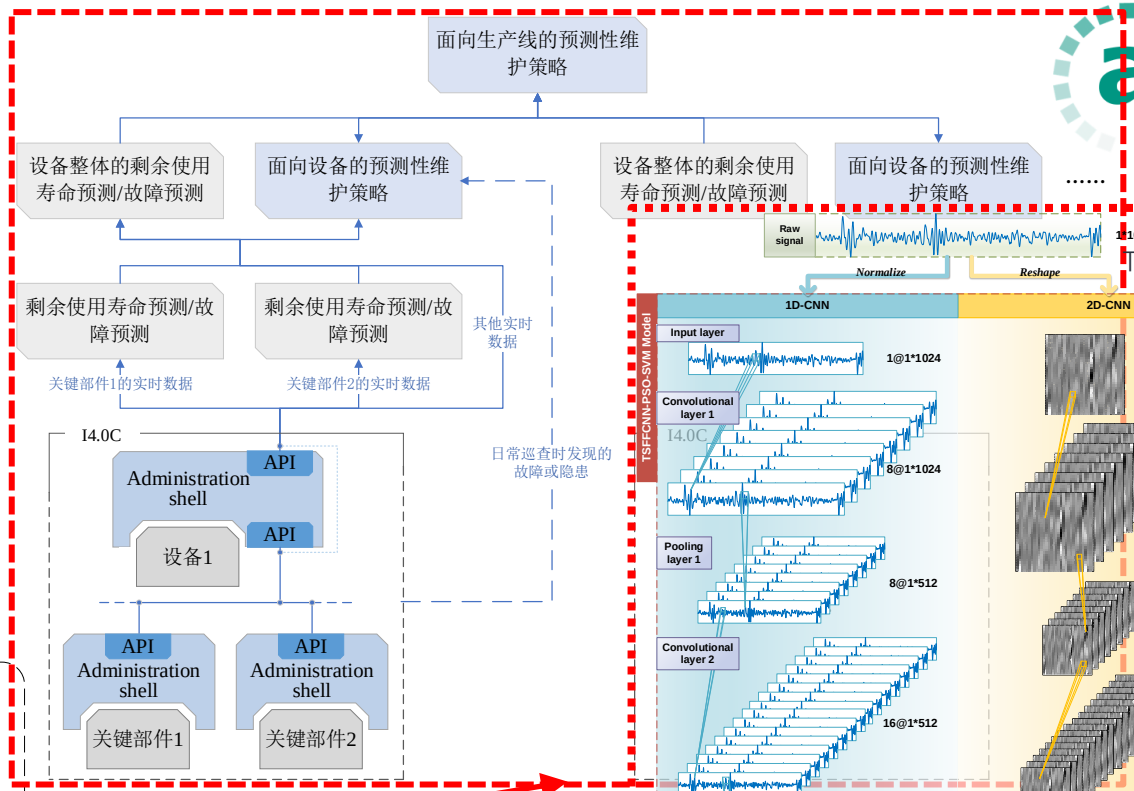
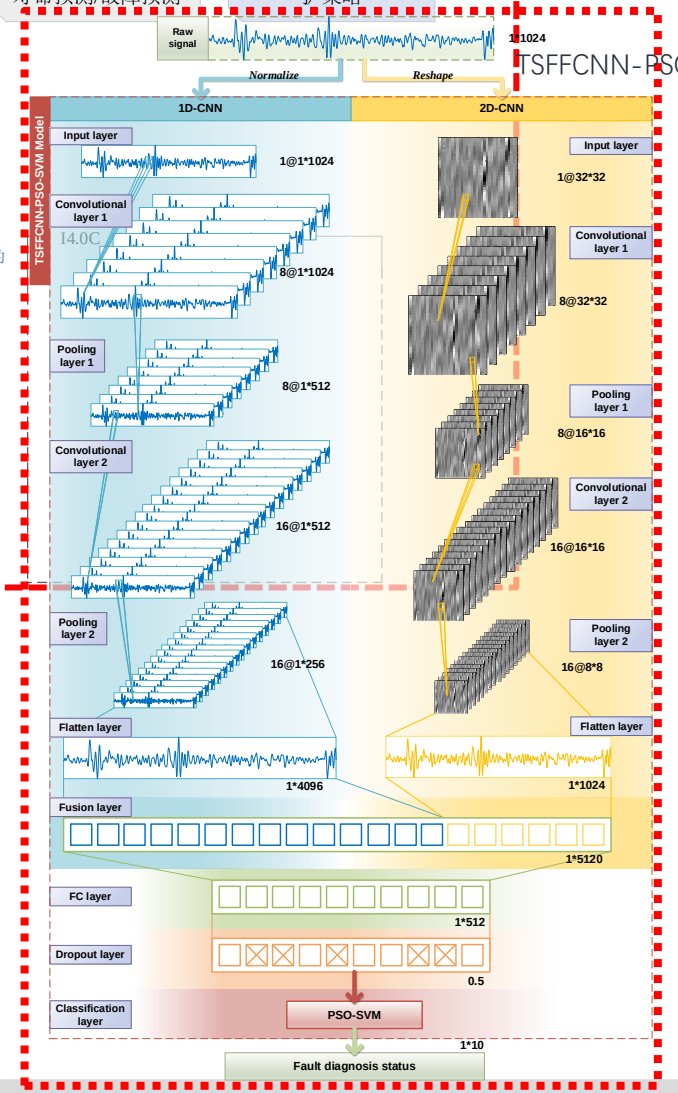
I4TP 工厂自动化交钥匙平台







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Deutsch-Chinesische Zusammenarbeit in Wissenschaft und Forschung

Tongji LFF for 5G and AI Technology Application

Advanced Manufacturing Technology Center, School of Mechanical Engineering, Tongji University, Shanghai, China
Weimin ZHANG

面向未来制造业研究教育

IALF

5G/AI 学习工厂
工业数据传输与分析

INTERNATIONAL
ASSOCIATION OF
LEARNING FACTORIES

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Ruhr-University Bochum

学习工厂的研究动机-制造业进步需求

- 从业人员的培养不仅仅在教室
- 工业进步需要研究成果的产业化

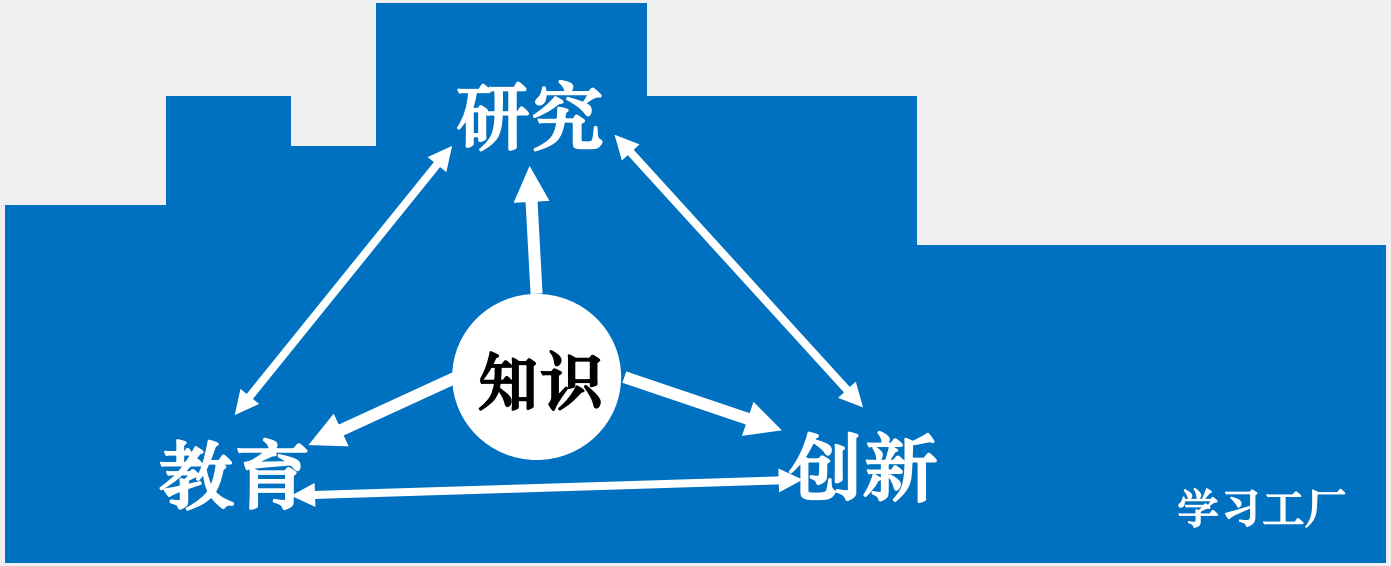
培训环境	学习过程	研究成果	专业知识
↓	↓	↓	↓
真实环境	工业实践	制造技术	工程能力

制造业在生产相关的技术、工具和工艺上都面临着快速的发展；但制造业教学培训既没有跟上制造技术的进步，也没有跟上劳动力市场的需求

Source: Prof.Abele

学习工厂的研究动机-工业界与学术界结合

- 通过研究产生知识，通过教育传播知识以及通过创新应用知识
- 应对学科交叉领域的挑战



Source: Prof.Abele

学习形式-----与工作关联的学习形式

典性案例
学习工厂

工作连接型	学习和工作场所和过程是分离的，但是彼此靠得很近，因此在执行工作任务时不一定伴随着学习过程
工作约束型	学习和工作场所和过程是相同的，学习机会以及相应学习设施扩大了工作场所
基于工作的学习	工作和学习场所完全分离的情况下，且在学习过程中工作任务或者价值创造的任务都不会得到专业的执行

工作约束型学习 在结合工作与学习效率上具有最大的潜力

Source: Prof.Abele

学习工厂的类型

- 改进生产工艺型学习工厂
- 生产与工厂布局规划重构型学习工厂
- 能源和资源效率研究型学习工厂
- 应用型教学工厂
- 工业4.0研究型学习工厂
- 其他主题相关的学习工厂

可持续性研究、产品出现过程研究、物流优化、管理与组织研究、工商管理研究、自动化技术研究

数字化和虚拟学习工厂的使用案例

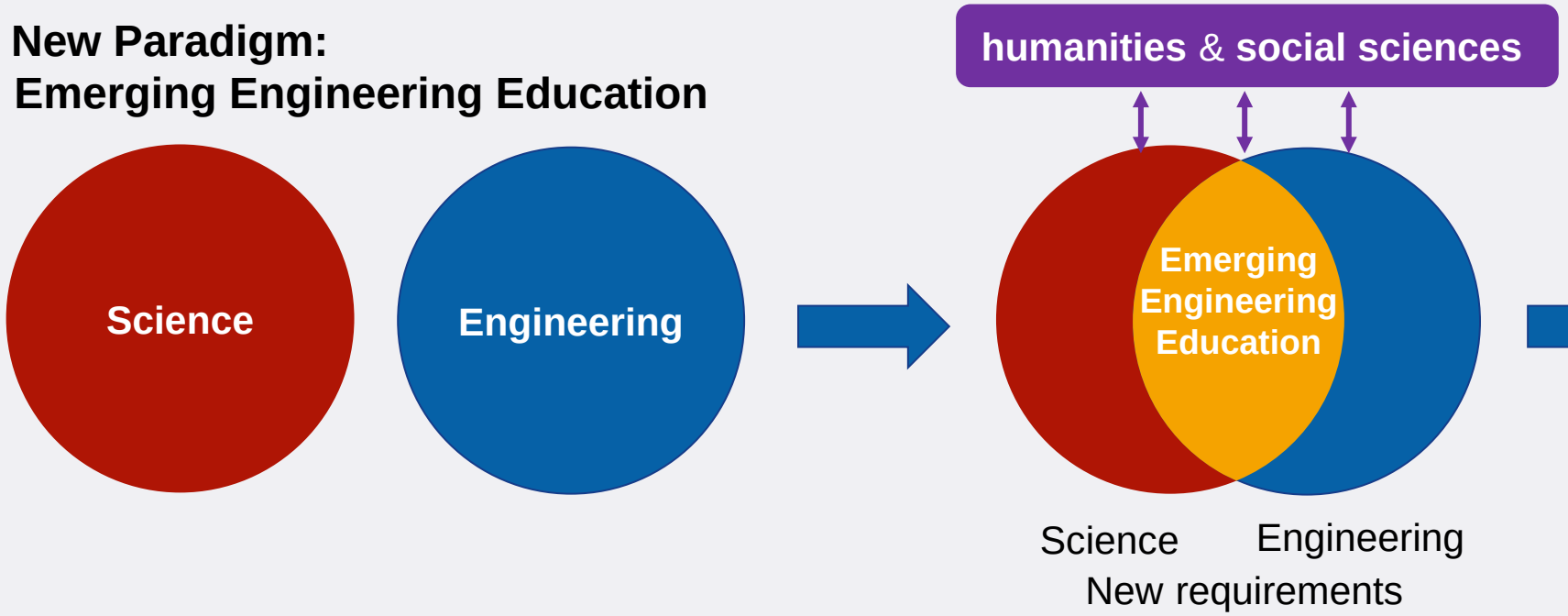
- LLF 与 “ 3DEXPERIENCE” 软件中创建的虚拟物理学习工厂具有相同的表示形式，将产品、资源和流程设计以及仿真集成到一个平台中。
- 虚拟模型作为对物理环境的补充，允许学生在实际应用之前就系统设计进行测试和验证。

罗伊特林根大学的ESB物流学习工厂

Source: Prof.Abele

Motivation 新工科

New Paradigm:
Emerging Engineering Education



Tongji LFF

Benefits:

1. Combining theory with practice
2. Easy to teach for teachers and easy to understand for students
3. As a LFF case, expand to the whole China

Since February 2017, Ministry of Education of the People's Republic of China has been promoting the construction of Emerging Engineering Education

Tongji University plays an active role in the construction.

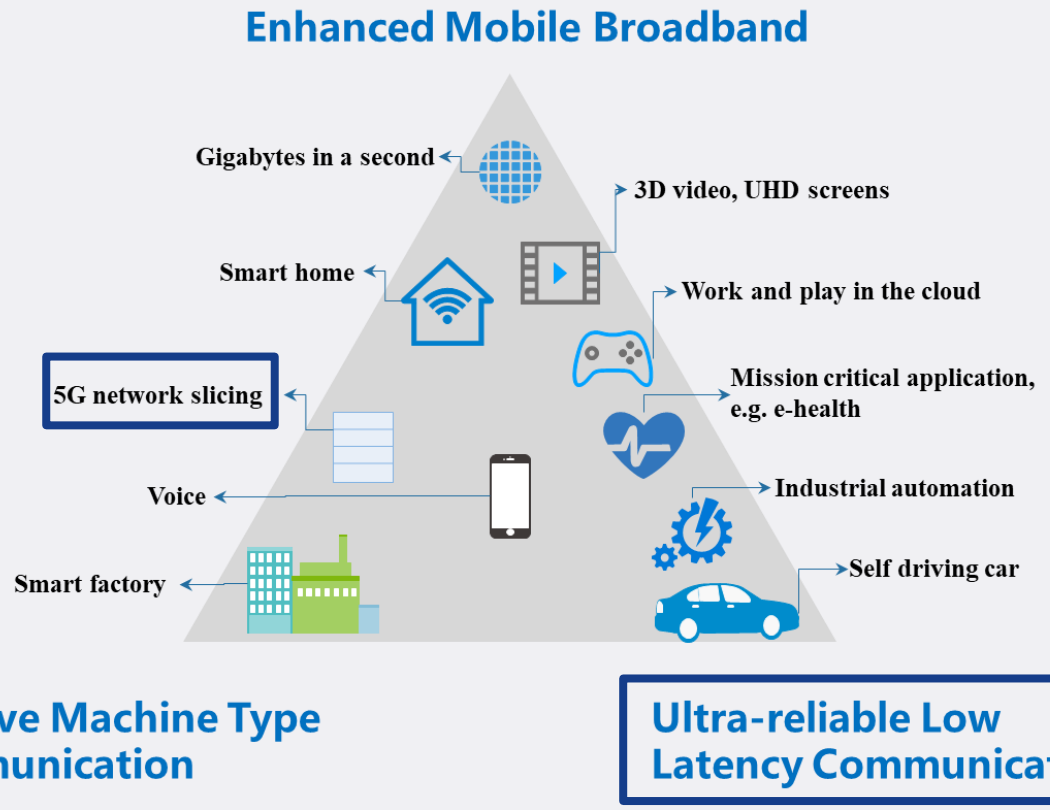
AMTC的5G和AI的学习工厂

研究与培训的主题

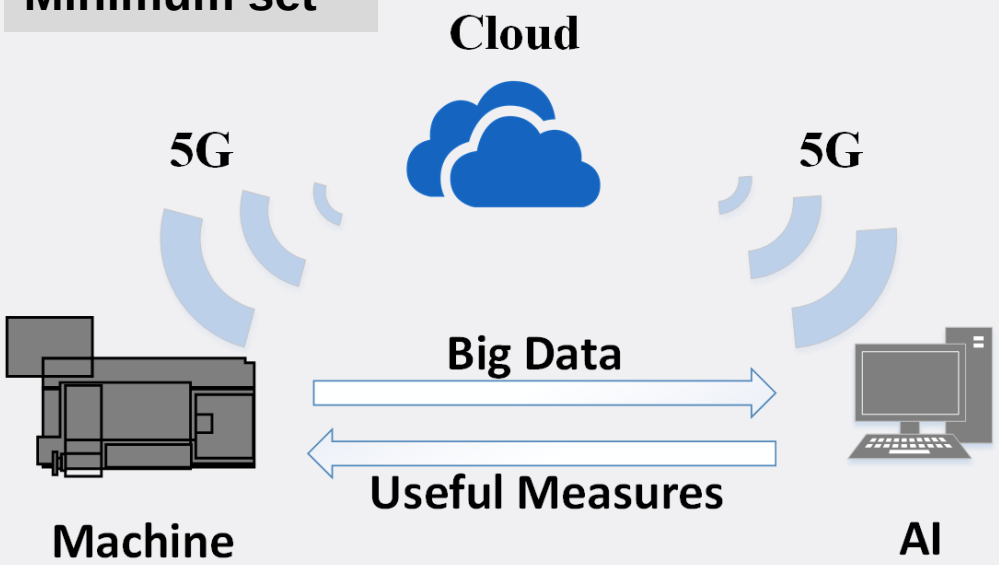
1. Application of 5G and AI technologies in production
2. Design and development of 5G adapter
3. Cloud/Edge computing using AI for machine tools predictive maintenance
4. Programming of robot-based flexible forming processes
5. Sensor and data acquisition in robot-based flexible forming processes
6. Joint stiffness identification of robots, position compensation and control with AI algorithms

Concept Design

5G scenarios



Minimum set



ABCD principle

AI	Big data	Cloud	Domain
Analysis and decision making	Data accumulating and transmitting	Platform with integrated functions	Applied to different industries

Didactical Method

Training

- Scene visits
- 5G adapter
- AI algorithm

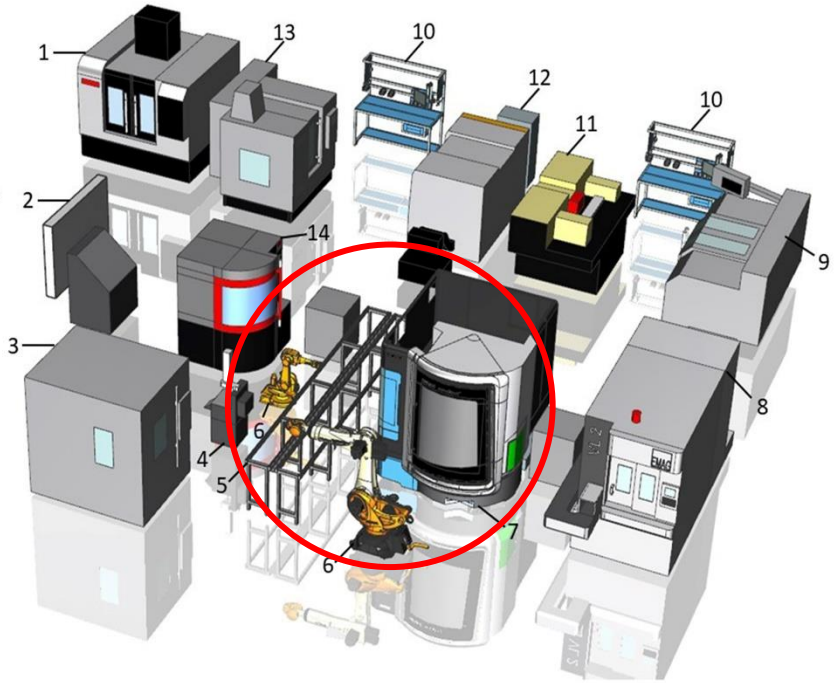
1. What is 5G? What is AI?
2. How can 5G and AI applications look like?
3. What do 5G and AI mean for manufacturing plants?

	Courses	
Phase 1: Production demo line experience	Experience the current AMTC state	a
	Theoretical Input about 5G and AI	b
	Active operation in demo line	a c
	Discussion session about 5G and AI	g
Phase 2: Experiencing the 5G and AI applications	Group division of the participants	h
	AI and 5G scene visits	a f
	Working with separate task	e
	Reflection and wrap up	g
Phase 3: Developing 5G and AI solutions	Lecture on potential of 5G and AI	b
	Working in group	h
	Discussion and perfection of solutions	g
	Presentation of results	d

Methods
a Instruction and practice
b Lecture and examples
c Observation sheet
d Presentation
e Task-driven
f Play round
g Class discussion
h Teamwork

Implementations

1 VMC850 milling machine
2 Active cockpit screen
3 M1.4 milling machine
4 Coordinate measure machine
5 TS2 Rexroth conveyer line
6 Industrial robot
7 Five-axis machine tool
8 VL2 vertical lathe
9 Cylindrical grinding machine
10 Assembly station
11 Face grinding machine
12 BOCHI lathe
13 MAG milling machine
14 EMCO milling machine



uRLLC ➔ wireless communication for time-critical operations

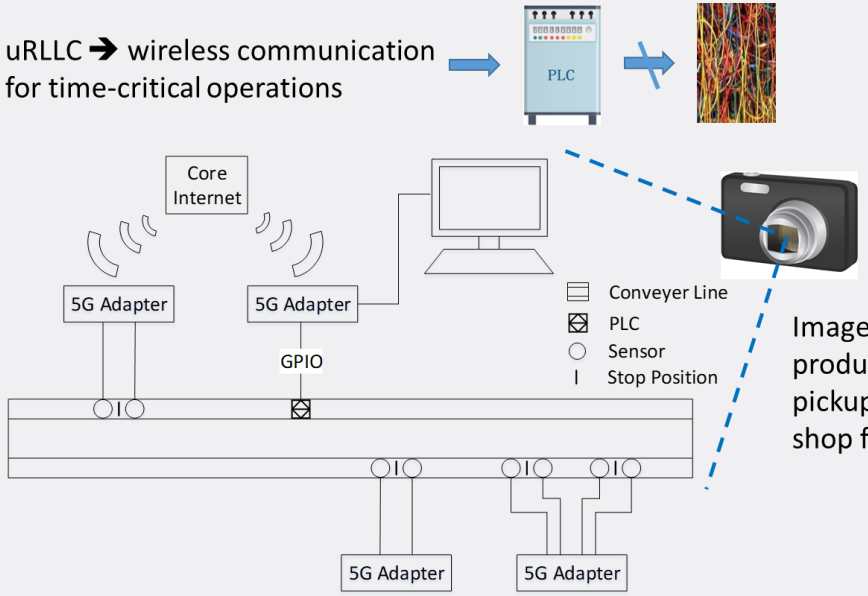
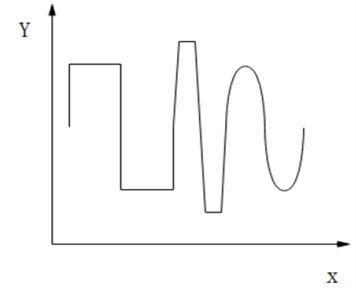


Image processing ➔ product positioning, pickup location and shop floor navigation

AI Examples



Machine learning ➔

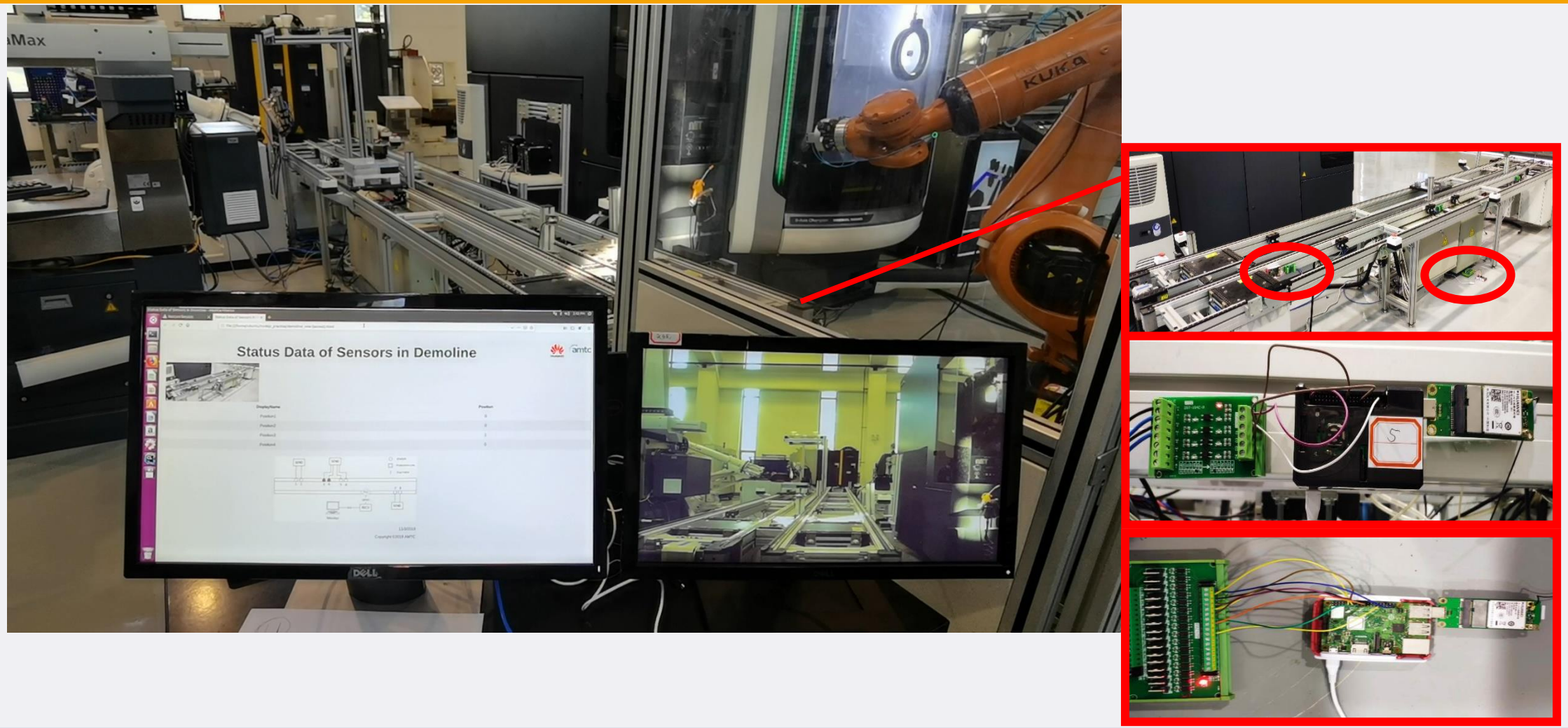
- Machine status monitor
- Predictive maintenance

5G Base Station

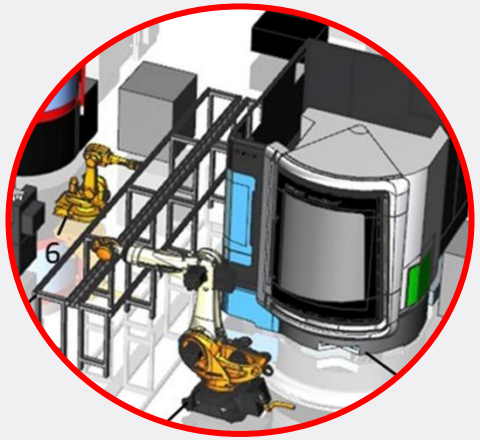
- **5G network slicing**
- **Ultra-reliable low latency communications**

- **Machine learning**
- **Computer vision**

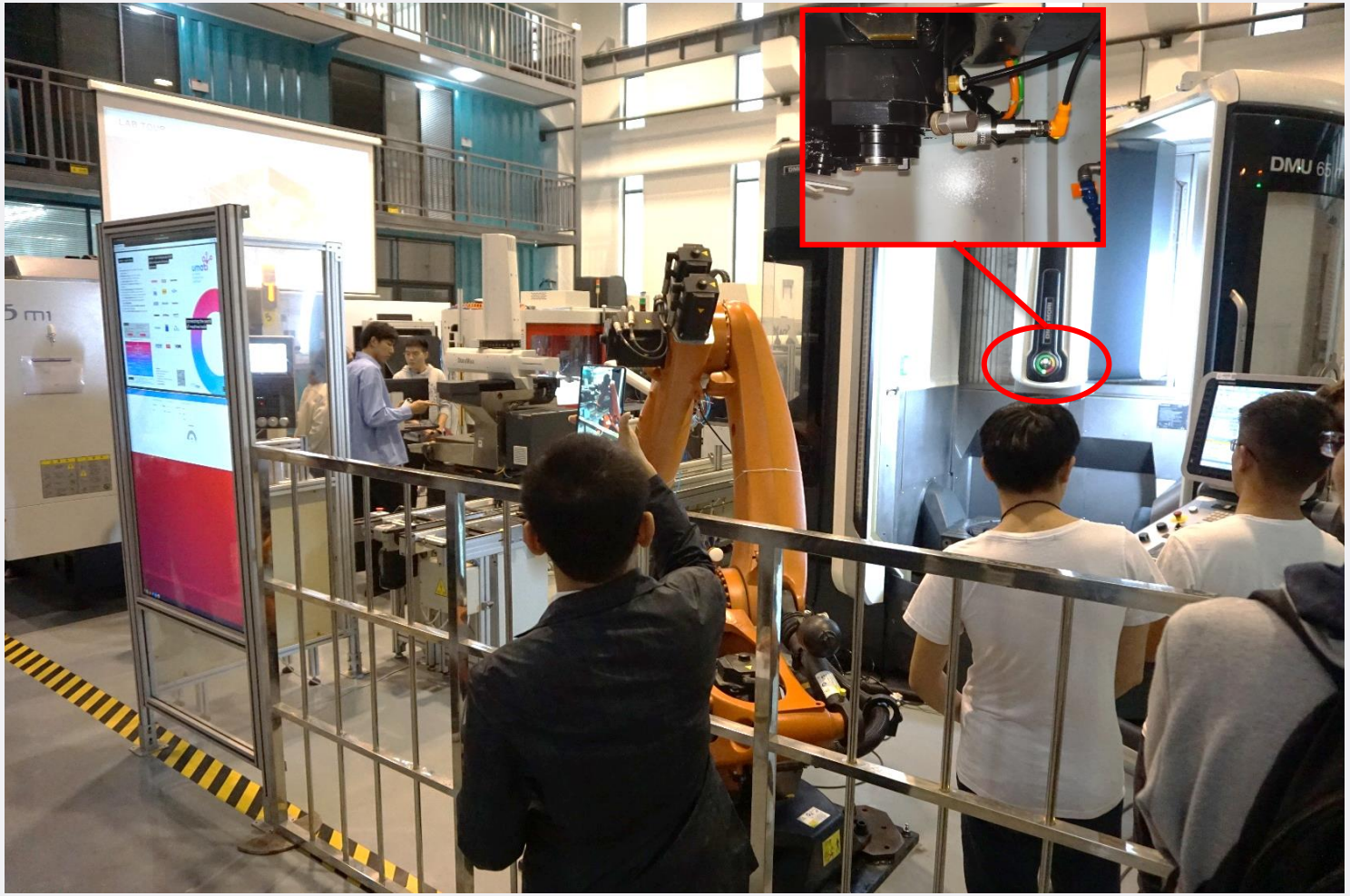
Implementations



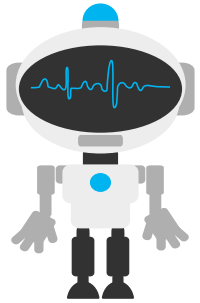
Implementations



5G and AI Application Presentation

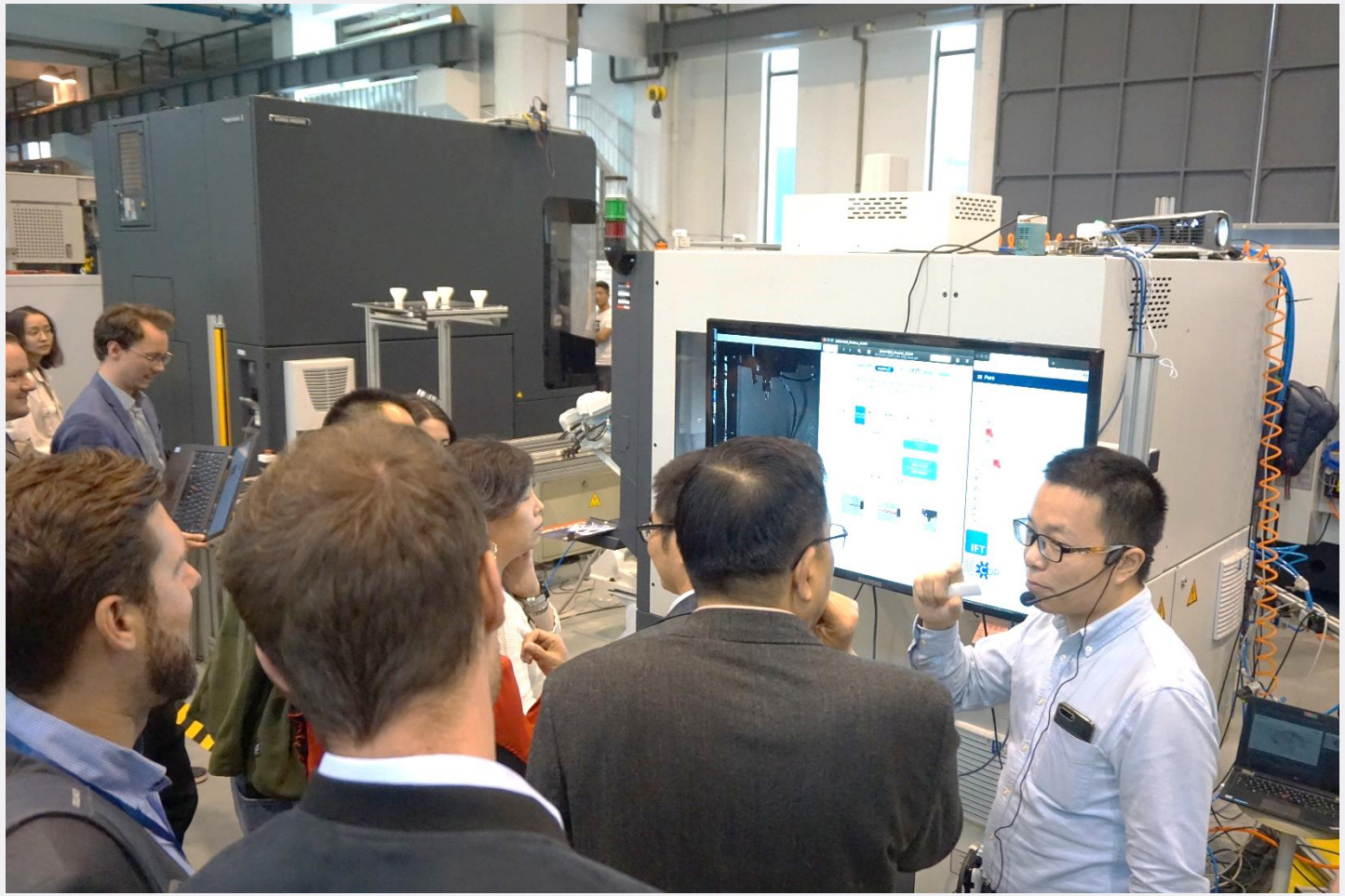


Implementations

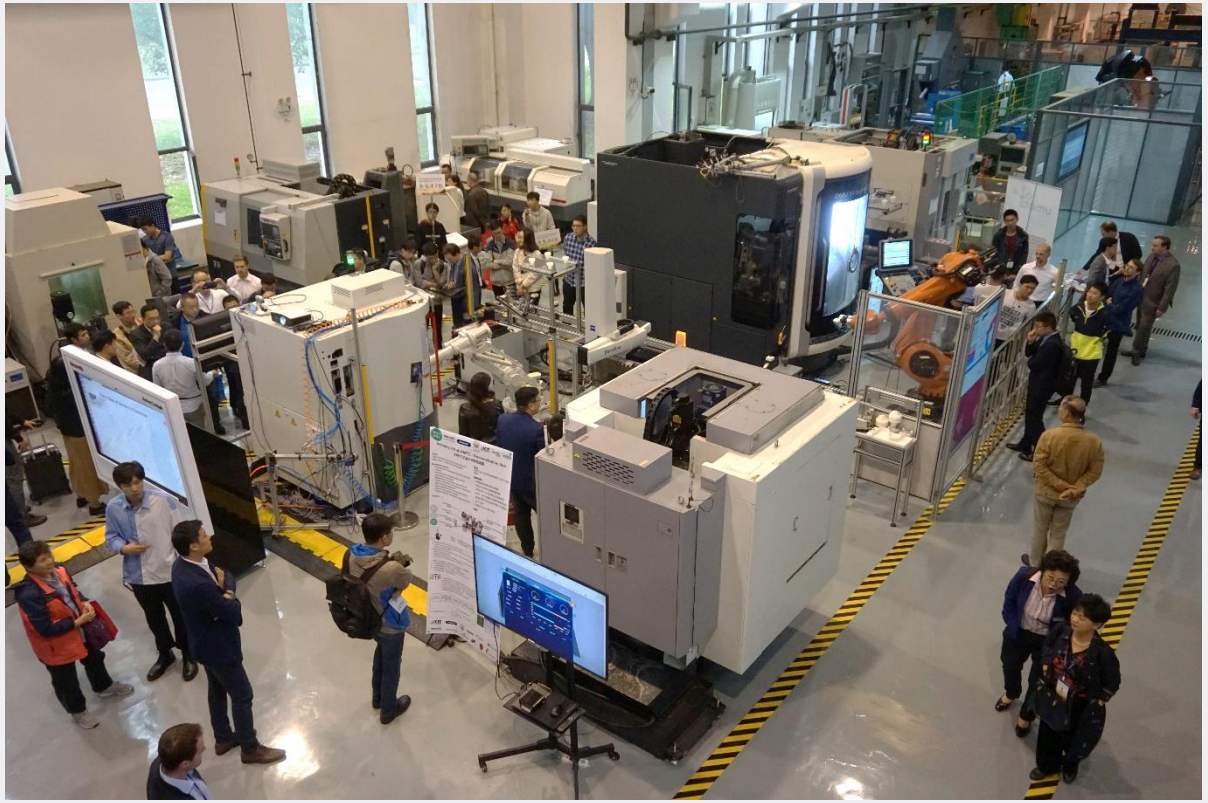


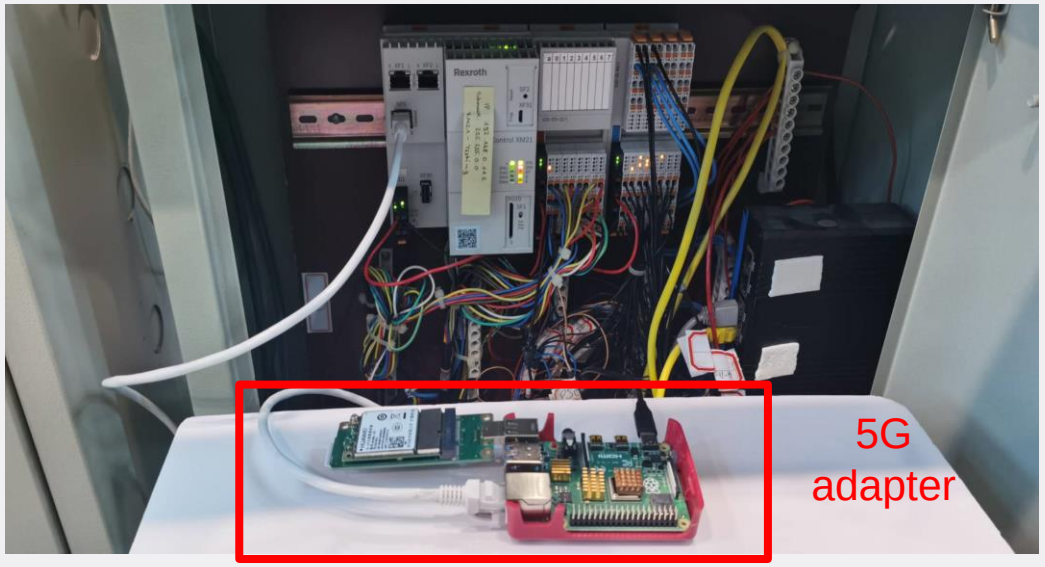
Artificial Intelligence

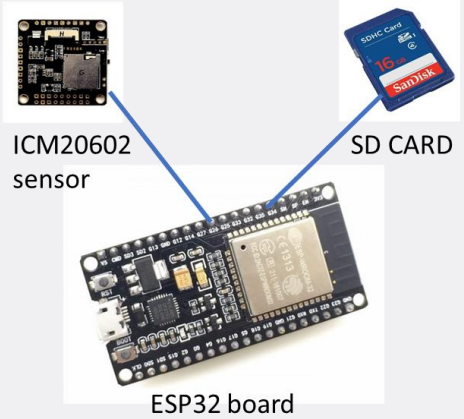
Computer Vision Identification of the tool features and conditions



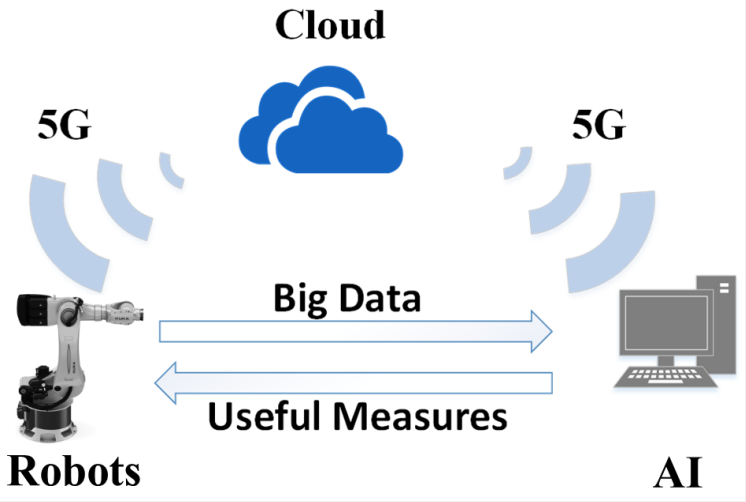
Implementations







Implementations



An example is presented to the students how to implement online data acquisition and real-time control **using AI algorithms** to compensate displacement and improve geometrical accuracy**,** as well as to control temperatures in the heat-assisted robot-based forming process for difficult-to-form materials. **5G will be implemented in future**.

AI案例-i5&iSESOL 整体架构

工业化+信息化

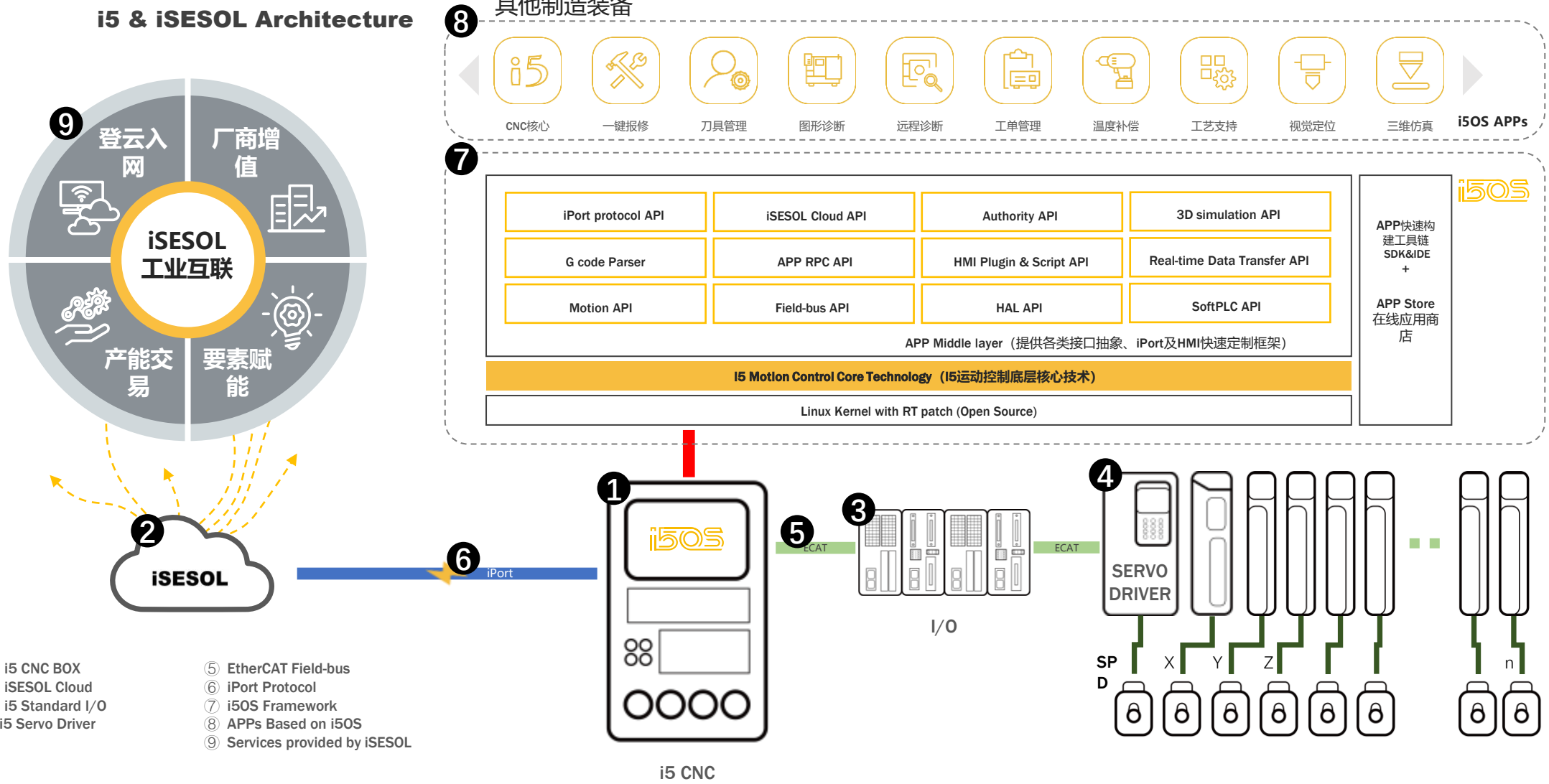
端 + 网 + 云 =

端：i5智能机床及其他制造装备

网：工业互联/物联网

云：云计算/大数据

i5 & iSESOL Architecture



① i5 CNC BOX
② iSESOL Cloud
③ i5 Standard I/O
④ i5 Servo Driver
⑤ EtherCAT Field-bus
⑥ iPort Protocol
⑦ i5OS Framework
⑧ APPs Based on i5OS
⑨ Services provided by iSESOL

i5OS AI案例

——热误差大数据补偿方案

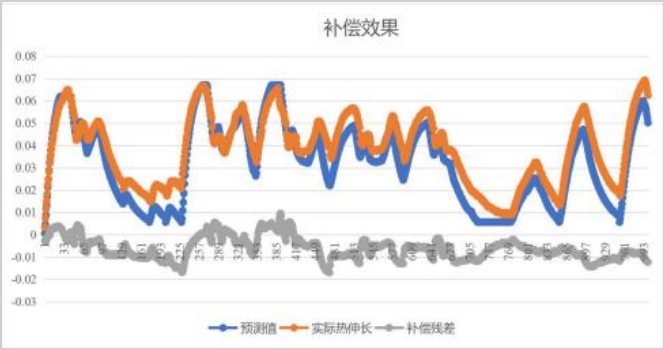
热误差补偿APP

建立数学模型预测误差值，再将误差值反向叠加到进给轴上：

- 无需热机和建立恒温车间，保持机床的加工精度
- 生产线停机时恢复过程缩短
- 节约加工成本、增加有效工时、提高生产效率
- 加工精度提高

数据采集与预测

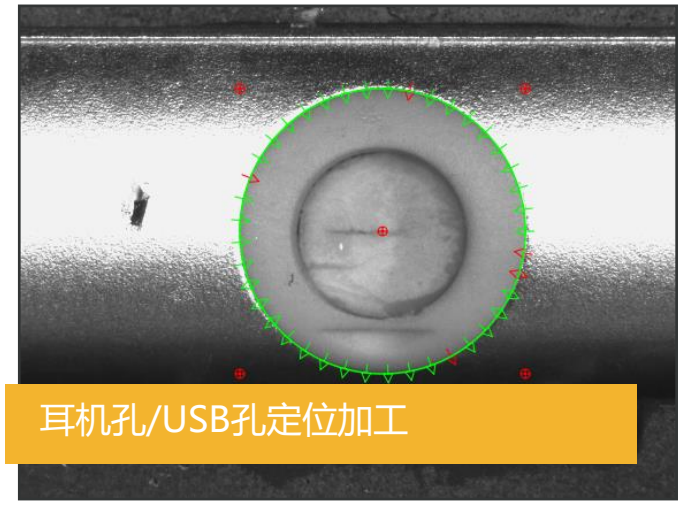
补偿实施

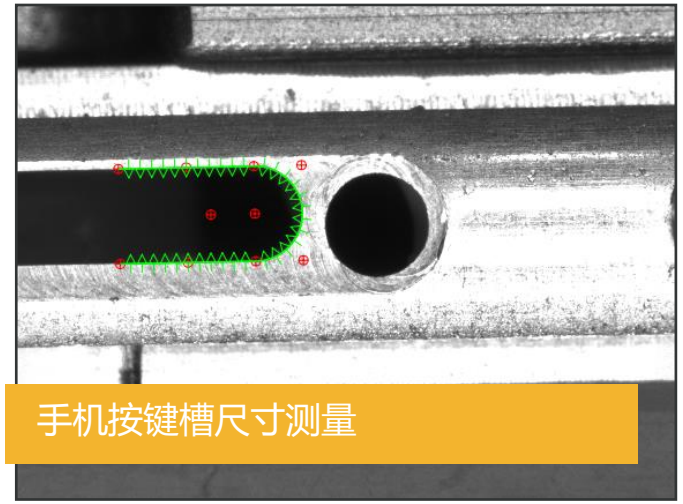


补偿效果

i5OS AI案例

——快速检测方案（视觉识别）





视觉识别APP

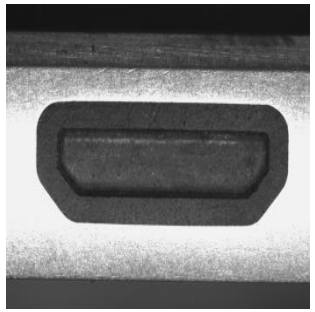
视觉识别

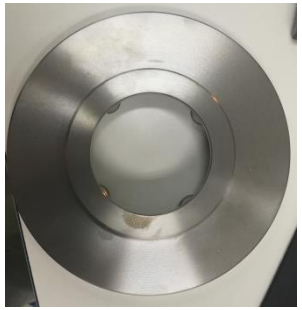
- 特征识别：对工件表面某一特征进行坐标定位；
- 提高加工精度：减小装夹误差；
- 安装简便：基于机床原有结构；

功能优势

1s内快速定位，识别精度5丝以内；

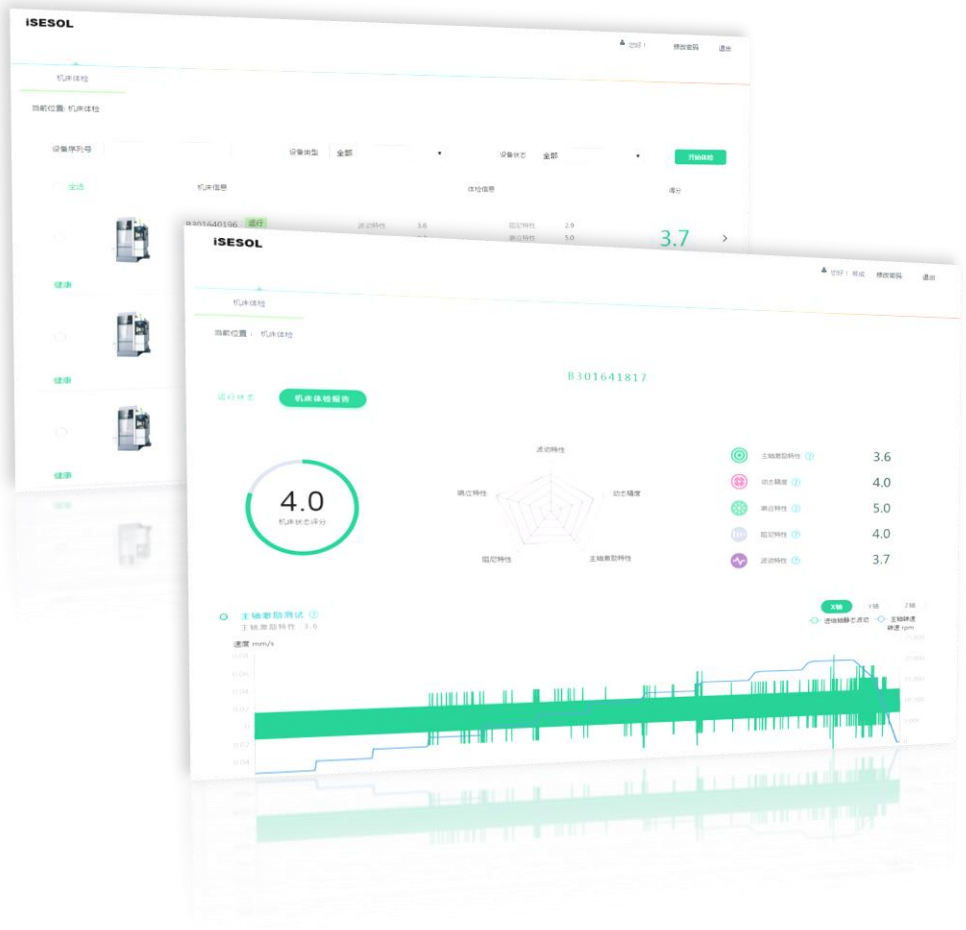
- 非接触式检测，避免对工件和刀具的损坏；
- 能够快速识别微小特征，精准定位，保证切削的精准度；
- 集成于CNC系统，操作简易、人性化；
- 工业级防护，外观简洁，稳定可靠。





i5OS AI案例

——工业大数据应用（机床体检）



运行标准测试程序并云端采集分析数据

- 为装备制造商提供智能装备出厂良品检测
- 制造企业可对自有智能设备进行自检自查
- 配合iSESOL装备服务协便于及时发现问题

机床体检APP

采集信号

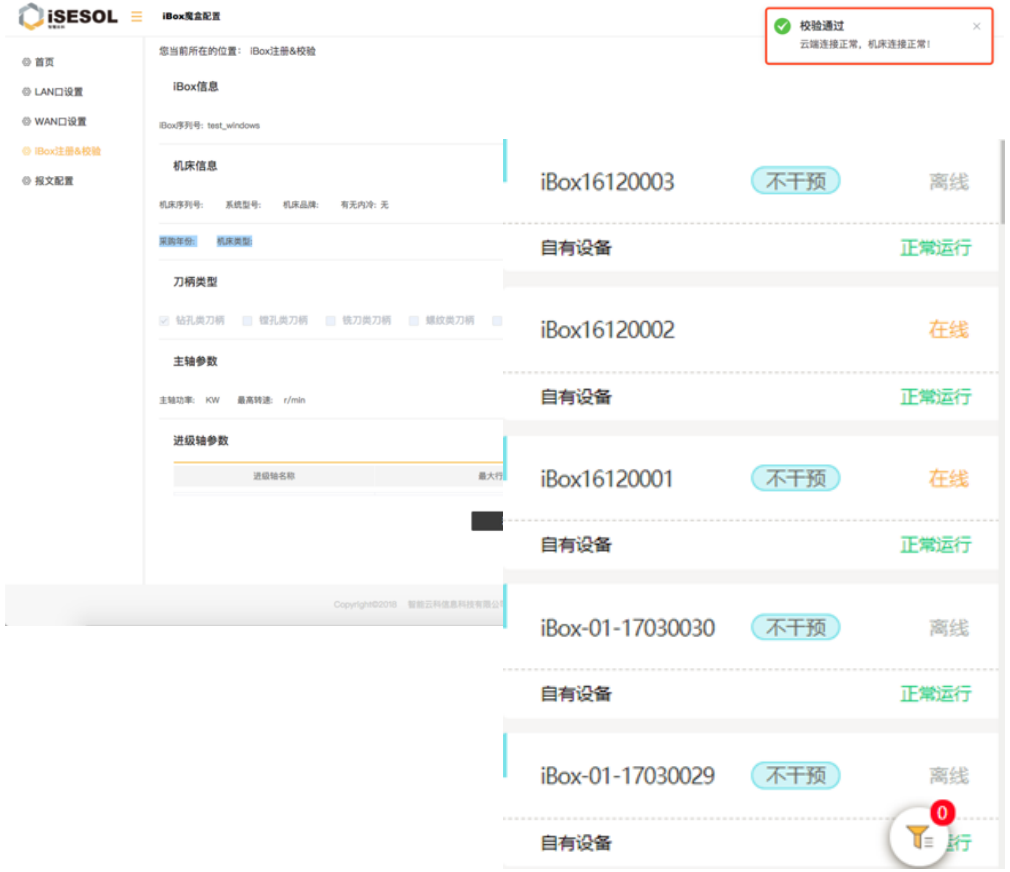
外部传感器
- 主轴功率信号
- 伺服电机功率信号
- 工作台加速度信号
- 主轴加速度信号

测试内容
- 丝杠受力分析测试程序
- 单轴测试
- 圆弧测试
- 双轴测试
- 主轴空转测试

内部伺服数据
- 进给轴理论速度
- 进给轴实际速度
- 进给轴理论坐标
- 进给轴实际坐标
- 进给电机电流

i5OS AI案例

——机器学习（iSESOL Box）

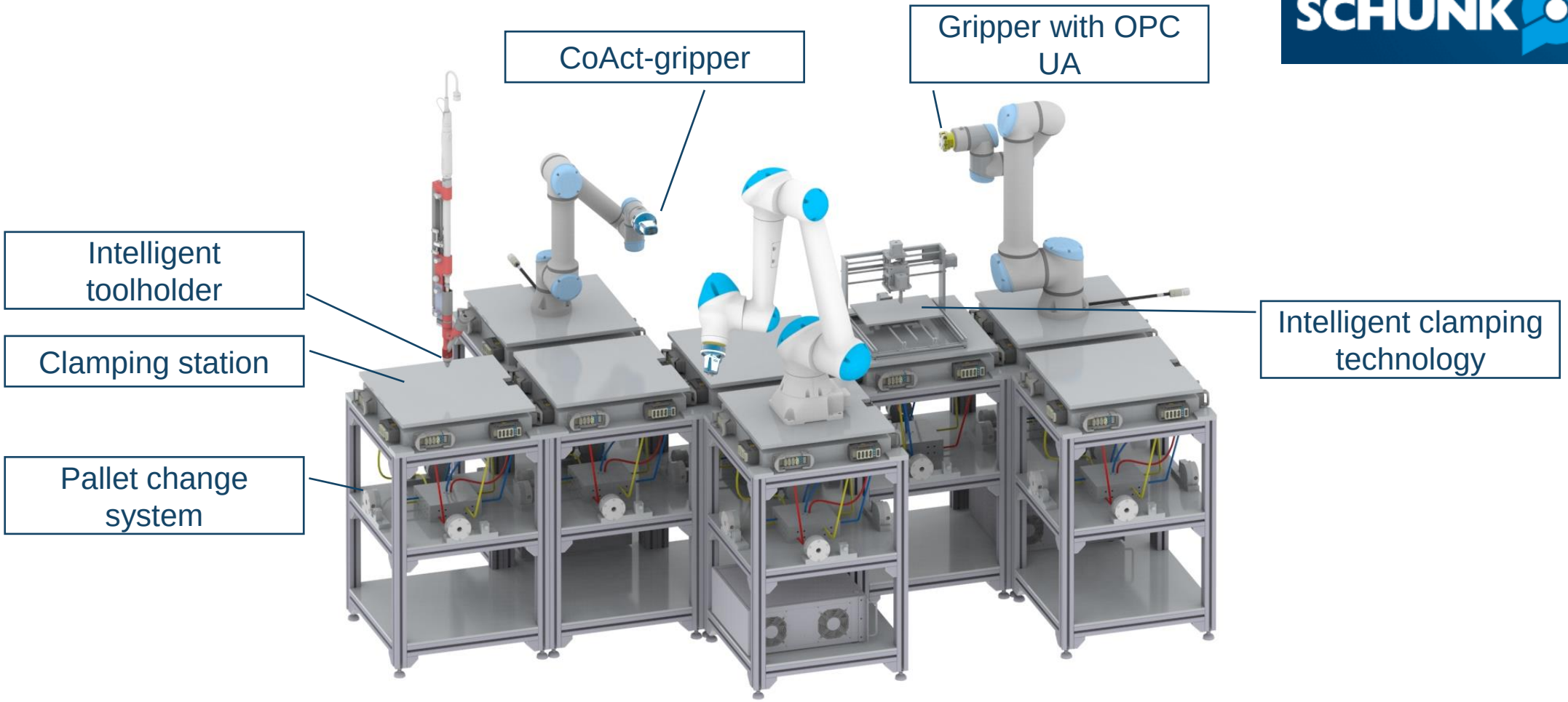


工业互联网平台级智能终端

iSESOL Box结合智能优化加工场景，接受云端下发的指令，并通过自适应核心算法计算来控制机床的进给倍率，以达到加工效率的提升。智能优化功能可针对SIMENS、FANUC等数控机床的粗加工和半精加工，提升机床加工效率的10%-25%。

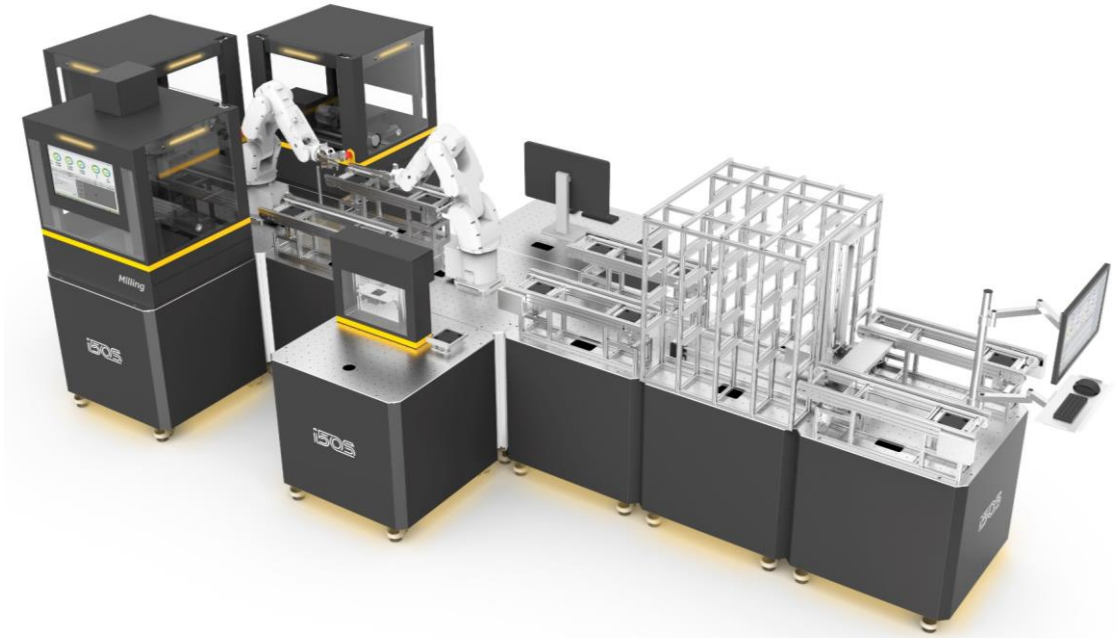
案例 MODULAR NETWORKED FACTORY

Use case – with products from **SCHUNK**

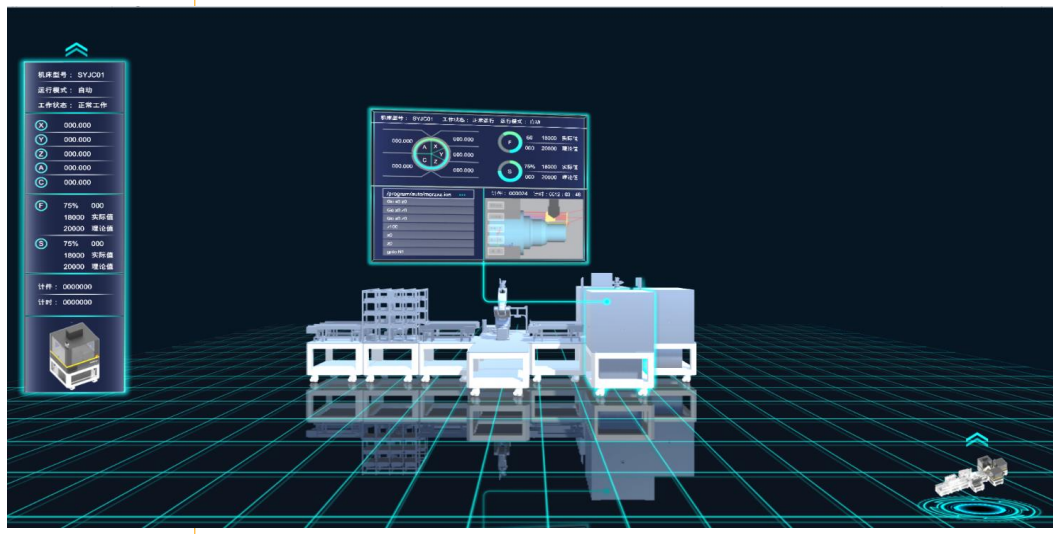


i5OS模块化实例

——i5Blocks智能制造生产线



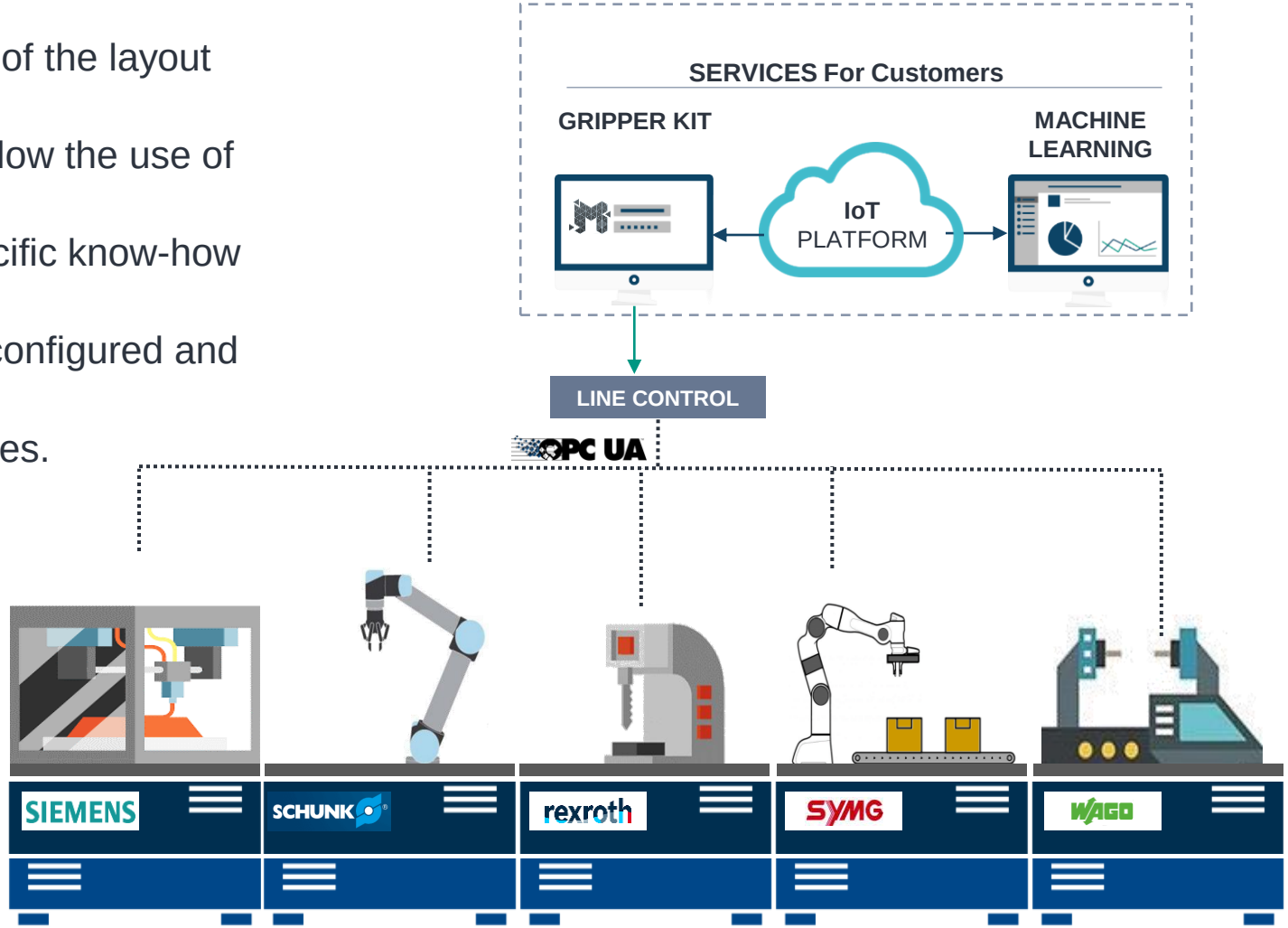
1、可快速重构
2、网络化协同制造、个性化定制
3、AR增强现实、现实虚拟无缝融合
4、数字双胞胎技术、现实虚拟同步
5、工业互联网
6、视觉识别模块
7、5G通讯技术、毫秒级通讯
8、全套课程解决方案
9、体积小、可上楼、操作安全可靠



MODULAR NETWORKED FACTORY

Our solution

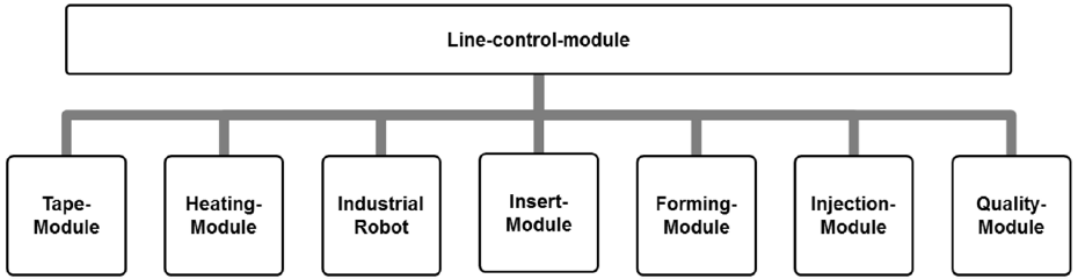
- Modular base frames allow easy configuration of the layout and uniform power supply
- Uniform OPC-UA Companion Specifications allow the use of different controllers
- The added value takes place with domain-specific know-how and intelligent components of the suppliers
- The service/based line control can be quickly configured and reconfigured with apps.
- Cloud services enable new customers use cases.



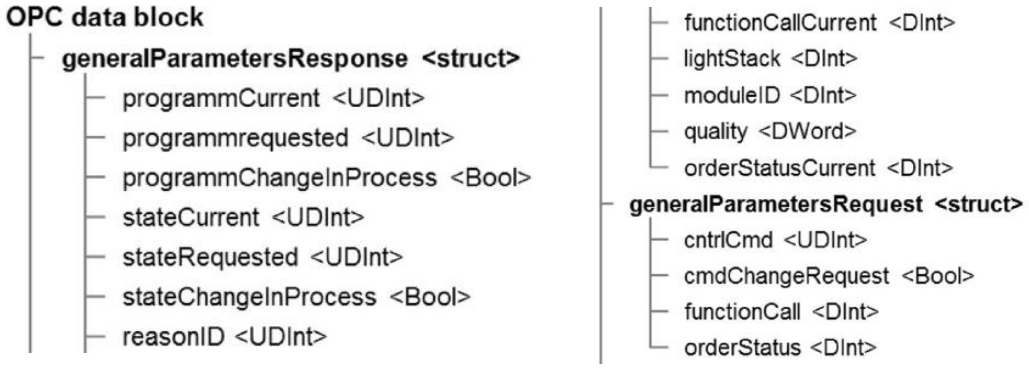
MODULAR NETWORKED FACTORY

Control

- Service oriented architecture
  - Each individual machine of the different manufacturers has its own control system (e.g. PLC)
  - The individual machines are connected to a basic control module -> Line control
    - Easily expandable
  - Information exchange between individual machines and the line control module via OPC UA protocol
    - Vendor-independent



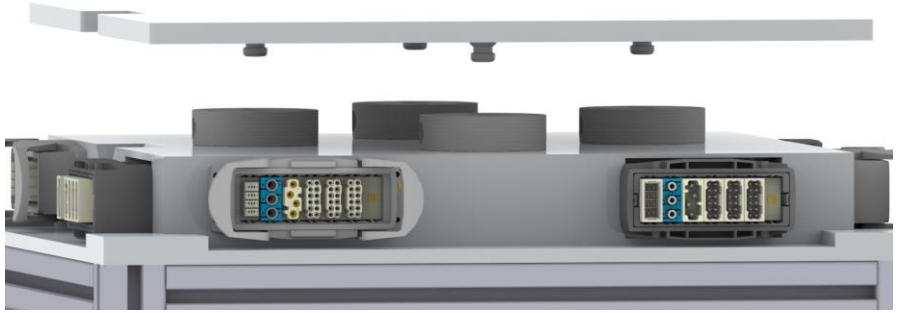
- Interface
  - On each module is installed a OPC server
  - Line control (OPC client) has access to it
  - Predefined interface parameters
    - Reduction of complexity
    - Know-how protection



MODULAR NETWORKED FACTORY

Modular base plate – Upgrades - **SCHUNK**

- Clamping station
  - Lock and position the frames together
  - Interface to superstructures
    - Very good repeat accuracy
    - Fast change
    - Very flexible
  - Chucks can be added directly



- Pneumatic pallet change system (NSR-A)
  - Locking and positioning the frames together
  - + transport energy, materials and information
    - Automatic operation
    - Quick layout change
    - High modularity
    - Robust design

总结
Conclusion

5G → IIoT → Industrial Communication

5G+AI 是智能制造的必然，是工业4.0的大脑，神经网络和发动机
随着5G标准逐渐完善，将会有越来越多的5G+AI工业应用
5G+AI将如同消费型互联网一样深刻改变我们的生活

Advanced Manufacturing Technology Center
www.amtc.tech

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© amtc Prof. Dr. J. Fleischer, Prof. Dr. W. Zhang, Prof. Dr. Y. Bian, C. Ehrmann

THANK YOU FOR YOUR ATTENTION

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