HotEdge '18

An Industrial Robot System Based on Edge Computing: An Early Experience

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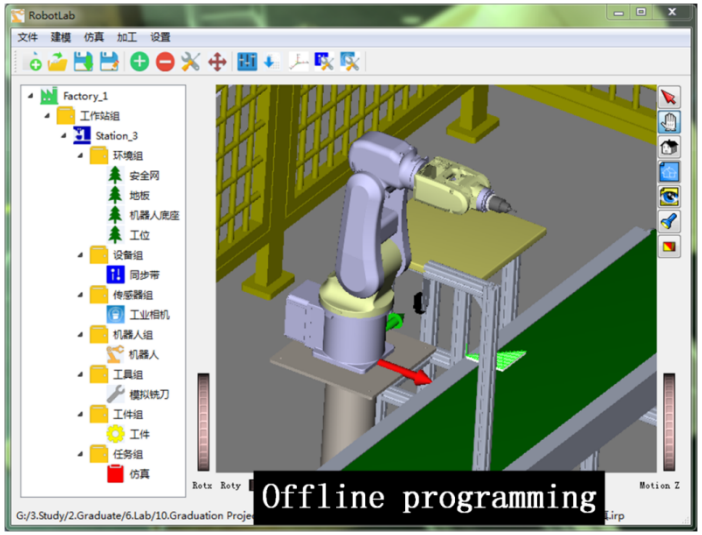
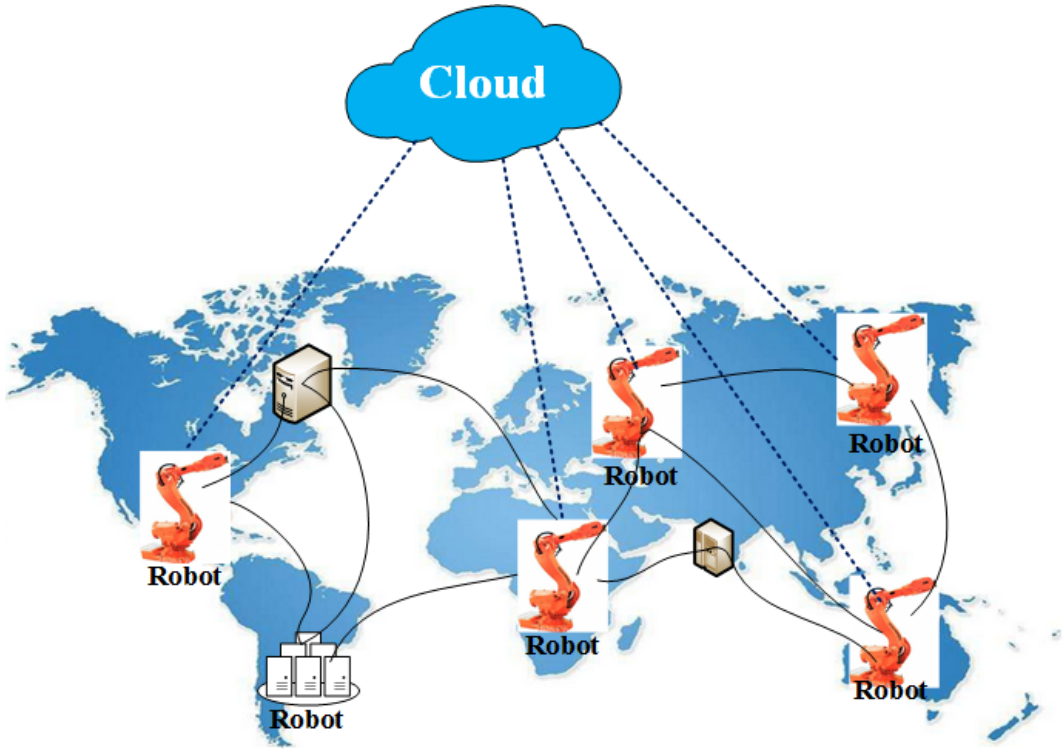
1 Development of industrial robot

Industrial robot technology combines technologies of computer, electronics, mechanical engineering, sensor, control theory and so on. It is widely used in automobile manufacturing, welding, assembly, spray painting, polishing, etc.

1 Development of industrial robot





- **Teaching programming:** tedious and inefficient
- **Offline programming**: large computation and no real-time
- **Cloud robot:** strong capability but heavy network traffics and long time-delay

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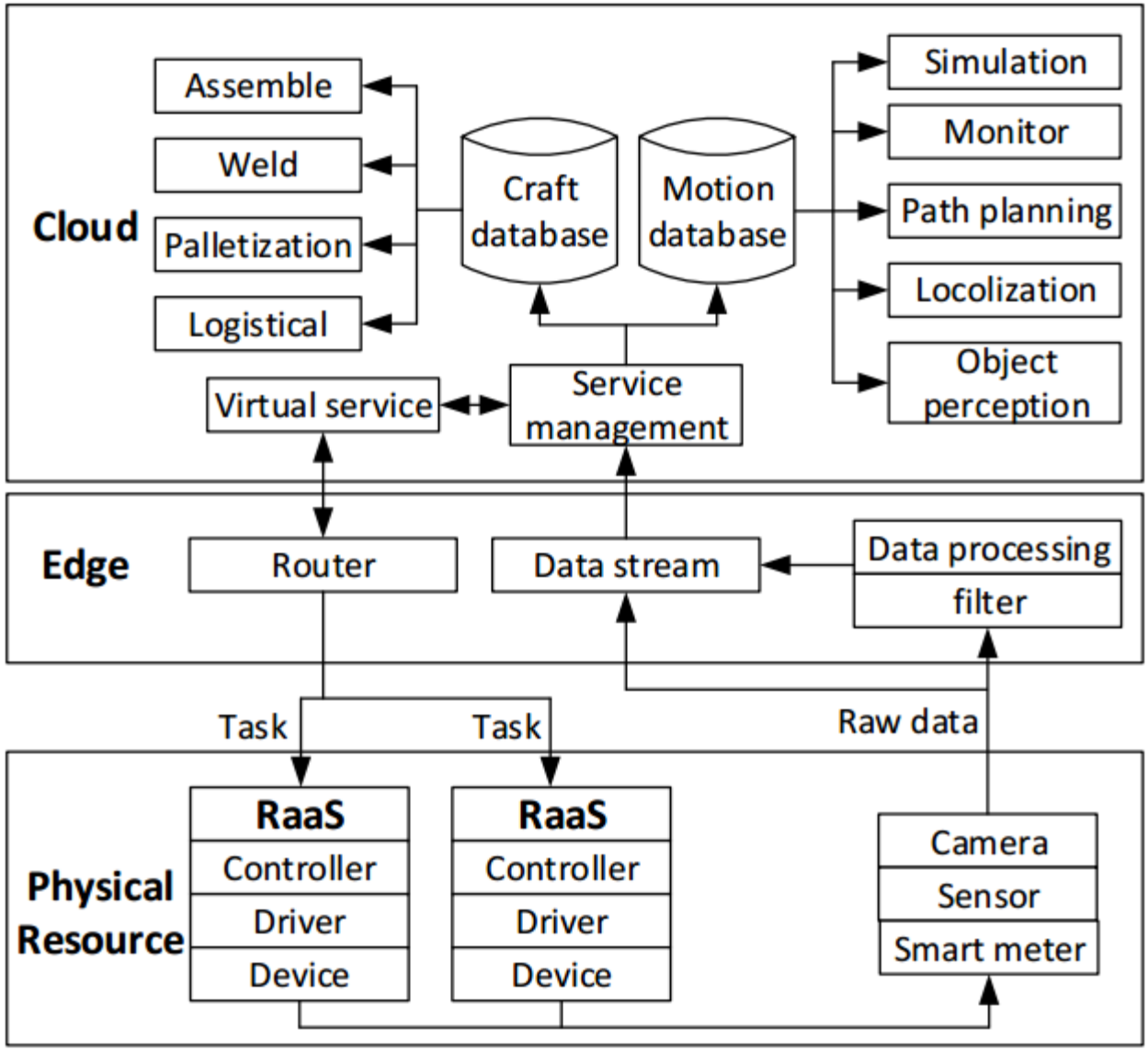
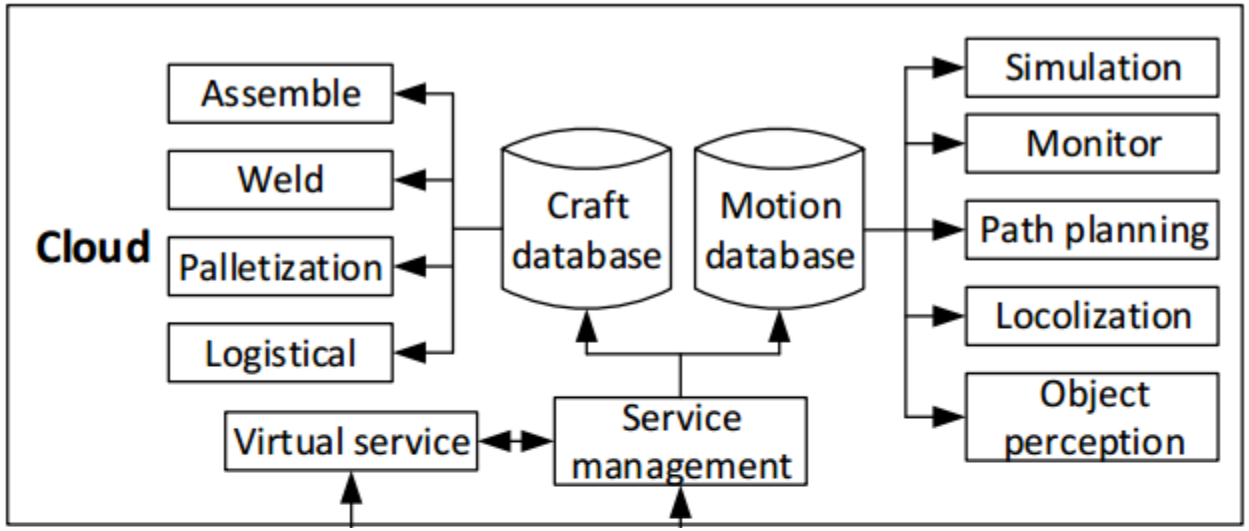
2 Industrial robot system based on edge computing



System architecture: Industrial robot system based on edge computing

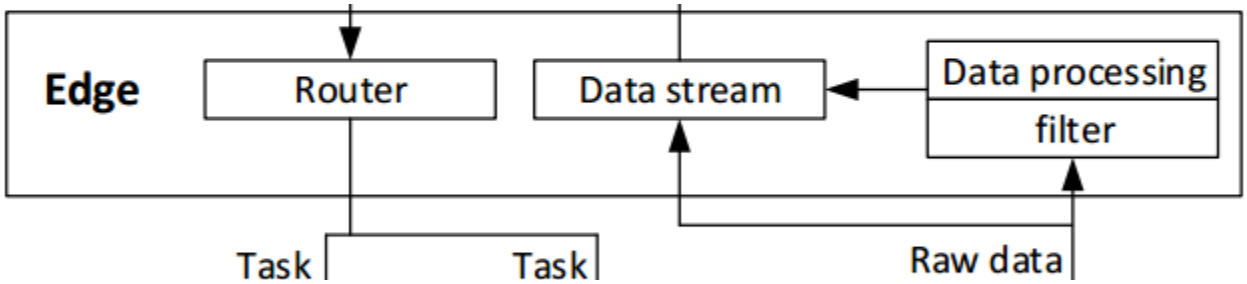
2 Industrial robot system based on edge computing



Cloud layer

- **Service management：** Provide all kinds of processes and algorithms to the robot in the form of service.
- **Resource monitor：** Monitor the energy consumption, memory and network status of cloud and edge nodes.
- **Craft database：** Robot process technology(assembly,welding,etc.)
- **Motion database：** The realization of services(simulation, data fitting, path planning, etc.)

2 Industrial robot system based on edge computing



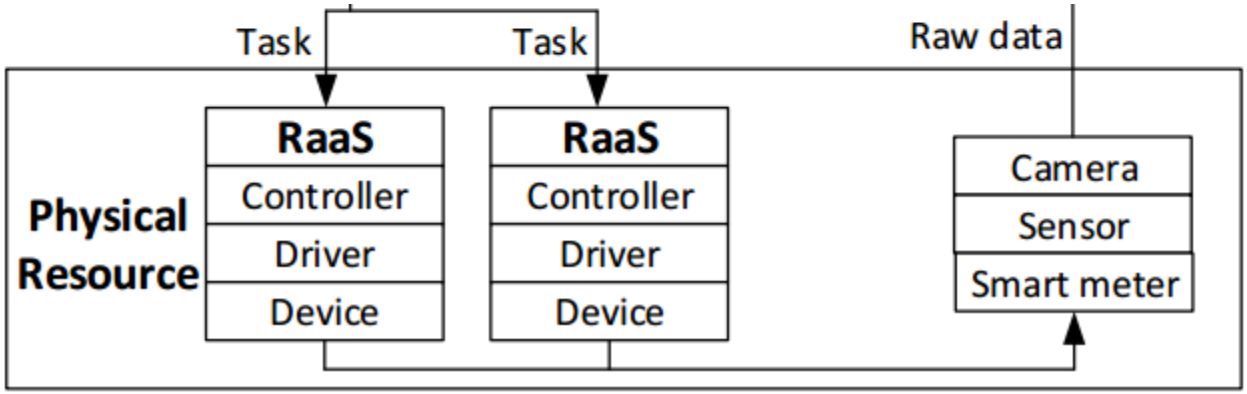
Edge layer

- **Device interface：** Integrated devices' interfaces API.
- **Data filter：** Pre-processing raw data from the field.
- **Workstation management：** Manage robotic workstation devices

Why choose Edge?

1. Pre-process raw data, save bandwidth.
2. Achieve the real-time capacity by controlling the field at the Edge instead of the Cloud.
3. Integrate various devices' interfaces.

2 Industrial robot system based on edge computing



Physical resource

- **Robot workstation**
- **Actuators:** Robot, gantry frame, conveyors, AGV, etc
- **Sensors:** Industrial camera, laser sensor, smart meters, etc
- **Closed loop robot system**
- Robot task is sent to workstation from the upper layer;
- Production process is measured via sensors and fed back to the upper layer.

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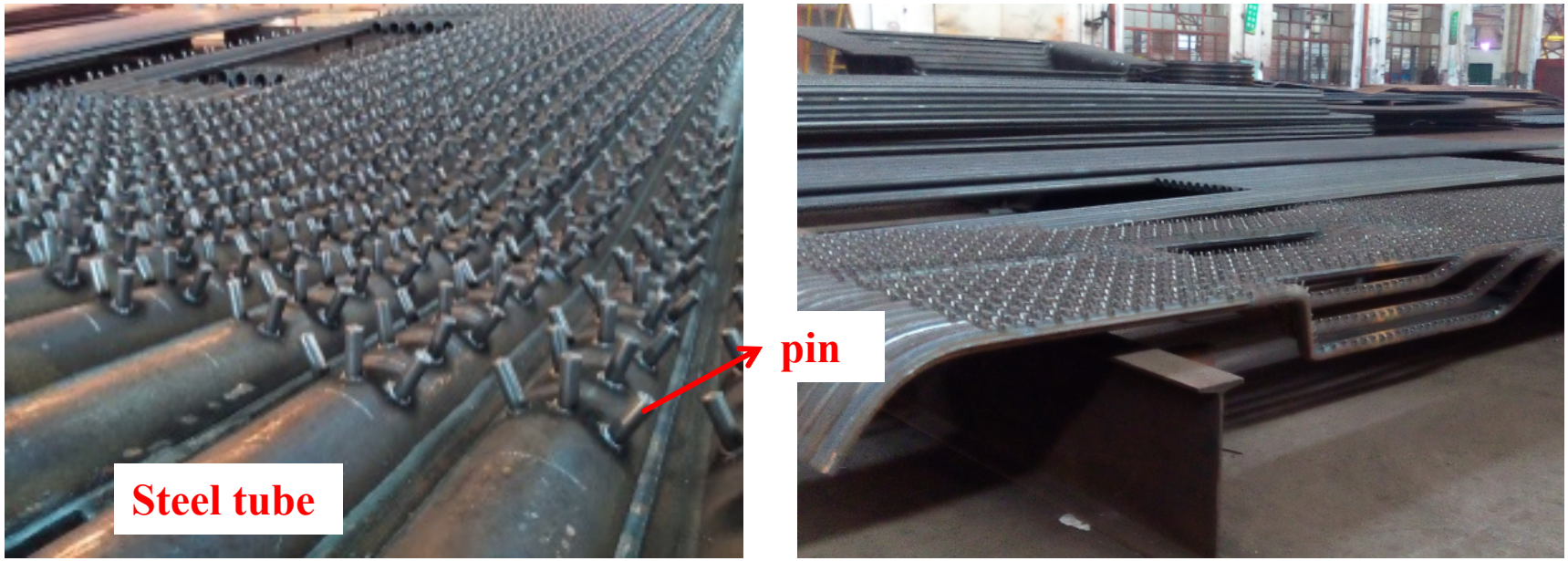
3 Case: robotic stud welding on membrane water wall



Membrane water wall

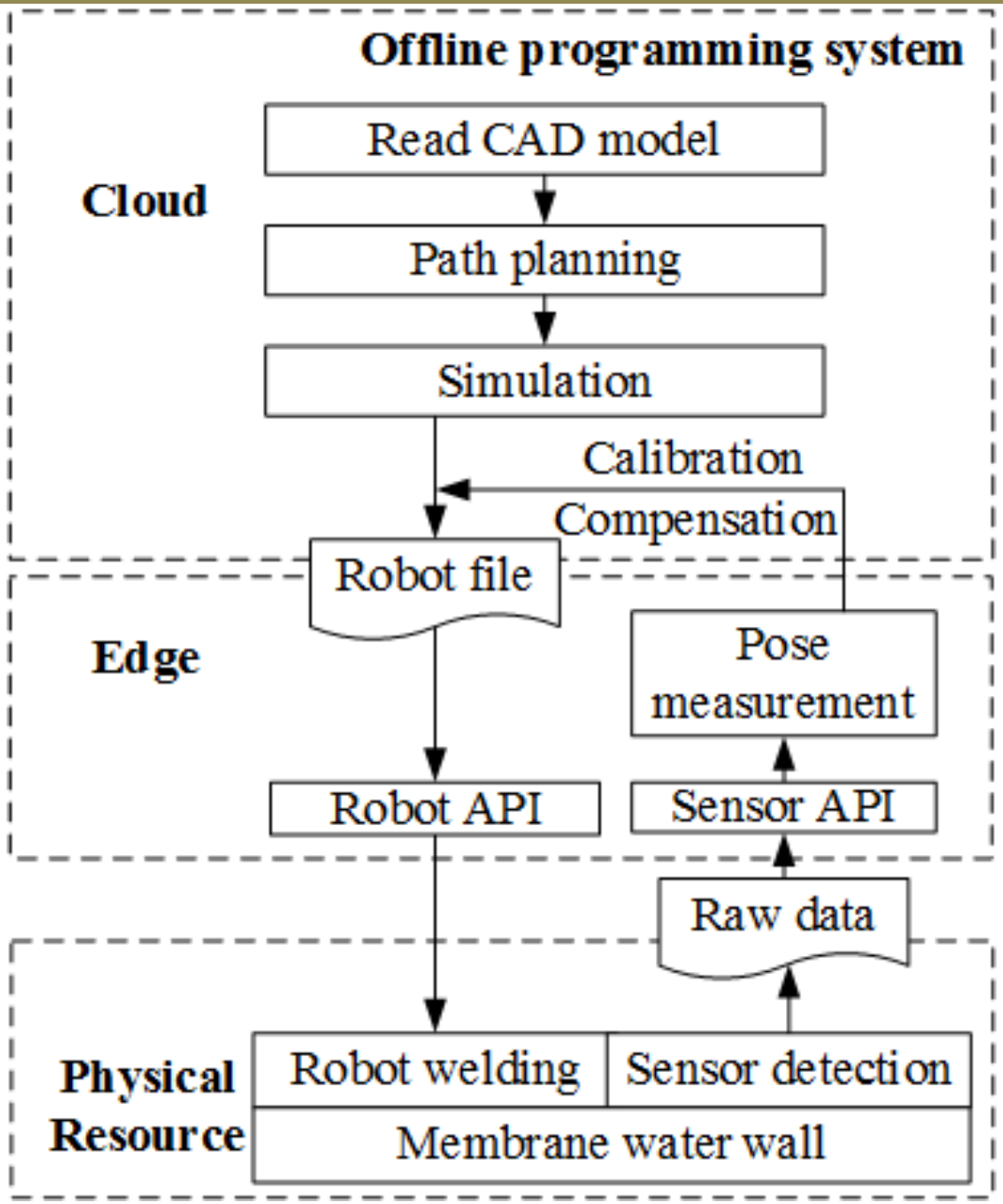
Membrane water wall is widely used in boiler industry. To fix and support refractory materials laid on membrane water wall, a large number of pins should be welded on the surface of membrane water wall.

3 Case: robotic stud welding on membrane water wall

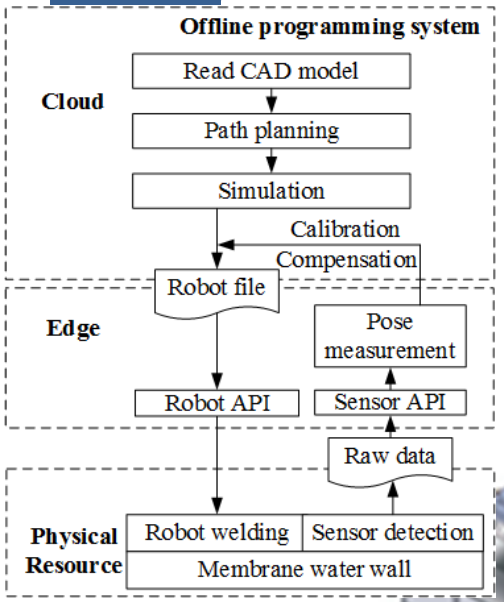
Current welding method: manual welding

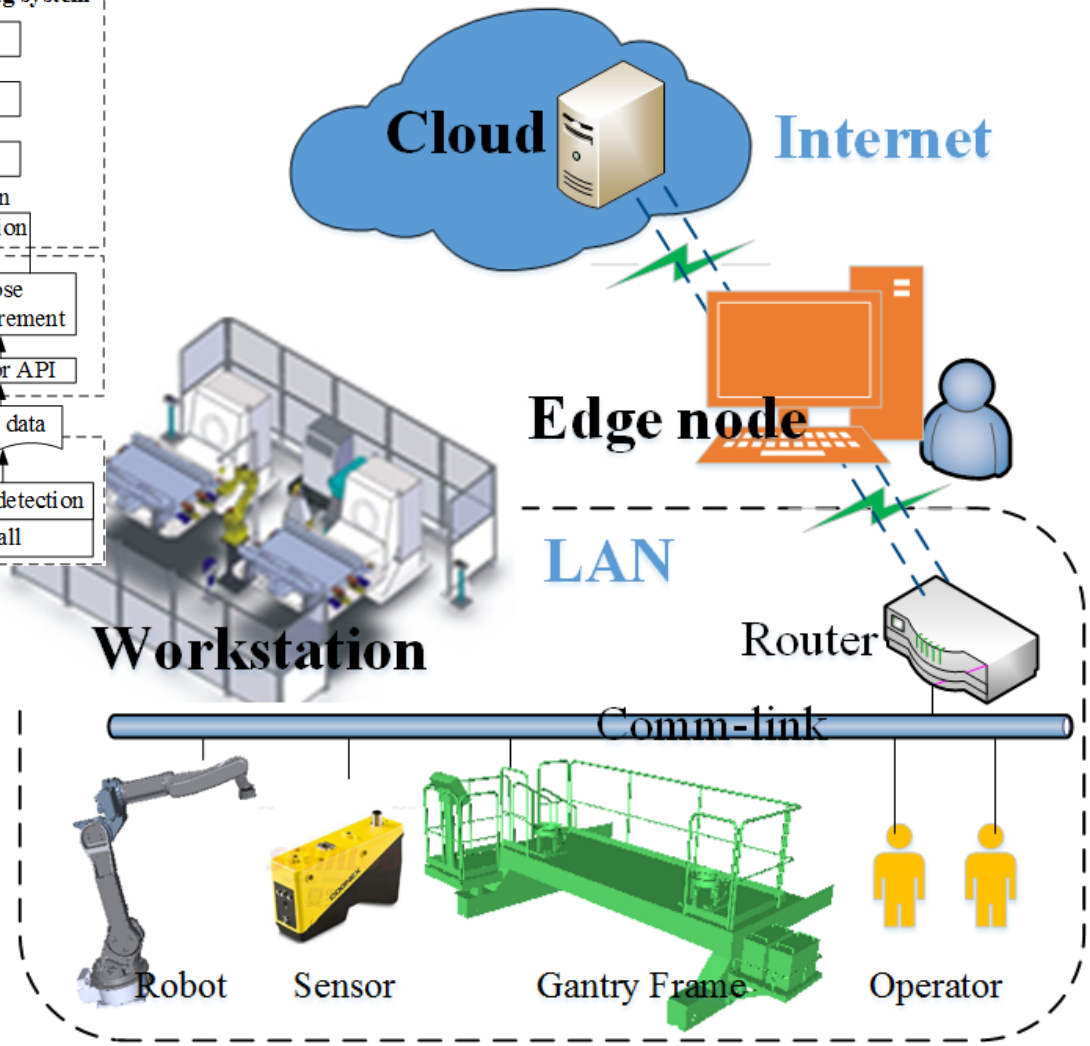
- High labor intensity, eg: a 11m×2m membrane water wall requires about **18000** pins
- Low efficiency
- Bad precision

3 Case: robotic stud welding on membrane water wall



3 Case: robotic stud welding on membrane water wall





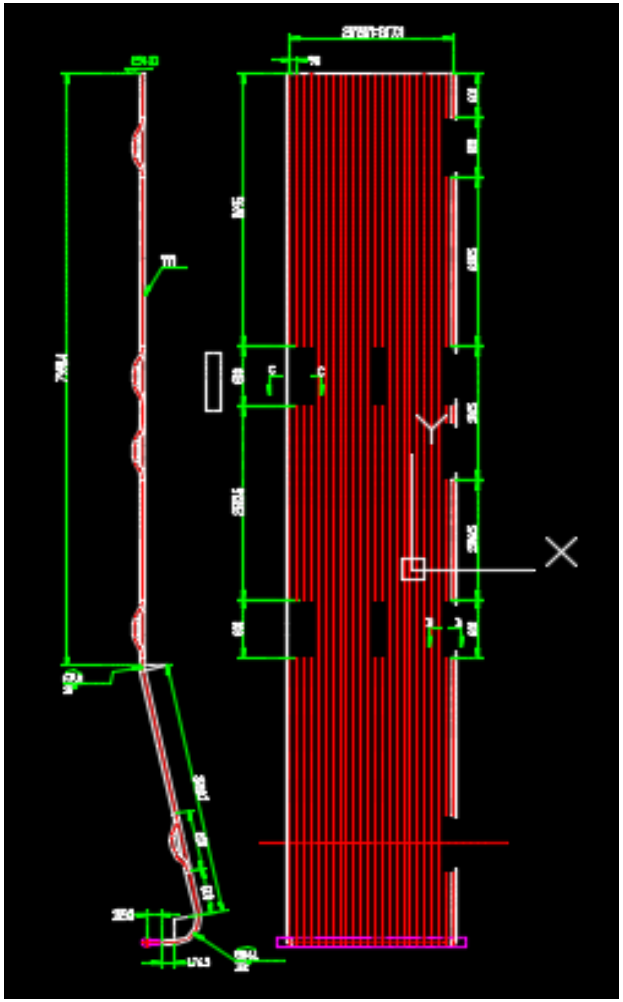
Cloud:
Alibaba Cloud

Edge node:
Local PC with 2 cores and 4G memories

Workstation:
LAN is set up to linking devices, each device is assigned a logical address

3 Case: robotic stud welding on membrane water wall

Read and parse the AutoCAD drawing

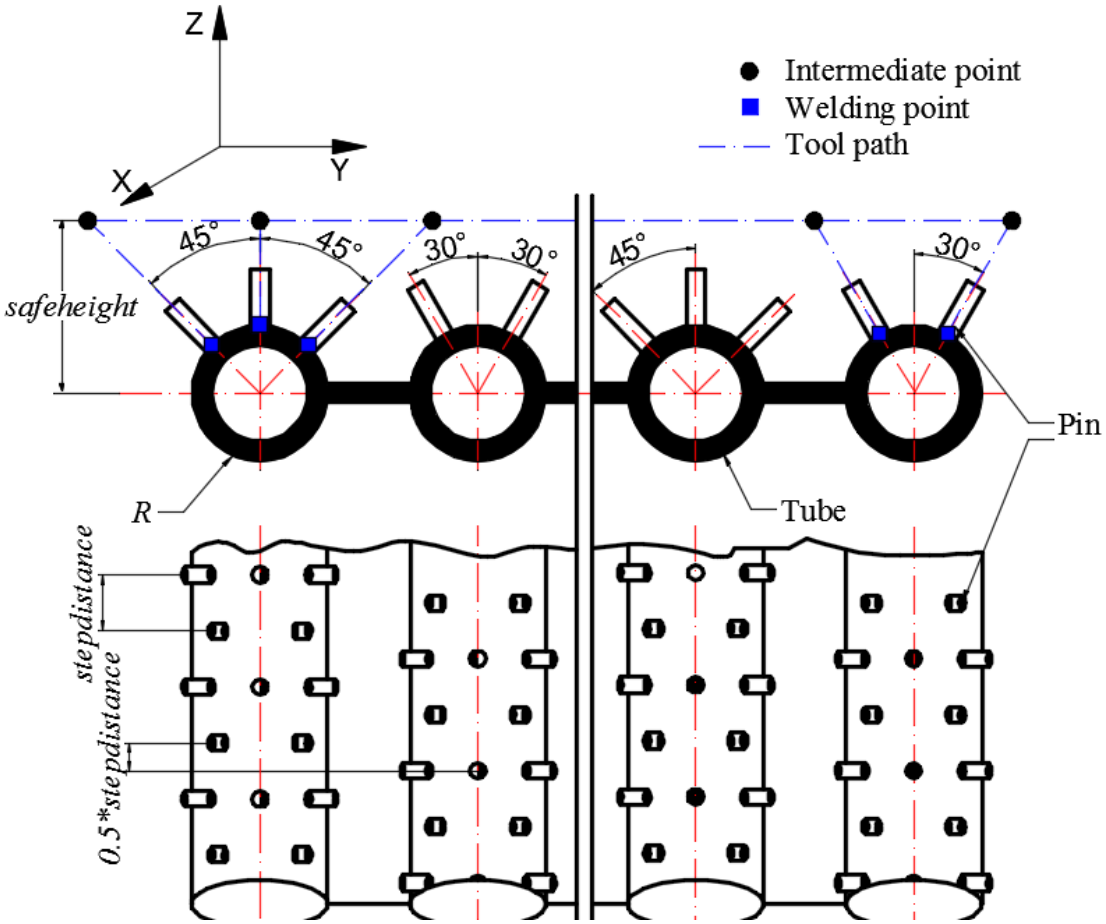


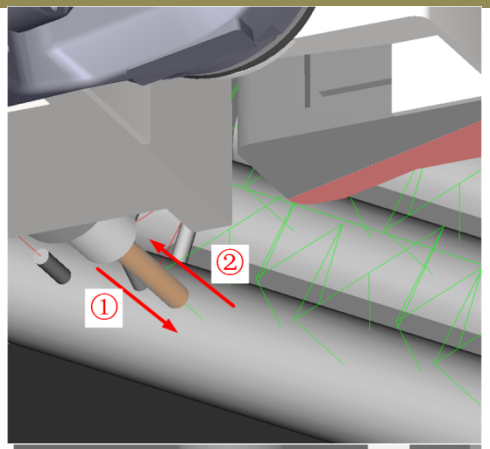
AutoCAD drawing of the membrane water wall

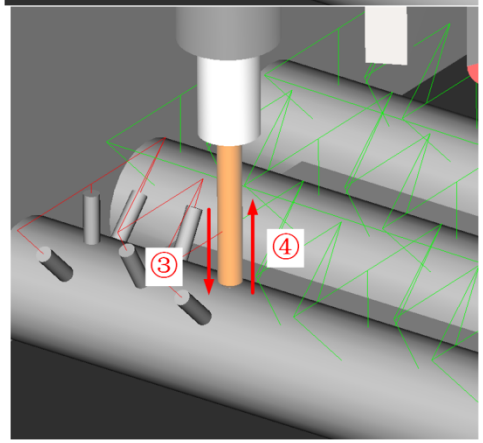
Parse the drawing and extract process information

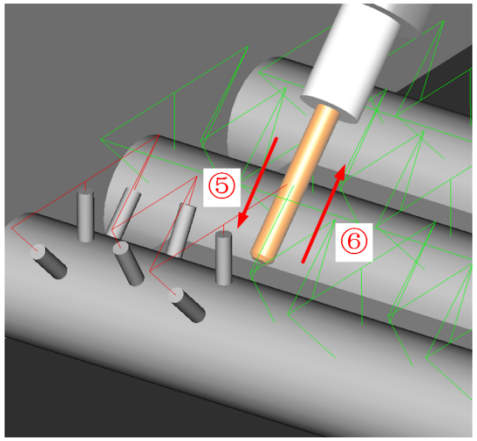
3 Case: robotic stud welding on membrane water wall

Robot path planning





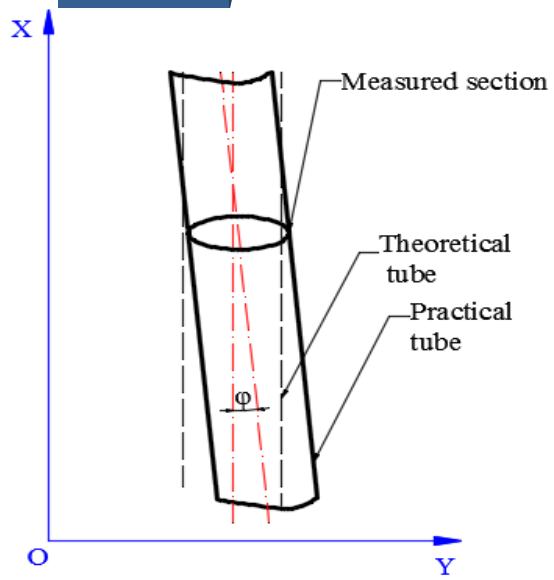


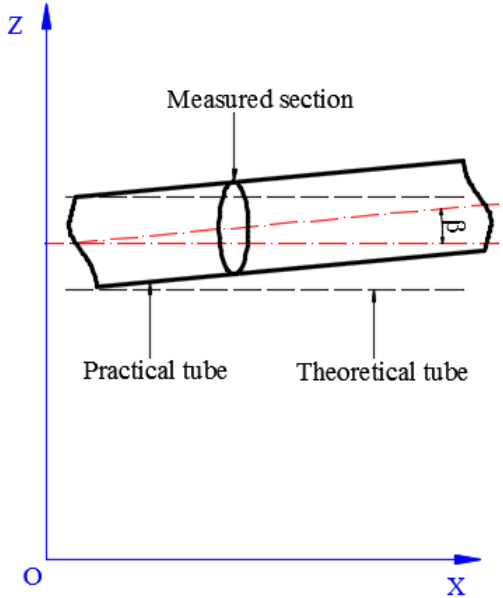


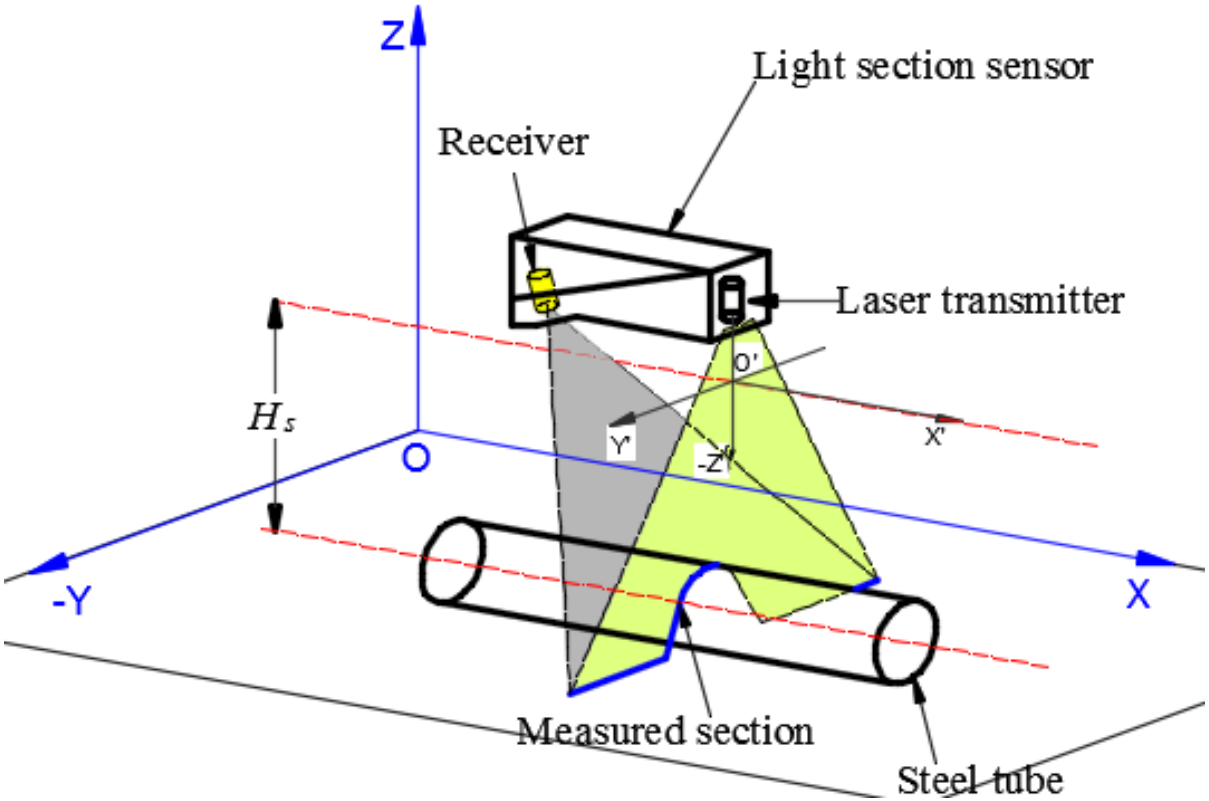
Welding technical requirements: Pins are welded vertically on the surface of the tube in a radial direction

3 Case: robotic stud welding on membrane water wall

Pose measurement







Pose measurement: Deformations and warps may occur while the tube is being welded. We adopted a light section sensor to measure the profile of the steel tubes. And then we use the measurement results to compensate the errors.

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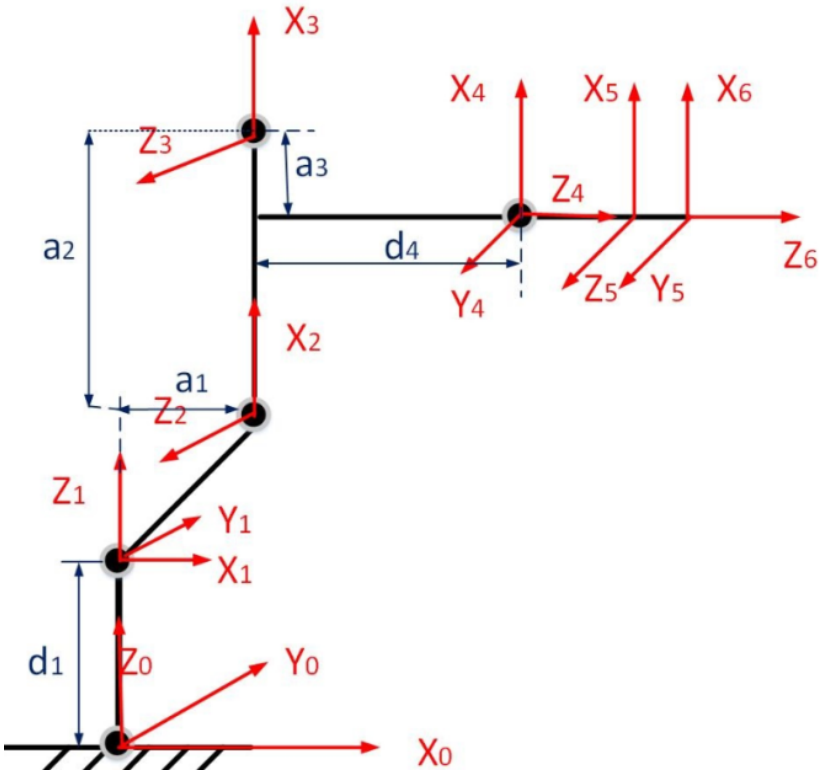
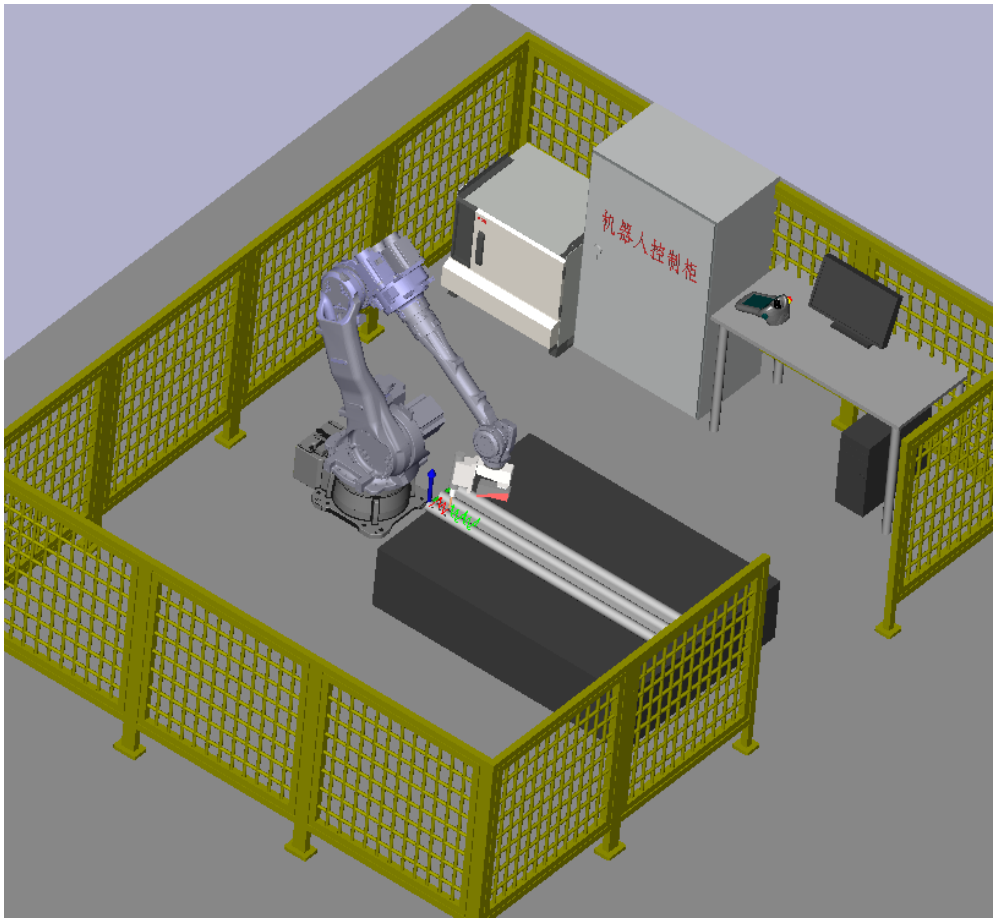
Modeling and simulation



Modeling: Robot modeling and kinematic analysis.



Simulation.

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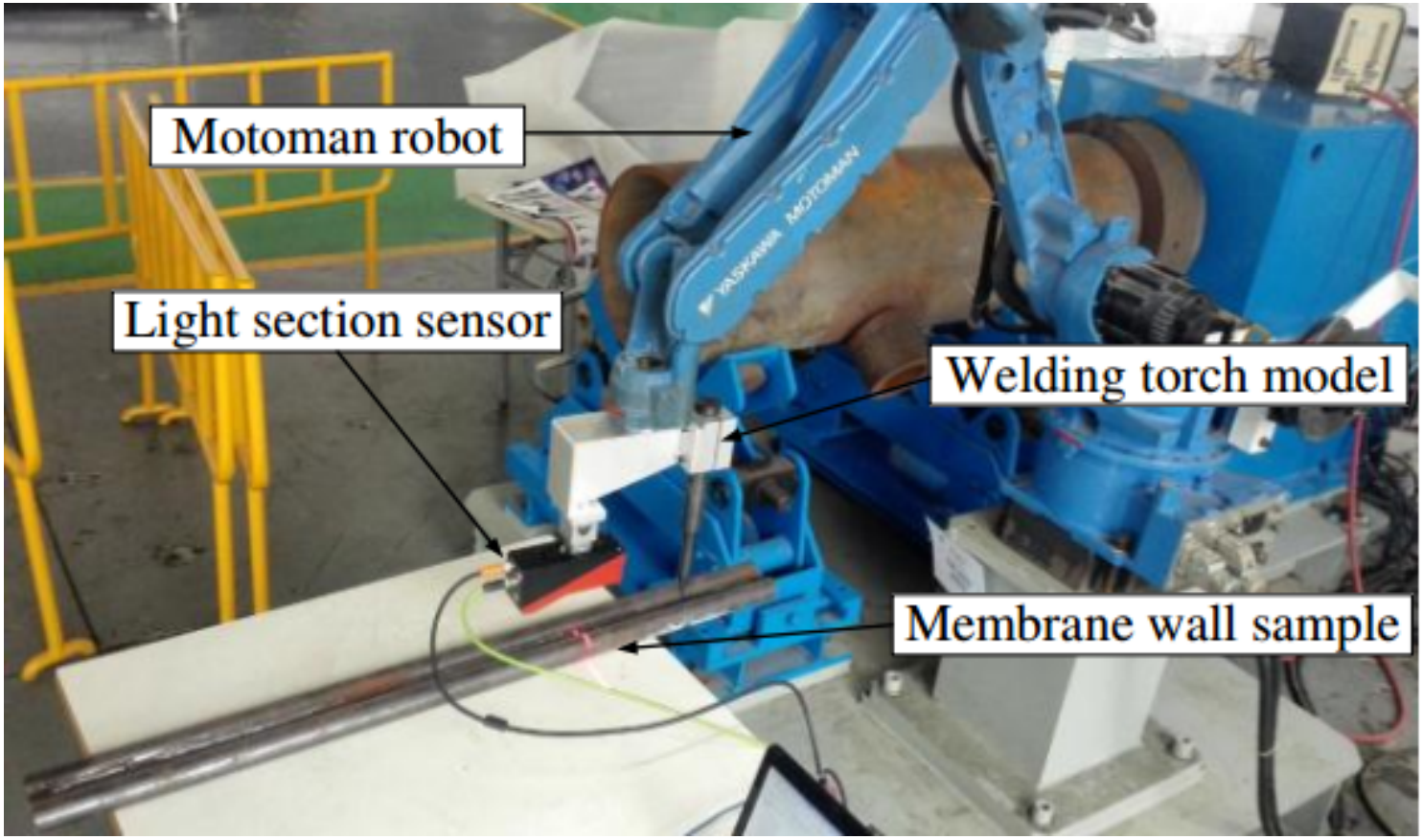
Experiment



Experiment: MH50II robot, LPS36HI light section sensor, membrane wall sample and a welding torch model

3 Case: robotic stud welding on membrane water wall

Two approaches: Cloud-based approach vs. Cloud-edge hybrid approach

Cloud-based approach: uploads all raw data to the cloud and executes all tasks on the cloud

Cloud-edge hybrid approach: executes pose measurements on the edge node and executes the remaining tasks on the cloud

Table 1: The two approaches' tasks

	Cloud-based	Cloud-edge hybrid
Path planning and simulation	√	√
Upload raw data	√	-
Pose measurement	√	√
Upload filtered data	-	√
Transfer robot file back	√	√

We conducted four experiments. The number of times that sensors detected is 1, 5, 20, and 50, respectively. The sensor detected times are the identity of the data amount that the system deals with.

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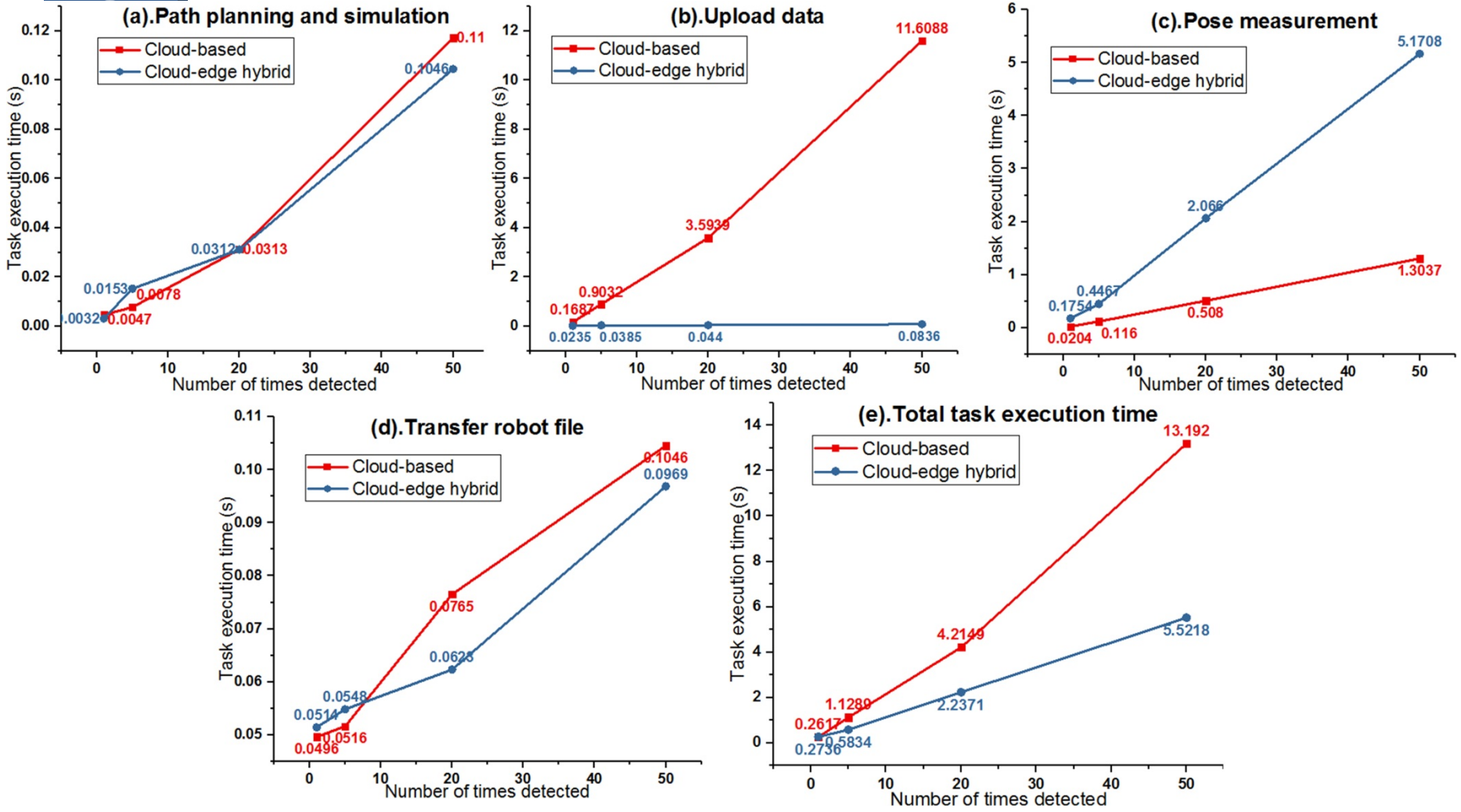

Results: All subtask execution time and total execution time. Red lines indicate the results of the cloud-based approach; blue lines indicate the results of the cloud-edge hybrid approach.

3 Case: robotic stud welding on membrane water wall

Table 2: The two approaches' occupied bandwidth.

Number of times detected	Bandwidth of cloud-based approach (Kb/s)	Bandwidth of cloud-edge hybrid approach (Kb/s)	Saved bandwidth (Kb/s)
1	885.25	0.92	884.33
5	1,011.49	2.17	1,009.33
20	1,108.83	2.23	1,106.61
50	885.63	2.25	883.38

Results: cloud-edge hybrid approach saves network bandwidth by nearly three orders of magnitude in all four experiments.

3 Case: robotic stud welding on membrane water wall

Conclusions:

- Although the edge node data processing ability is inferior to the cloud server, the Cloud-edge hybrid approach has a better real-time performance than the cloud-based approach.

- Edge node pre-processing sensor data can save a lot of network bandwidth and significantly reduce data transmission time.

Future work:

- Further expand and develop the system based on edge computing.

- Conduct more experiment in the robot workstation. Some progress has been made.

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4 Open issue

Open problems:

1. **Safe and stable network**. We will expand the system to conduct more experiment on the robotic stud welding on the membrane water wall. But how can we establish the industrial robot system with stable and safe network? How to deploy the edge nodes? We're appreciate to get feedback from you!

2. **Necessity**. Some may think there is no need to use cloud even the edge computing, a standalone PC with better performance is enough to deal with the workstation. However, on one hand, the membrane water wall is in large size, tens of thousands of points are required to be calculated, measured and processed; on the other hand, we are establishing a workstation with 2 robots, 2 sensors and a gantry. We are afraid that a standalone PC cannot work well in this case.

3. **Multiple workstations.** We just test our system on one workstation, but for the industrial network of the IoT? Dose our system can deal with numbers of workstations at the same time? Much work needs to be tested and solved.

4. **Dynamic offloading task on the edge nodes**.

THANKS