Fusion of sensor and robot

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Haruhisa Fukano, Fujitsu

Masao Shimizu, Ph.D., Professor, RITSUMEIKAN UNIVERSITY

Jeff Brower, CEO, Signalogic, Inc.

Haruhisa Fukano

Fujitsu
TSC member, LF Edge Akraino Project

- Current work
  - Business and architecture planning about edge computing
- Career:
  - Heterogeneous computing R&D
  - FPGA design for NW equipment
- Favorite things:
  - Camping

Introduction

Masao Shimizu, Ph.D.
Professor, RITSUMEIKAN UNIV

・Robot hand R&D using electronic device
・Career:
  ・R&D about application of sensors to medicine and industry
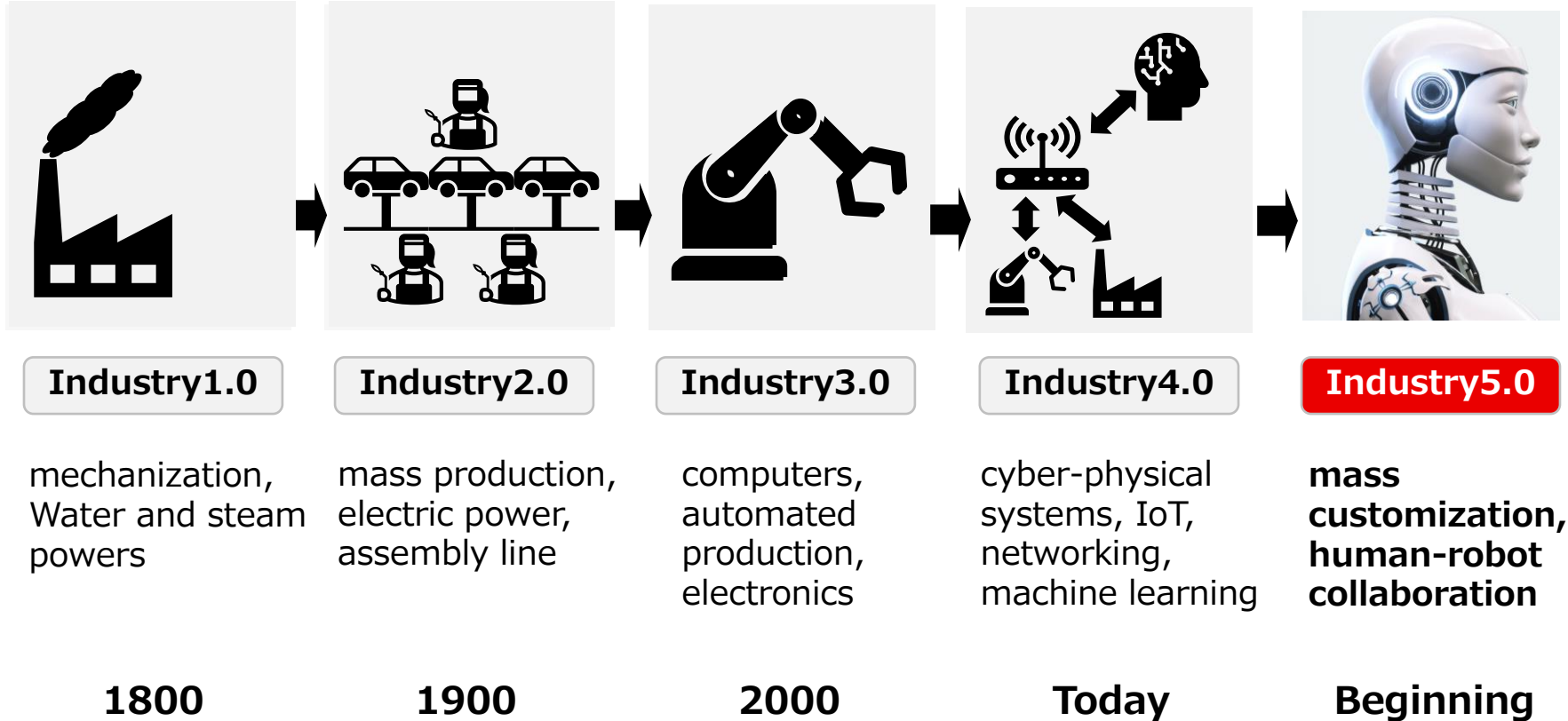 ・Sensor device R&D
・Favorite things: Aikido

Jeff Brower
CEO, Signalogic

・Real-time ASR (automatic speech recognition) in edge computing and telecom applications
・Deep learning
・Telecom
・HPC, supercomputing
・Signal and image processing and algorithms

Agenda

- What is Industry 5.0?

- Robot Challenges in Industry 5.0

- Solutions for these challenges
  - What is SSES (Sensor-Rich Soft End-Effector System)?
  - What is light weight ASR (Automatic Speech Recognition)?

- Activities at Akraino
  - CPS Robot blueprint family
  - Robot basic architecture based on SSES blueprint

- PoC in food factory

- Activities in future

Industrial Revolutions

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Industry1.0	Industry2.0	Industry3.0	Industry4.0	Industry5.0
mechanization, Water and steam powers	mass production, electric power, assembly line	computers, automated production, electronics	cyber-physical systems, IoT, networking, machine learning	**mass customization, human-robot collaboration**
1800	**1900**	**2000**	**Today**	**Beginning**

Key attributes of Industry5.0

1.Human and robot collaboration
・Improve productivity of complex tasks that only human can do.
　→Expect the spread of robots to various industries.

2.Mass customization

・Automated mass production by robot

・Customization according to consumer preferences

　→Provide new value

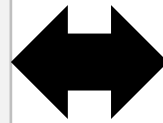**Robots play important role in realizing industry5.0.**

Can we use today's robot in industry5.0?

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Robot today

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- Object: <u>standardized, uniform</u>

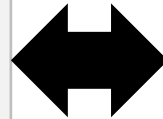- Field circumstance: <u>stable</u>

Robot in Industry 5.0

- <u>diverse shapes, flexibility, frictional properties</u>
- <u>ever-changing</u>

Challenge: Autonomous handling control by robot

Robot Challenges in Industry 5.0　2/2

Robot today

- Isolated from human
- Programmed routine

Robot in Industry 5.0

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- Work with human in same field
- Act flexibly

Challenge: Rapid communication with human

Solution for these challenges

Challenge 1 - Autonomous handling control by robot

Solution
  Flexible robot handling for various objects under various environments "SSES (Sensor-rich Soft End-effector System)"

Challenge 2 - Rapid communication with human

Solution
  Reliable and low-latency speech recognition

What is SSES?

SSES (Sensor-Rich Soft End-Effector System)

Ritsumeikan University and other companies research and develop SSES in SIP [1]

- SSES Approach
  - Enhancement of cognitive ability
    - Sensor-rich technology for multi-dimensional data acquisition
    - AI/IoT technology with force/contact information
    - IoT maintenance and inspection technology
  - New Mechanical
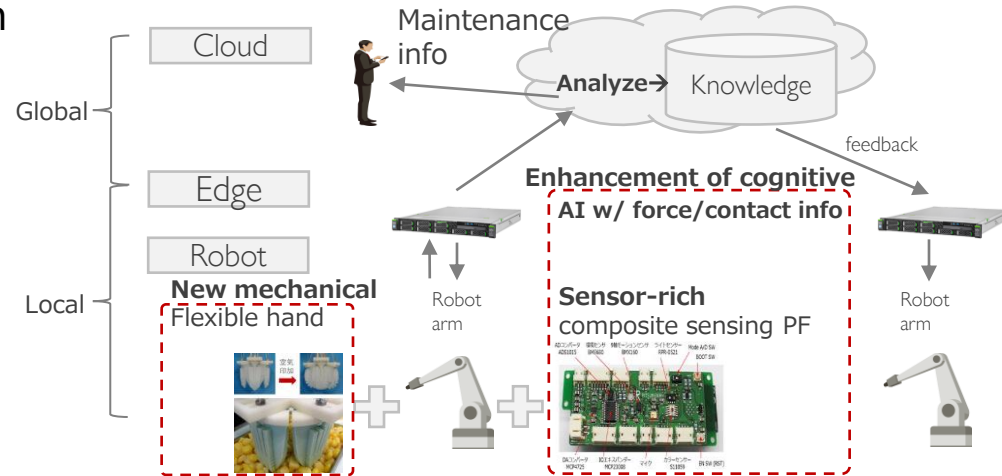   - Flexible manipulators using polymer materials
    - Advanced 3D printing technology

Figure: SSES architecture(https://sip-sses.net/)

[1] Cross-Ministerial Strategic Innovation Promotion Program
A program for R&D and practical application of science and technology that will revitalize economy and industry, with investment from Japan Cabinet Office.

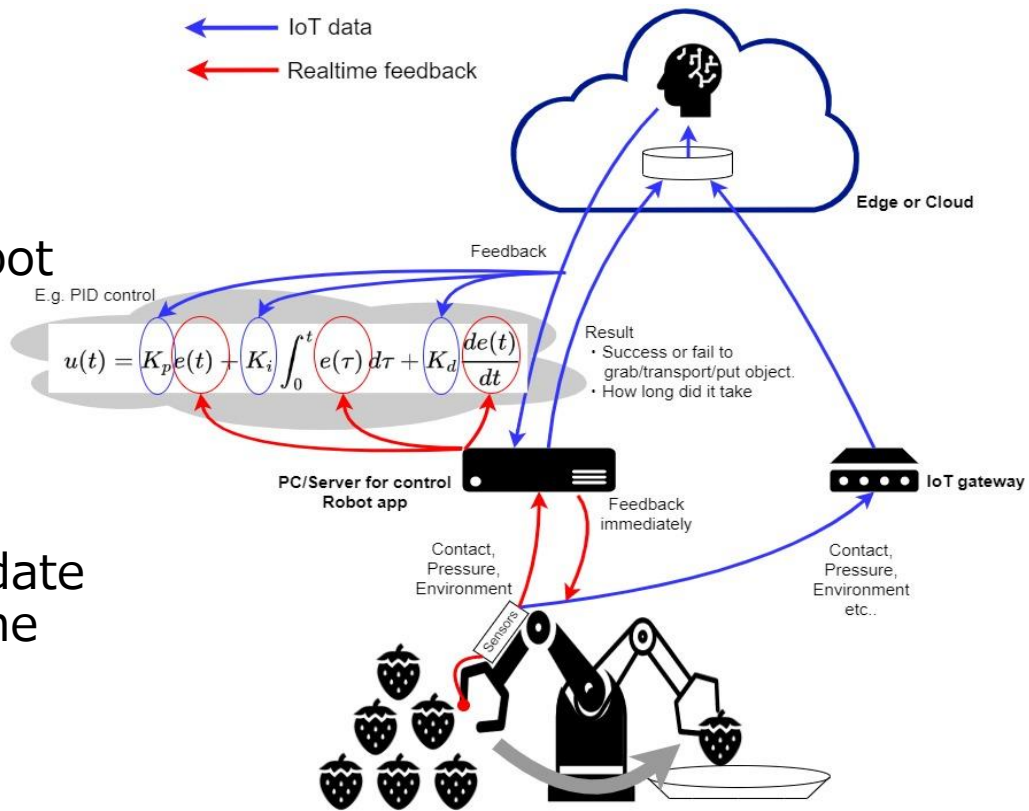# SSES from network perspective

SSES has two data path

- Real-time feedback path
  - Latency: 1ms
 - Immediately reflected in robot control

- IoT data path
  - Latency: 100ms~
  - Analyze by cloud AI and update robot control in non-real-time

→ IoT data

→ Realtime feedback

Edge or Cloud

Feedback

E.g. PID control

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{de(t)}{dt}$$

Result
- Success or fail to grab/transport/put object.
- How long did it take

PC/Server for control
Robot app

Feedback immediately

IoT gateway

Contact, Pressure, Environment

Contact, Pressure, Environment etc..

Sensors

R-CPS (Reconstructable basic system for Cyber Physical System)

・Data collection/analysis and feedback to physical space for SSES
・Construct and reconstruct various systems easily and at low cost
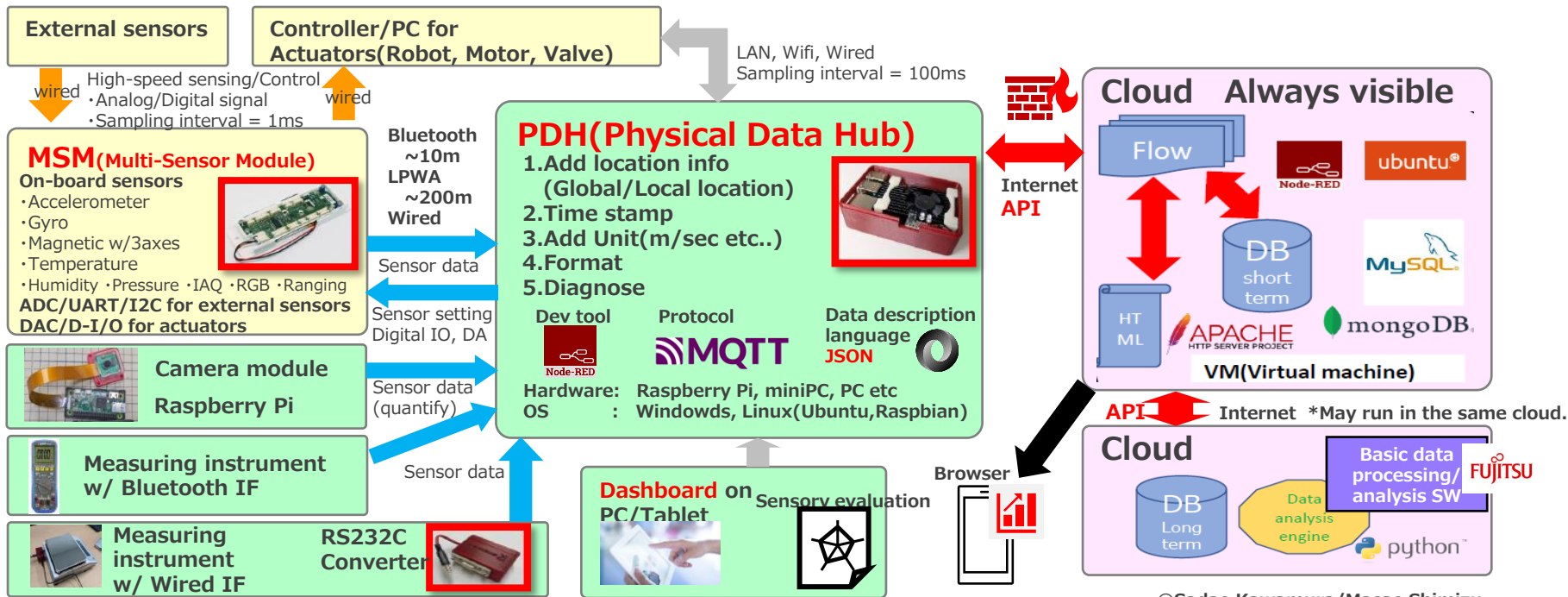
©Sadao Kawamura/Masao Shimizu

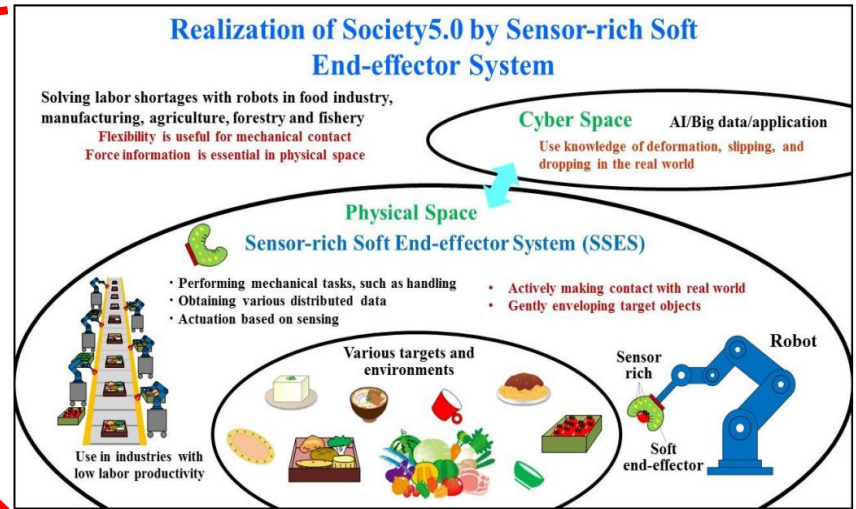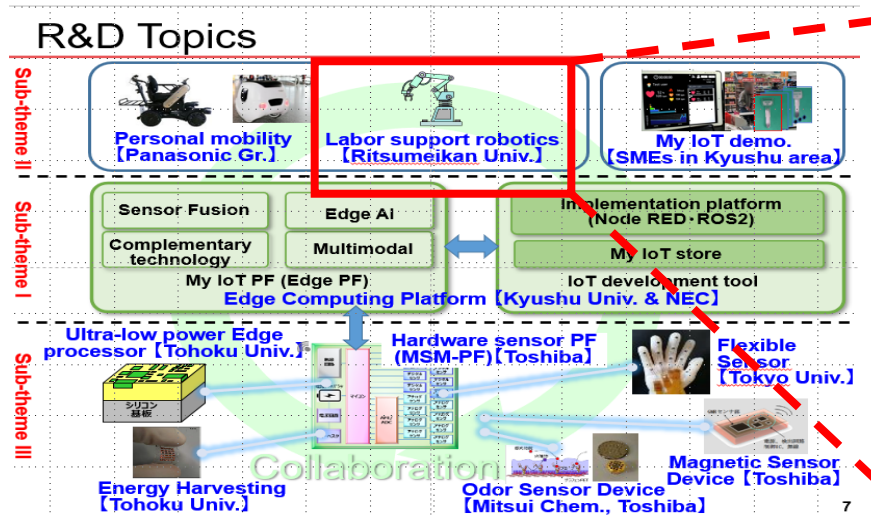# SSES use case and demo

Remove dishes from table

Dishwashing

Serve on plate

**All video from
SIP SSES project**
https://sip-
sses.net/publicinformation/

SSES (Sensor-rich Soft End-effector System)

○ **Japan Cabinet Office invests in R&D on flexible robot handling "SSES" through SIP [1]**

SIP Symposium 2021
https://www.sip2021.go.jp/docs/02_briefing_paper_SIP2021.pdf

SIP R&D Plan
https://www.nedo.go.jp/content/100903325.pdf

[1] Cross-Ministerial Strategic Innovation Promotion Program

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# What is Signalogic ASR Engine?

ASR (Automatic Speech Recognition)

Signalogic developed light weight ASR engine

○ Capabilities

    ○Urgent/safety voice commands; e.g. "stop"

    ○Operating commands; e.g. "change mode"

ASR Features
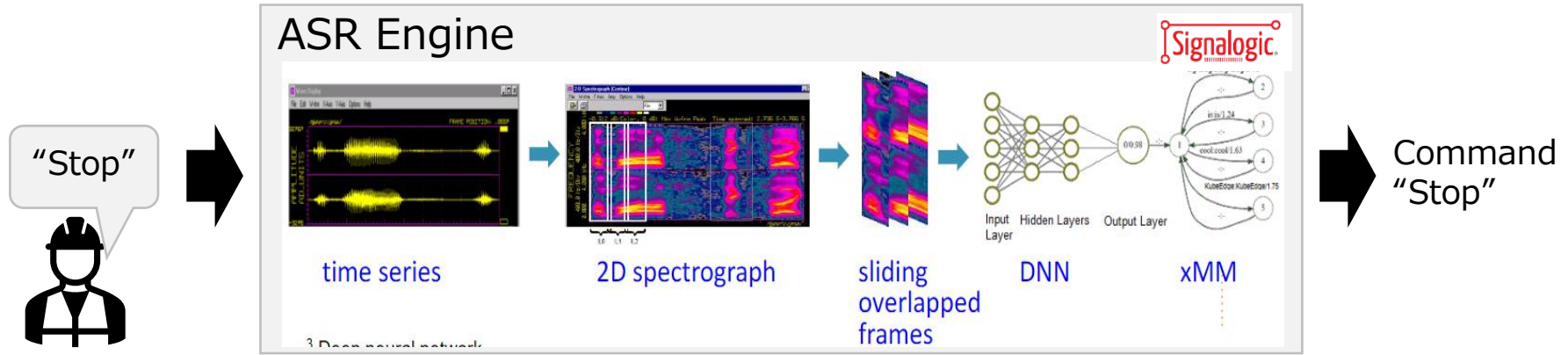
○ Light weight
  ○ ~50W power consumption, no fans
  ○ Consumes one Atom CPU core(x5-E3940)
  ○ 20k word vocabulary

○ Noise removal
  ○ Spectral subtraction and sound classification minimize robot background noise; e.g. servo motors, wheels
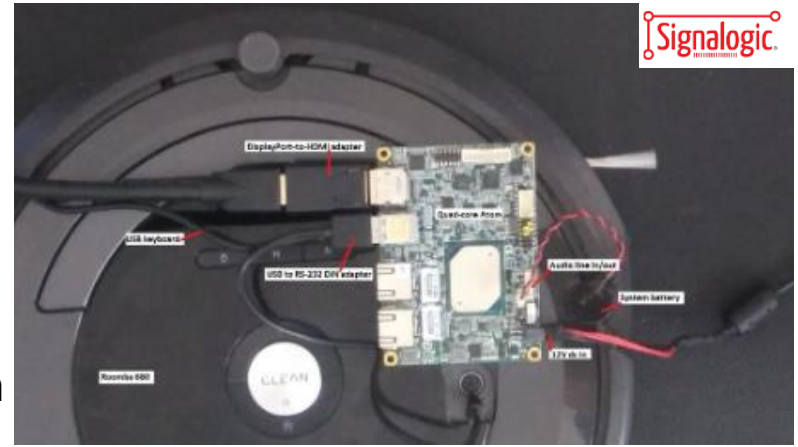
Roomba onboard ASR demo

Accurately recognize voice commands in the field, regardless of internet connectivity – prioritize human safety

Activity in open community

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Activity in LF Edge Akraino project

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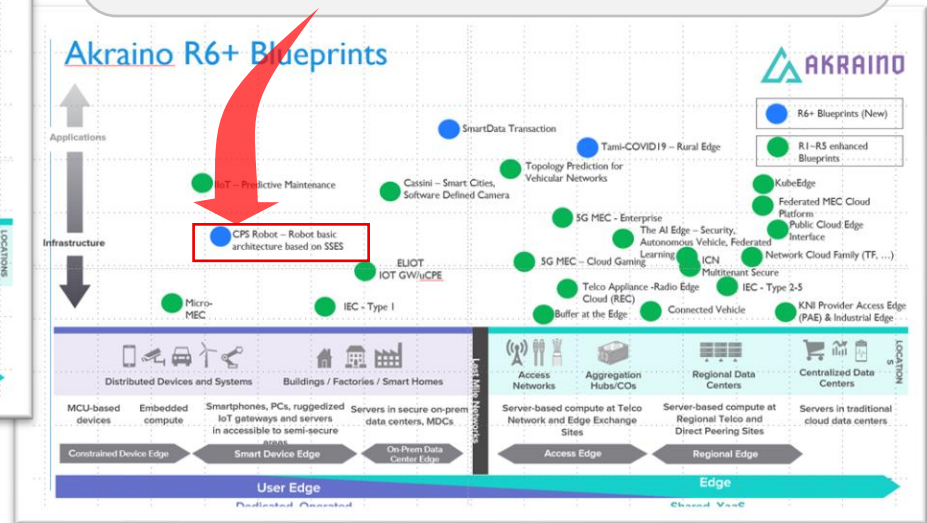
○ Publishes solutions as OSS stack "Blueprints" for everyone to use

Akraino community creates edge computing use case OSS stacks

LF Edge - long form - MASTER

RITSUMEIKAN   FUJITSU   Signalogic

・ SSES (Sensor-Rich Soft End-Effector System)
・ R-CPS (Reconstructable basic system for Cyber Physical System)
・ ASR (Automatic Speech Recognition)
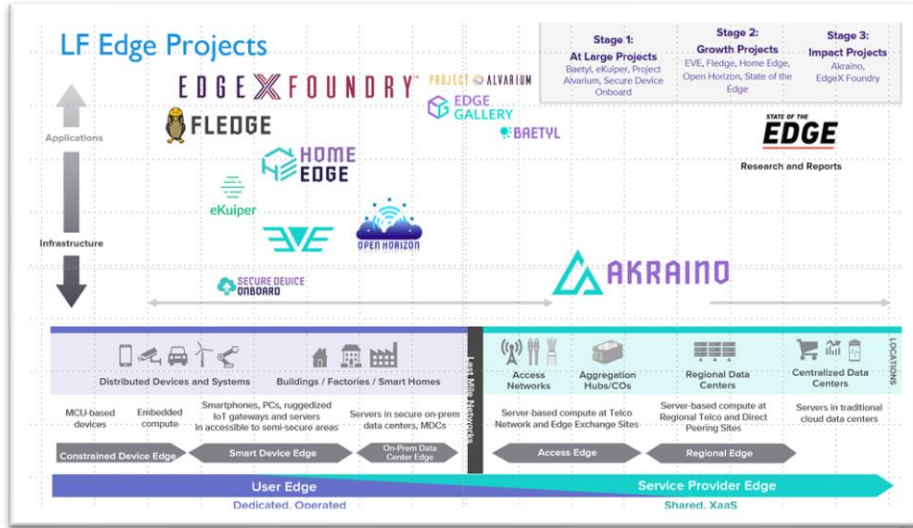
What is Akraino Blueprint?

LF Edge - long form - MASTER

CPS Robot Blueprint family overview

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○ There are many challenges and use cases, and solutions will be a combination of elemental tech

○ We launched CPS Robot Blueprint family in the Akraino community

○ Focus is on "Robot basic architecture Blueprint" to provide OSS stack based on SSES/R-CPS
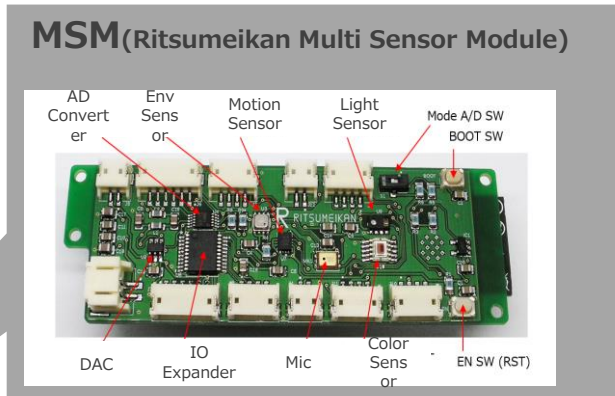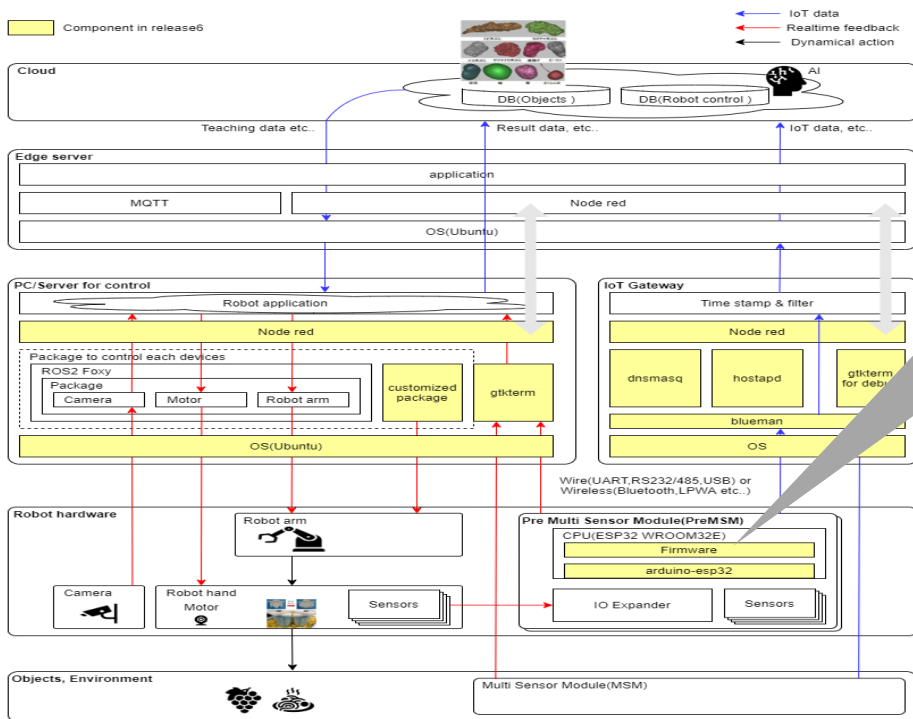

BP: Robot basic architecture based on SSES

BP Candidate 2: Robot maintenance

Cloud

• Create DB by teaching info
• Use information to market

DB → Analyze → Knowledge

Challenge：Maintenance automation
• Manage large number of robots
→Failure prediction and calibration by IoT

Global

Edge

Robotics

Strengthen cognitive abilities

AI processing by audiovisual + force/haptic

Sensor enrichment
Composite sensing infrastructure

Local

New mechanical
flexible end effector (hand)

Robot arm

Challenge：simplify teaching robot
• High level of skill required
→Human demonstrates movement, rate, level of strength

skilled human

BP Candidate 1: Robotics Teaching

Challenge：High-level cooperation among robots
Cooperative control of multiple robots
→High-precision time synchronization between robots

BP Candidate 3: Multi Robotics co-working

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Robot basic architecture based on SSES Blueprint

○ Open software stack for
  - ○ Collect sensor/robot data
  - ○ Analyze data
  - ○ Feedback to robot control

○ Received Akraino award
  - ○ Blueprint of the year 2022

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Detail of blueprint in Akraino R6

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MSM (Ritsumeikan Multi Sensor Module)
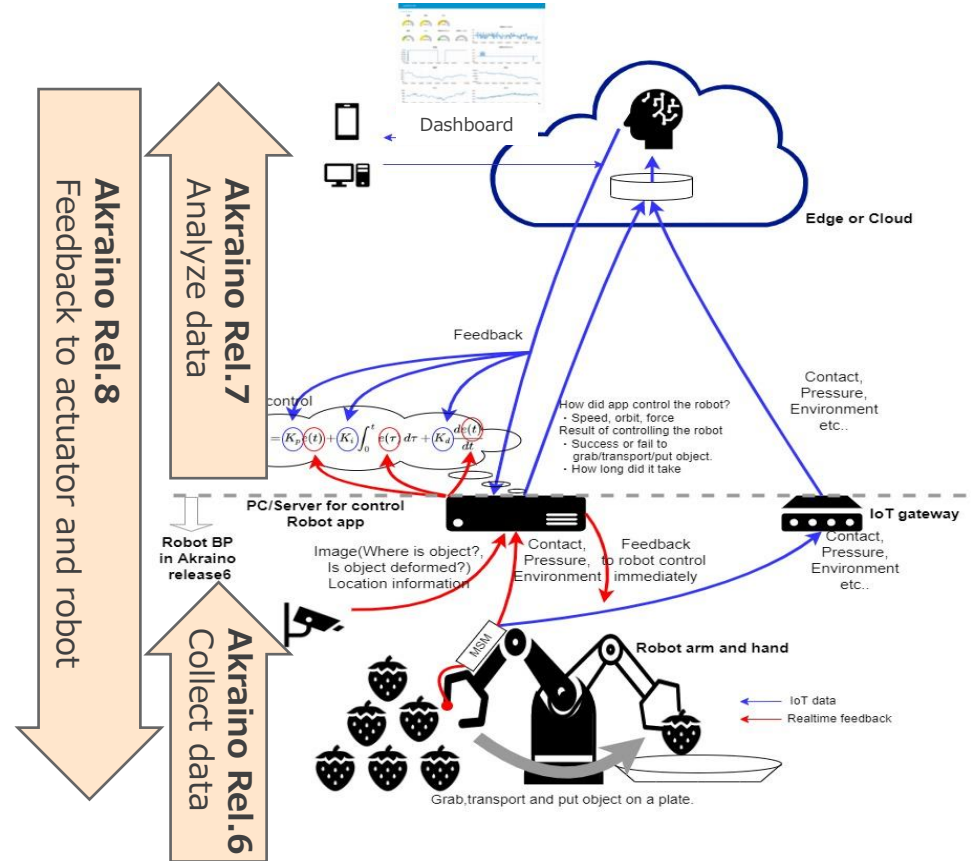
○ Documents are available on wiki

Robot basic architecture based on SSES - Akraino - Akraino Confluence

   ○ Architecture document
   ○ Installation/Test document

You can easily build data collection function

# Detail of blueprint in Akraino R7

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○ Enhance functionality
- ○ Data processing
- ○ Data analysis

Release basic data processing and analysis software libraries to support a variety of use cases

○ Light weight,
high performance ASR

Basic data processing and analysis software
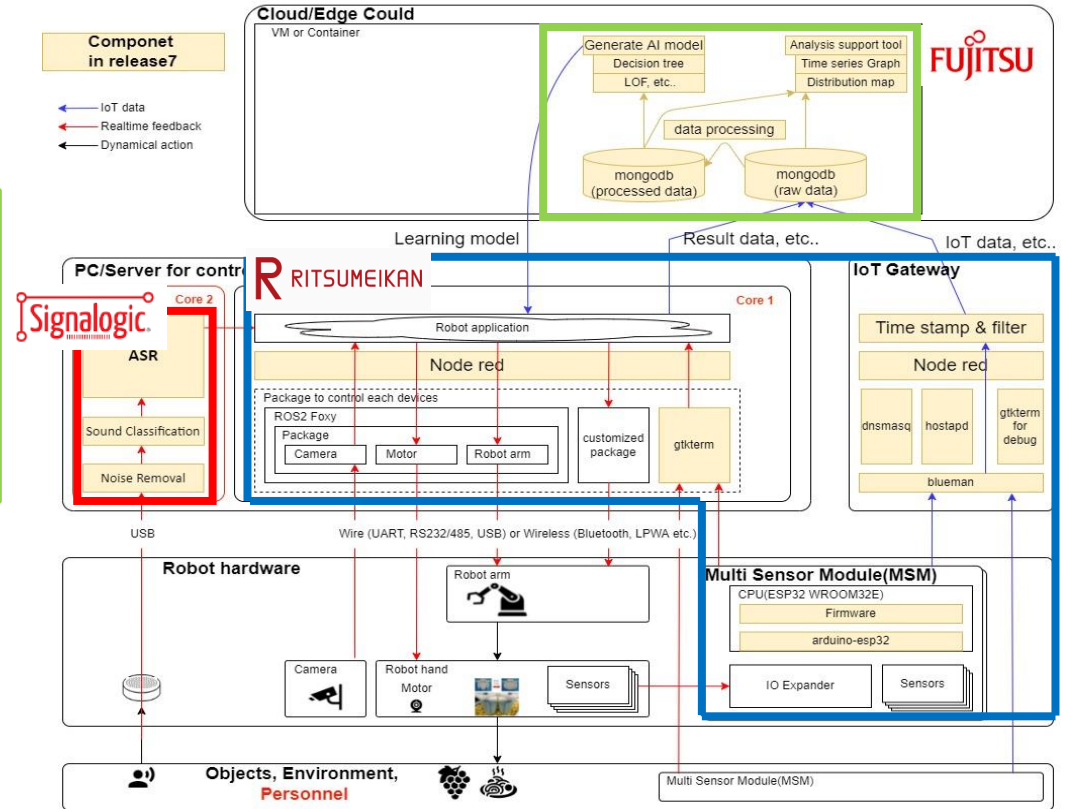
○ Data processing and analysis methods differ depending on use case

○ Software library accelerates implementation of data processing and analysis

· Various kind
· Various pattern
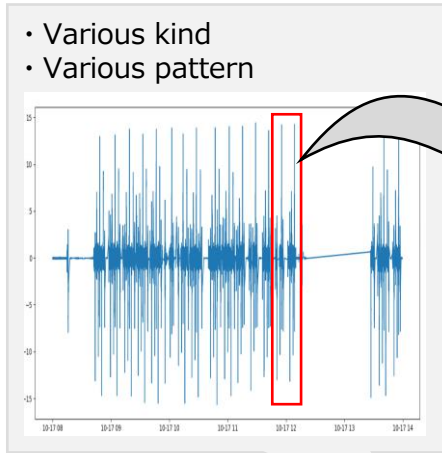
Basic data processing and analysis SW
Example

· Split time series data
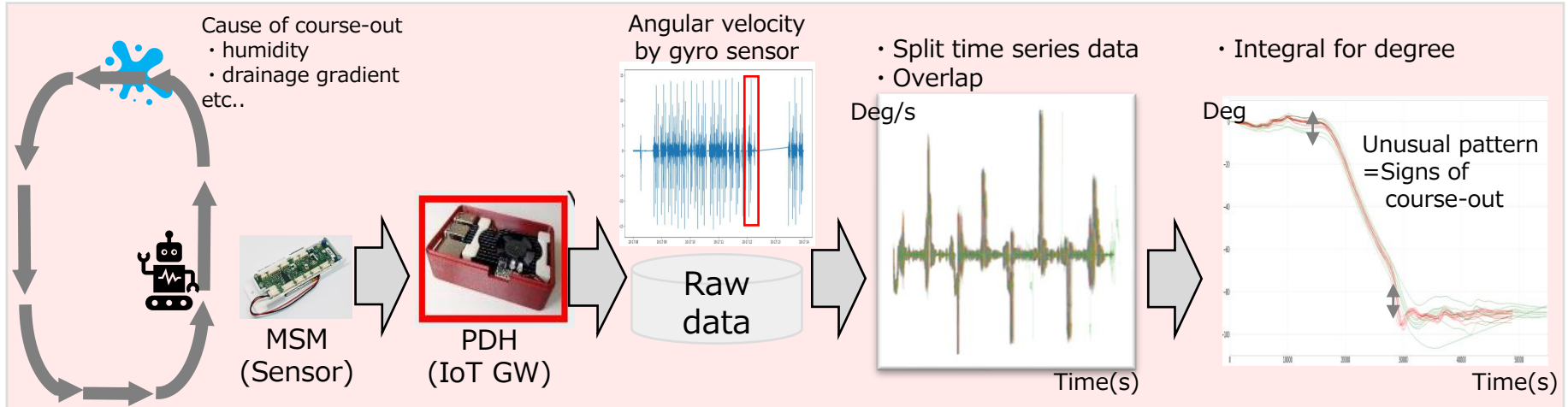· Detect peak
· Calculus
· FFT
· Remove noise
...

Collect → Raw data → Process → Processed data → Analyze → Result

Basic data processing and analysis software
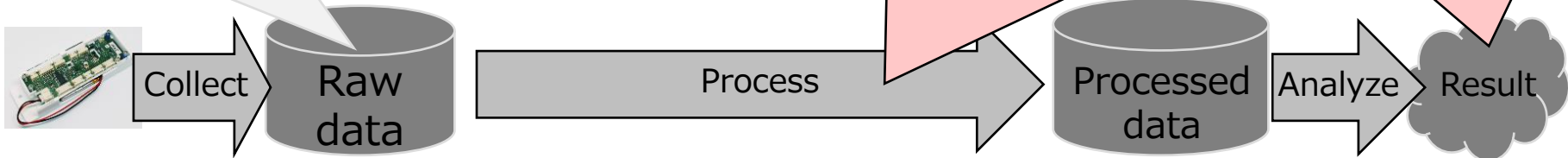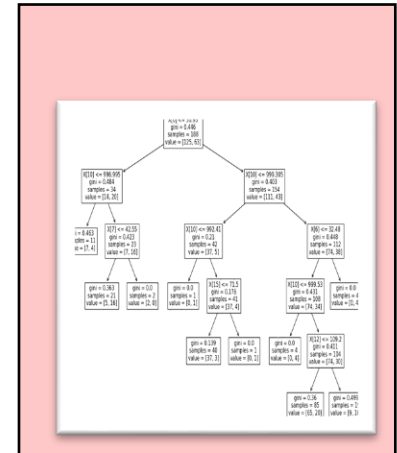
Classification	function	Summary
Data processing	read_db_env	Returns the environment data for the specified time period.
	detect_change	Detect the point of change in data for a specified time period.
	resample	Resampling Input time series data.
	calc_maxminavg	Calculate the maximum, minimum, and average values for a specified time priod.
	integral	Calculate integral of Input time series data.
Data analysis	kmeans	Classify time series data by k-means method.
	plt_overrap_fig	Create a chart that overlays multiple time series data.
others	diagnose	Graph the reception period of R-MSM data and detect reception errors.

Proof of Concept in food factory

Proof of Concept in food factory

○ Theme: detect signs of AGV (Automatic Guided Vehicle) course-out (i.e. off course)
  - ○ Road surface of a food factory is unstable due to humidity, drainage gradient, etc.
  - ○ Difficult to operate AGVs stably without course-out
  - ○ Confirmed that R-CPS and Basic data process and analysis SW can detect course-out indicators

Cause of course-out
・humidity
・drainage gradient
etc..

MSM
(Sensor)

PDH
(IoT GW)

Raw data

Angular velocity by gyro sensor

・Split time series data
・Overlap

Deg/s

Time(s)

・Integral for degree

Deg

Unusual pattern
=Signs of course-out

Time(s)

Robot Blueprint activities in future

- Enhance current blueprint functionality
  - Autonomous optimization of Robot;
    e.g. Parameter optimization of PID control
  1. Store data measured by sensors
  2. Analyze data in cloud for better parameters
  3. **Feedback new parameters**

  - **Interface with Robot arm and hand**
    - There are various kind of arm and hands depends
      on use cases
    - Need to absorb difference of HW
    - ROS2 is a candidate solution

Welcome participants
Contact: fukano.haruhisa@fujitsu.com

Appendix

LF Edge industry solution showcase
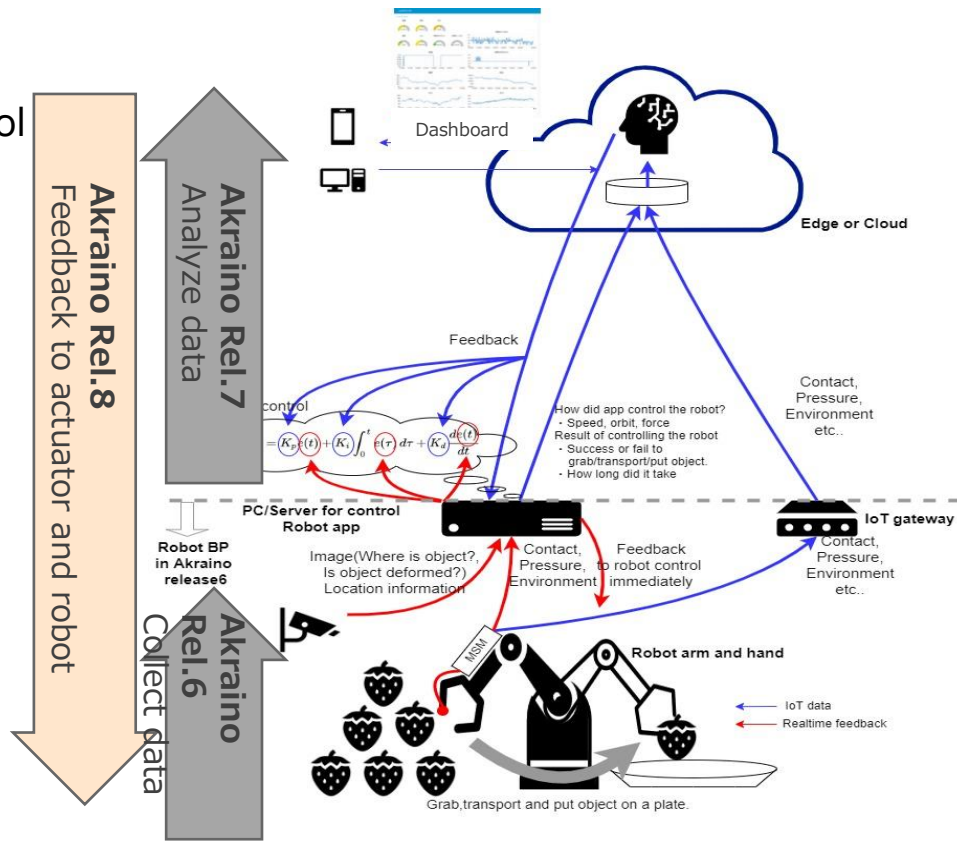
○ Showcase objectives:
  ○ Promote LF Edge projects and highlight edge computing use case
  ○ Increase user adoption of LF Edge projects

○ Showcases

・**Robotics (Akraino)** ・IoT (Fledge, eKuiper, Akraino)

・Clean Energy (EVE, Alvarium) ・MEC (Akraino)

・Retail (EdgeX, OpenHorizon, SDO) ・Factory, Plant (Fledge, EVE)

We are exhibiting in LF Edge booth at ONE summit

Acknowledgements

Cabinet Office   https://www.cao.go.jp/index-e.html

NEDO New Energy and Industrial Technology Development Organization   https://www.nedo.go.jp/english/index.html

SIP Cross-ministerial Strategic Innovation Promotion Program   https://www.jst.go.jp/sip/en/index.html

Thank you

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