Sep. 23rd, 2020
SICE AC 2020 RT-Middleware Tutorial

Part1: About OpenRTM-aist and Outline of RT-Component Programming

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Software Platform Research Team, Team Leader
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Outline

- Basic concept and overview of RT-Middleware
- Comparison with ROS
- Activities of RT-Middleware community
- RTC development overview
- Conclusion

What is RT-Middleware?

What is RT?

- RT = Robot Technology cf. IT
  - not only standalone robots, but also robotic elements (sensors, actuators, etc….)

RT-Middleware developed by AIST

OpenRTM-aist

- RT-Middleware
  - middleware and platform for RT-element integration
- RT-Component
  - basic software unit in RT-Middleware

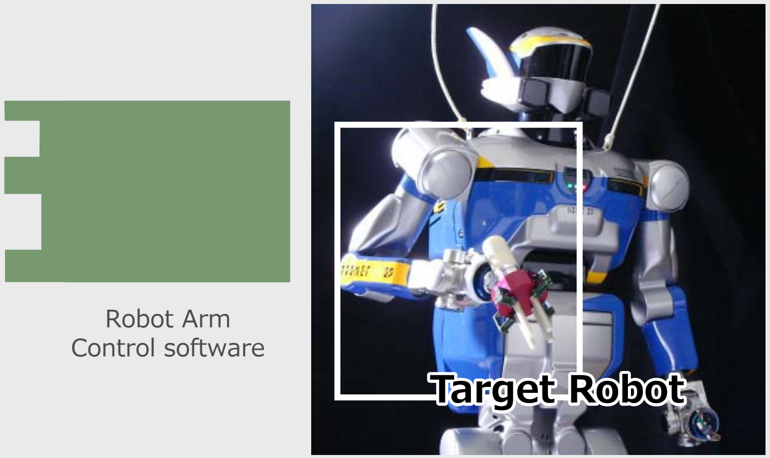
About Robot Middleware

- **Platform software** that provides common functions to streamline robot system construction
  - Sometimes called "robot OS"
  - Commonization and standardization of interface and protocols
  - Examples
    - Providing modular or componentized frameworks
    - Supports communication among modules
    - Provides parameter setting, deployment, startup, and module composition functions
    - Realize inter-OS and inter-language cooperation / interoperability by abstraction
- Development became active from around 2000
  - Various middleware is being developed and released all over the world

Conventional systems

Controller software

Controller



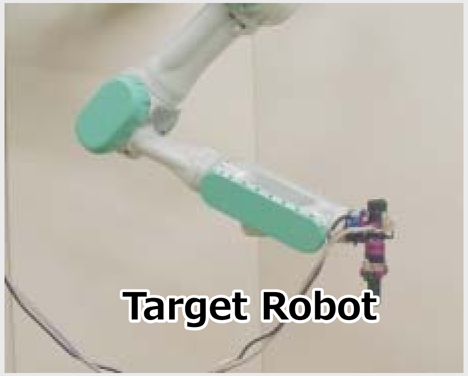
Robot Arm
Control software

Compatible interfaces are connectable

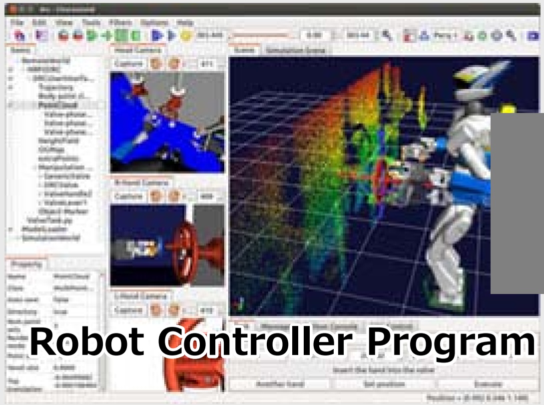
Robot Arm1

Conventional systems

Humanoid's Arm
Control software



Robot Arm2



Controller
software

Controller

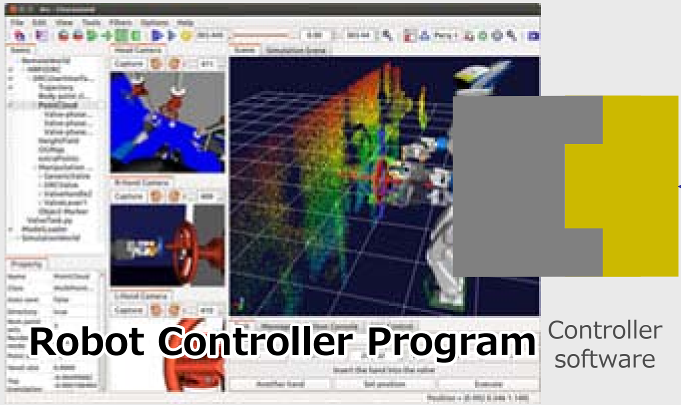
Robot Arm
Control software

Robot Arm2

Each robot has each control interfaces.
If no compatibility, cannot connect each other.

By using RT-Middleware

RTM provides a common I/F for connecting separately made software modules



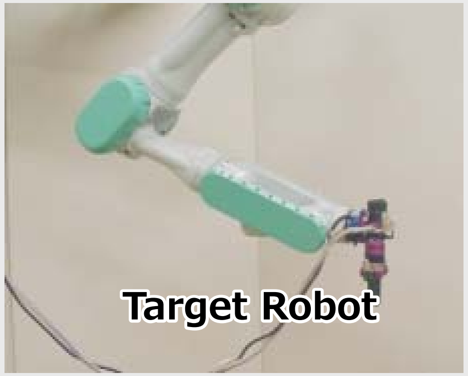
Controller software

Controller

Arm A
Control software

compatible
arm interfaces

Arm B
Control software



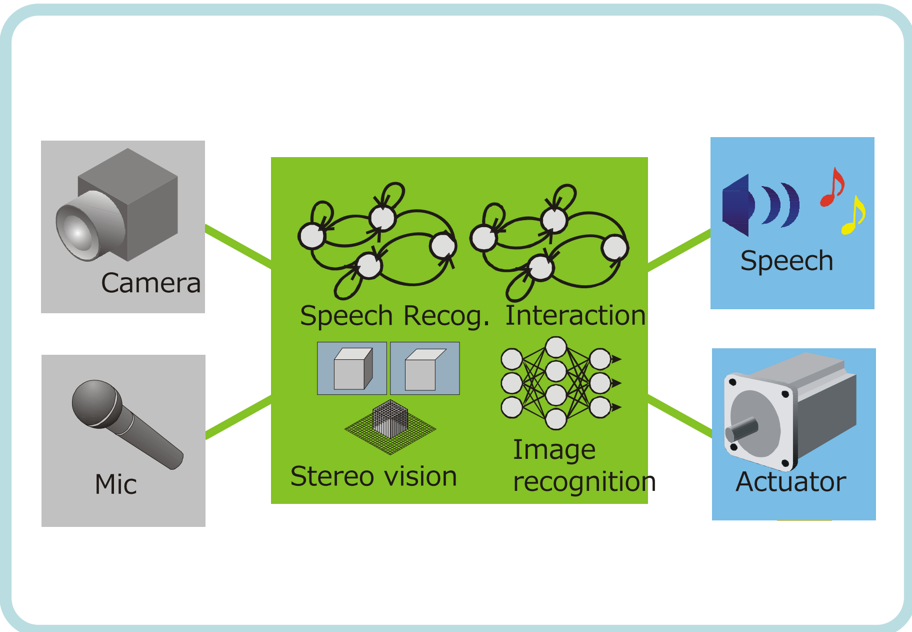
Robot Arm2

Robot Arm1

Improved software reusability
Easy to build RT system

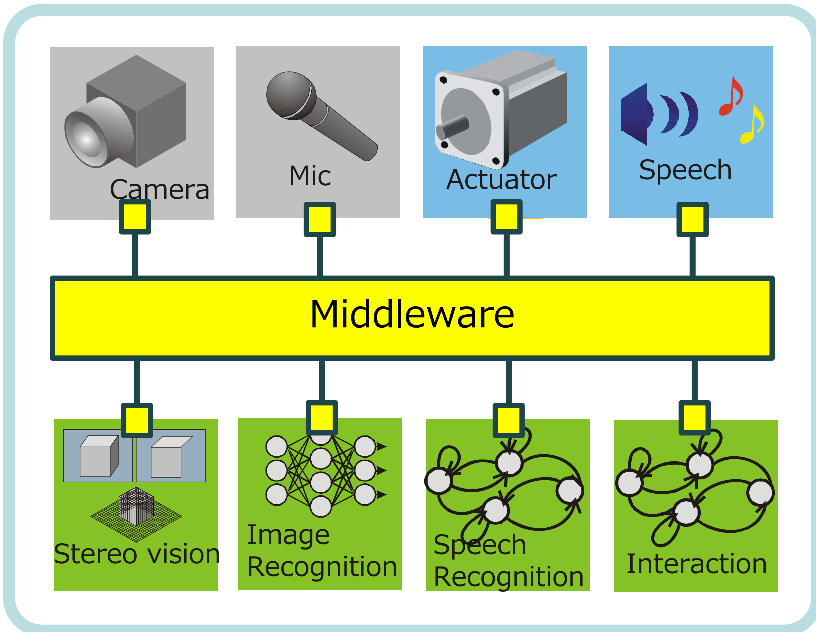
Trend of Robot Software Development

Conventional Style



- ✓ Integrated design of various functions
- ✓ High run-time efficiency, but inflexible
- ✓ Development becomes difficult as the system becomes more complex

Component Oriented Development



- ✓ Division/integration of large-scale complex functions
- ✓ Improvement of development and maintenance efficiency (reuse of functions, etc.)
- ✓ Increased system flexibility

The benefits of modularization

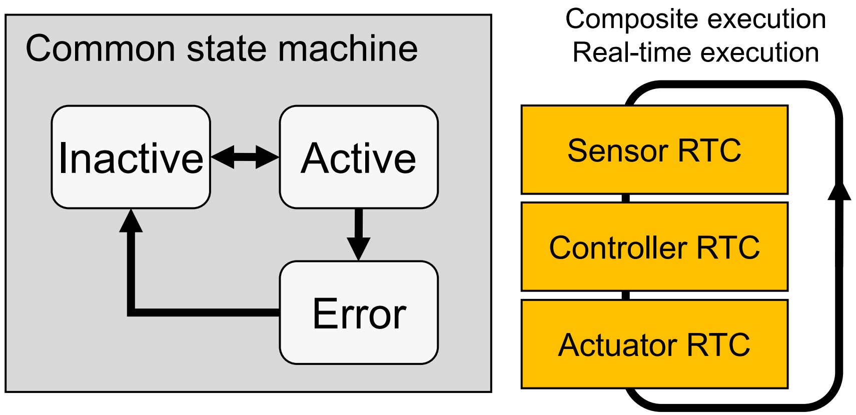
- Reusability
  - A component can be reused in various systems.
- Diversification
  - Various type of same functional modules can be tried in systems.
- Flexibility
  - System structure can be changed easily.
- Reliability
  - Easy to test a module and well tested modules are reliable.
- Durability
  - Well divided and independent module error does not affect too much to whole systems.

The benefits of RT-Component model

- Provides rich component lifecycle to enforce state coherency among components
- Defines data structures for describing components and other elements
- Supports fundamental design patterns
  - Collaboration of fine-grained components tightly coupled in time (*e.g*. Simulink)
  - Stimulus response with finite state machines
  - Dynamic composition of components collaborating synchronously or asynchronously

Main features of RT-Component

Activity, Execution context

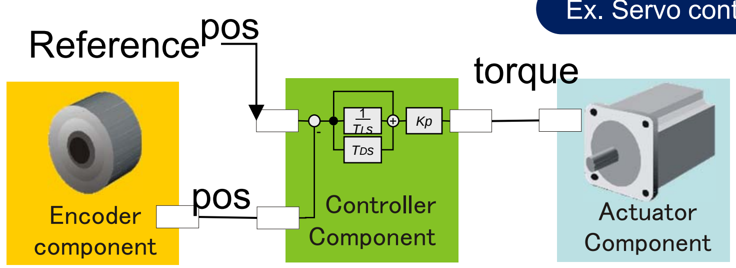


Life cycle management, core logic execution

Data Port

- Data centric communication
- Continuous data transfer
- Dynamic connection/disconnection

Ex. Servo control

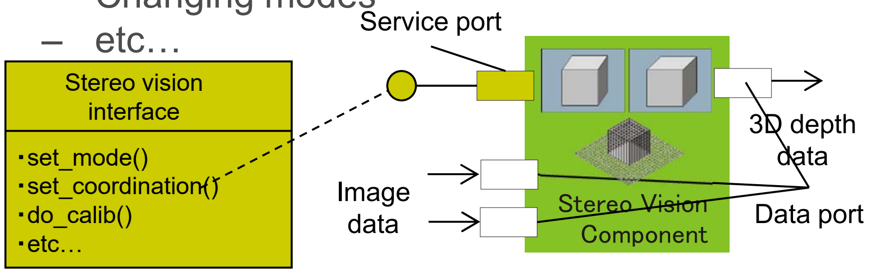


Data-centric communication

Service Port

- User defined interface
- Access to detailed functionality of RTC
  - Getting/setting parameters
  - Changing modes
  - etc…

Ex. Stereo vision

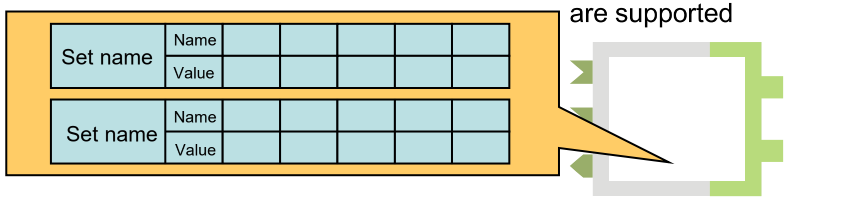


Service oriented interaction

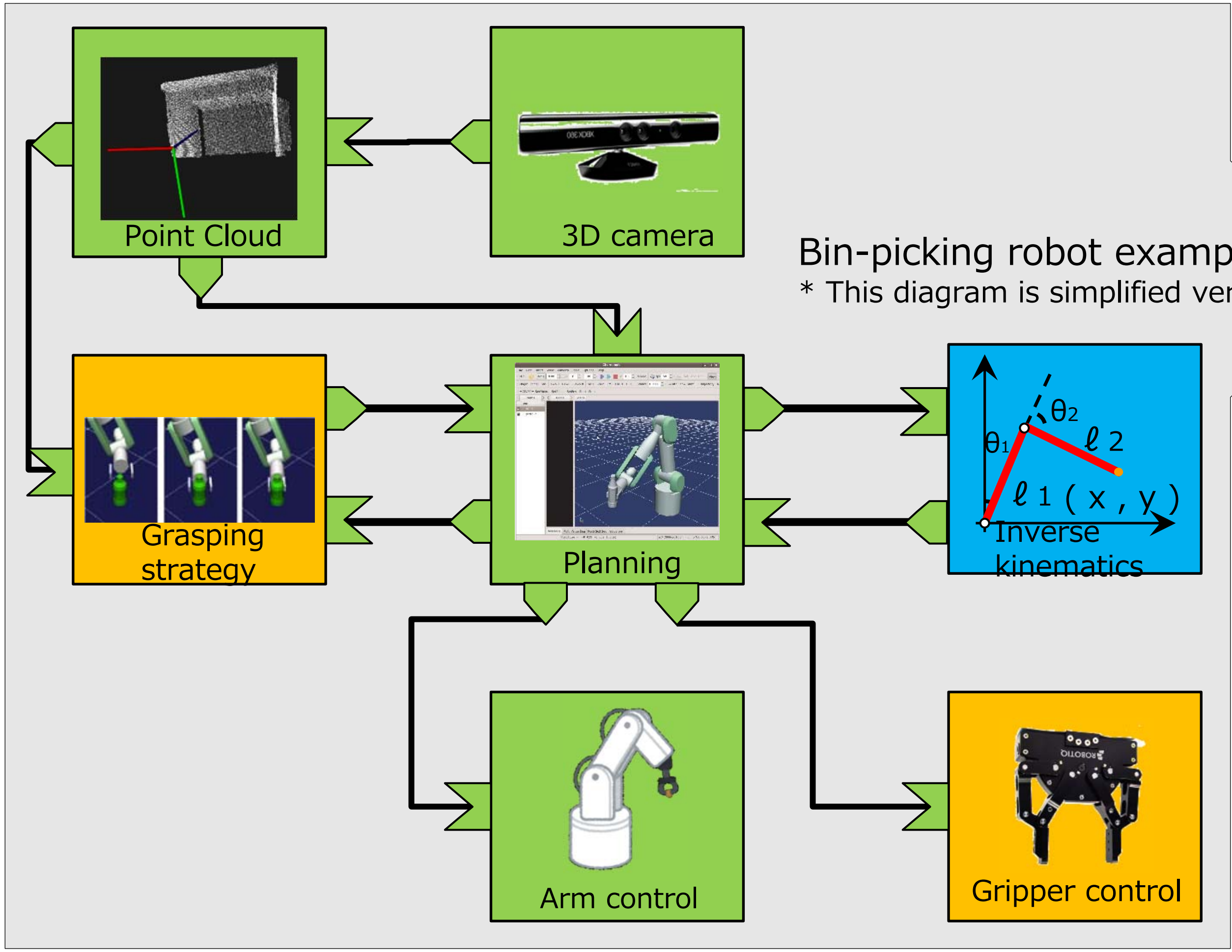
Configuration

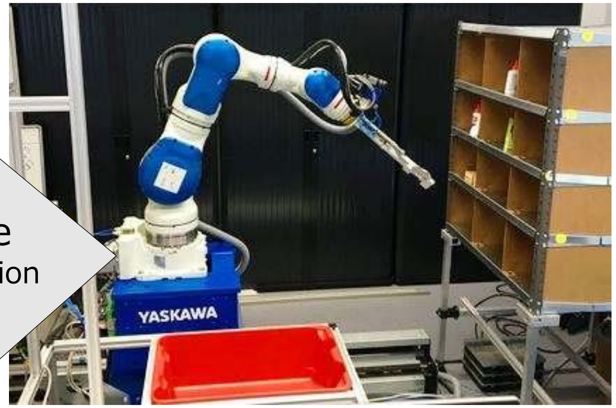
- Function for internal parameter
- Multiple parameter sets
- They can be changed from remote in run-time

RTC can have several configuration sets. Runtime reconfiguration and dynamic switching are supported



Advantages of RTM based development





Reusable RTCs

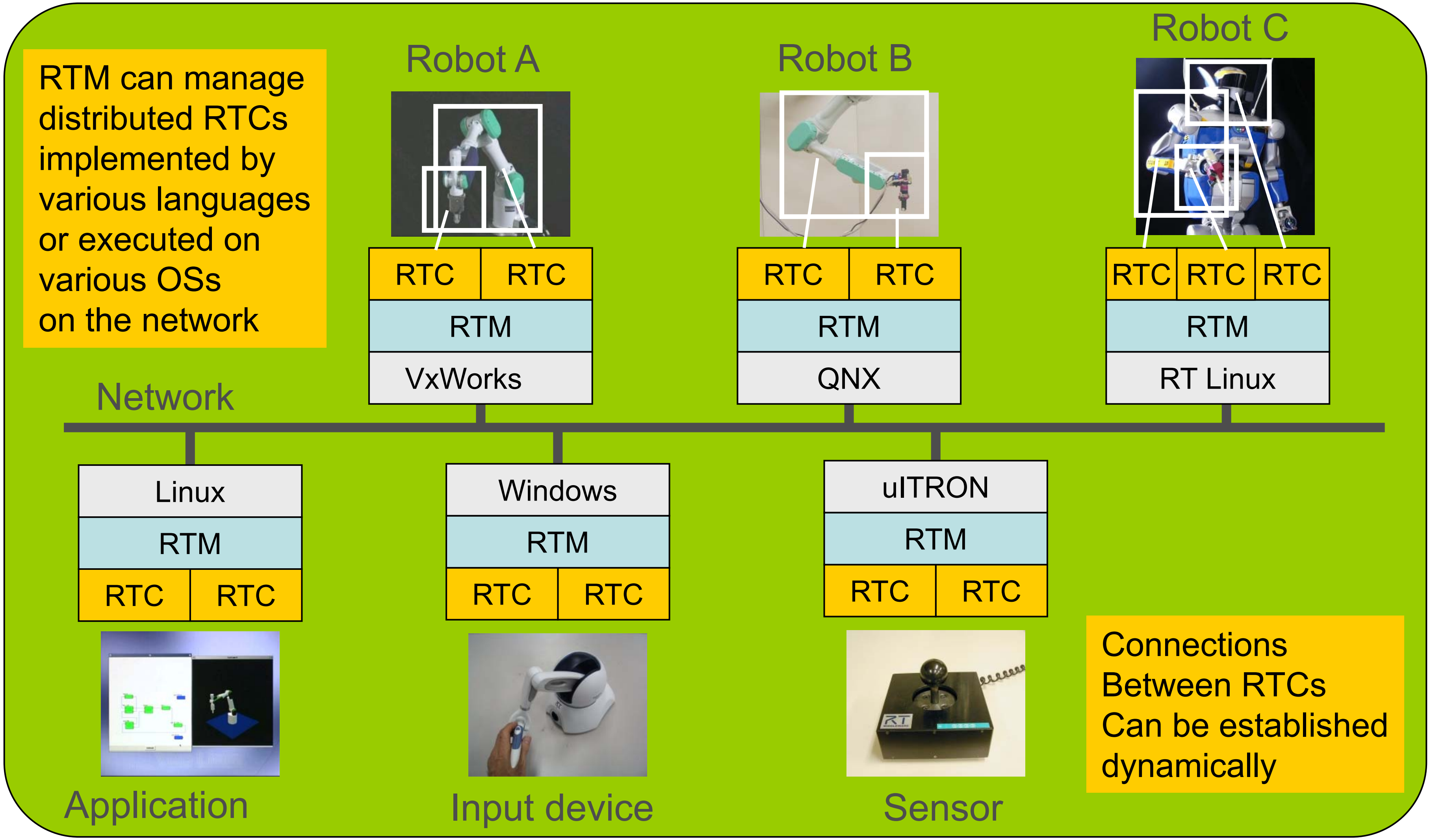
Self development using existing libraries

Develop from scratch

By using RTM, existing module can be reused

Reduce development from scratch

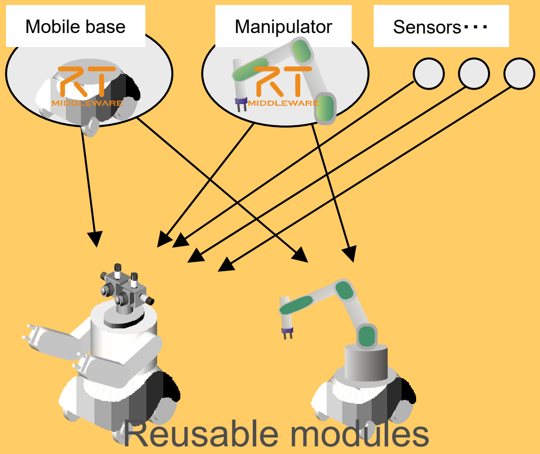
RTM based Distributed Systems



The aim of RT-Middleware

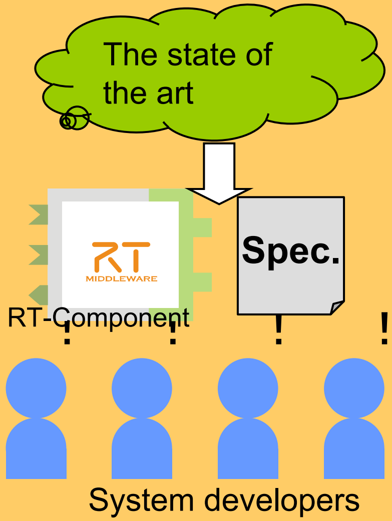
Problem Solving by Modularization

Cost



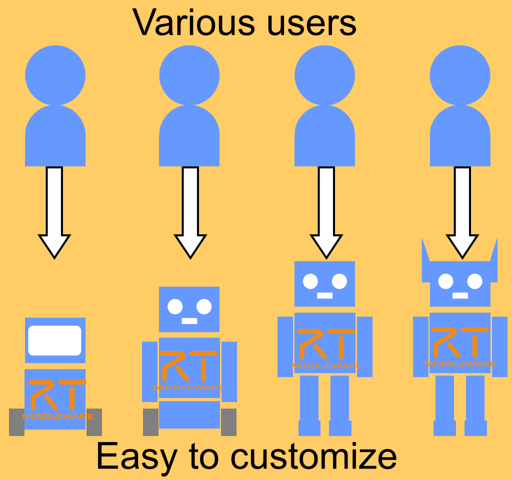
Realize
low-cost robots

Technical Issue



Utilize
the state of the art

Needs



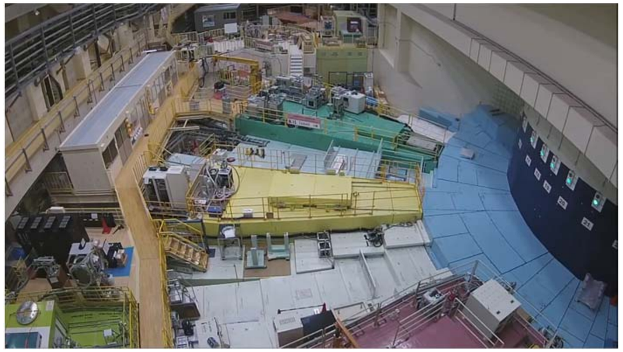
Satisfy
various needs

Robot System Integration Innovation

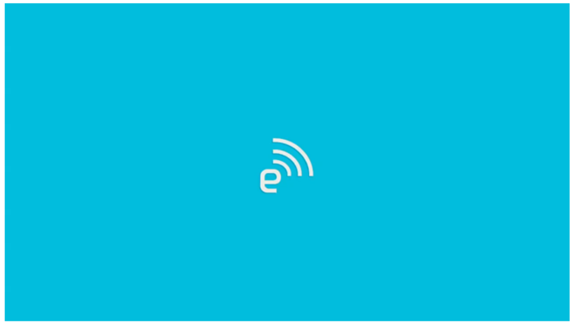
Practical/commercialization examples

HRP series: KAWADA and AIST

S-ONE : SCHAFT



DAQ-Middleware: KEK/J-PARC
KEK: High Energy Accelerator Research Organization
J-PARC: Japan Proton Accelerator Research Complex



HIRO, NEXTAGE open: Kawada Robotics

THK: SIGNAS system

TOYOTA L&F : Air-T

VSTONE’s education robots

OROCHI（RT corp.)

Robot operation simulator: NEDO

RTM as a International Standard

Date: September 2012

OMG
OBJECT MANAGEMENT GROUP

Robotic Technology Component (RTC)

Version 1.1

Normative reference: http://www.omg.org/spec/RTC/1.1
Machine consumable files: http://www.omg.org/spec/RTC/20111205/
Normative:
http://www.omg.org/spec/RTC/20111205/rtc.xmi
http://www.omg.org/spec/RTC/20111205/rtc.h
http://www.omg.org/spec/RTC/20111205/rtc.idl
Non-normative:
http://www.omg.org/spec/RTC/20111205/rtc.eap

History

- September, 2005
  Request for Proposal issued (starting standardization)
- September, 2006
  Specification approved by OMG
- April, 2008
  OMG RTC ver.1.0 released
- September, 2012
  Updated to ver. 1.1
- September, 2015
  FSM4RTC (FSM based RTC standard) adopted

OMG Standard

Standardized by OMG process
→ It can not be modified by just one company
→ Various compatible implementation
→ It promoted competition and interoperability

Ten or more RT-Middleware implementation exist

Implementation	Vendor	Features	Compatibility
OpenRTM-aist	AIST	Reference implementation by AIST	---
HRTM	Honda R&D	ASIMO is now moving to HRTM	◎
OpenRTM.NET	SEC	.NET(C#,VB,C++/CLI, F#, etc..)	◎
RTM on Android	SEC	RTM implementation for Android	◎
RTC-Lite	AIST	Tiny implementation on PIC and dsPIC	○
Mini/MicorRTC	SEC	RTM/RTC for CAN and Zigbee	○
RTMSafety	SEC/AIST	Functional safety standard capable RTM implementation	○
RTC CANOpen	SIT, CiA	RTM for CANOpen standard	○
PALRO	Fujisoft	Yet another C++ PSM implementation	×
OPRoS	ETRI	Implementation of Korean national project	×
GostaiRTC	GOSTAI, THALES	C++ PSM implementation on a robot language	×

Users can chose and continue to use
on of the RTM implementations

Comparison with ROS, and trend

ROS and RTM

Pros of ROS

- Design policy based on UNIX culture
  - Officially supports only Linux
  - ROS2 supports Windows and MacOS
- Original package management systems
- Abundant quality and quantity of nodes (components)
  - Many nodes whose quality is directly controlled by OSRF
- Large number of users
- Discussions such as forum and ML are open and active
  - Sometimes core lib's specification moves by users opinion
- Large number of English documents

Pros of OpenRTM

- Many OS/Language support
  - Windows, Linux (and other UNIX), MacOS, Real-time OS (VxWorks, QNX)
  - Windows native support
- Mainly spread in Japan
  - Japanese document, ML, tutorials
  - Less numbers of users
- GUI tools for beginners available
  - Eclipse based tools officially provided
  - CUI tools also available (rtshell)
- Standardized specification
  - Open revision procedure at OMG
  - Third-party implementation is welcome
  - Some compatible implementations exist
- Well-defined component model
  - High affinity with object-oriented, UML and SysML design
  - Model-based development
- IEC61508 functional-safety certification ready
  - RTMSafety by SEC corp.

From ROS1 to ROS2

- When they undertook NASA's work, ROS original messaging protocol was not allowed to use. So prototyping was implemented in ROS, but they are re-implemented from scratch in the final product.
- DDS (Data distribution service, which is one of the OMG standardized messaging protocol) was used, because the only standardized protocol is allowed in NASA.
- There are inconvenient constraints such as no component model exists, only one-node-one-process model is allowed, ROS-master's SPOF (single point of failure) problem.
- Therefore, ROS2 is completely new implementation to overcome these problems, so no compatibility between ROS1 and ROS2.

ROS2

- Current release : Foxy Fitzroy, June 5th, 2020
- Use of standardized middleware
  - Stop reinventing the wheel
  - Communication middleware is DDS standardized in OMG
- Component model is introduced
  - Suitable for embedded use and performance effective architecture like RTC
- Expansion of supported OS
  - ROS1 only supports Linux (only Ubuntu Linux supported)
  - Windows and MacOS support are added in ROS2
  - But no support for commercial real-time OS such as VxWorks, QNX

Communication middleware standard with a proven track record in aviation, military, medical, railway, etc.

http://design.ros2.org/articles/ros_middleware_interface.html

RT-Middleware community

Project web pages

- Users can upload their own RTCs on the openrtm.org
- Users can search and download other users RTCs

Project type	Number
RT-Components	405
RT-Middleware	14
Tools	19
Documents	4
Hardware related RTCs	28

RT-Middleware Summer Camp

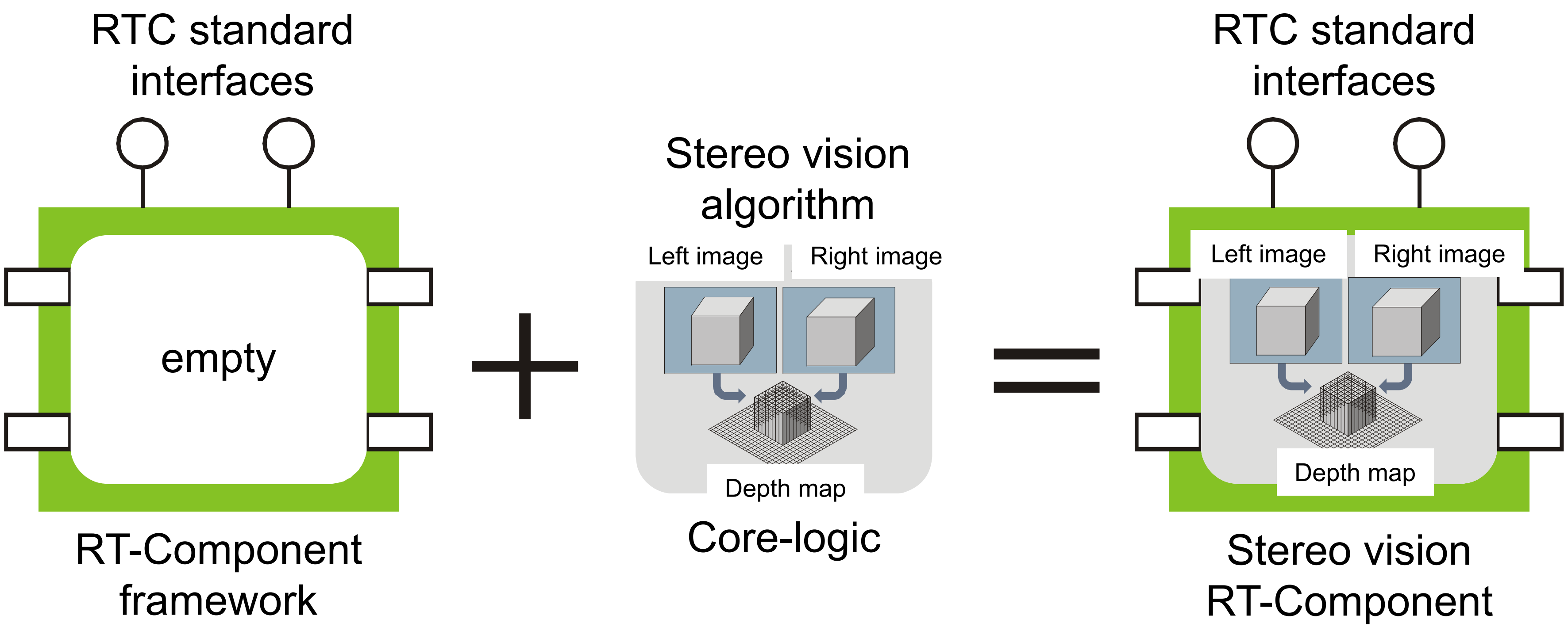
- 1 week camp every summer
- This year: August 24-28
  - The first online camp
- Number of participants: 11
- Venue: AIST Tsukuba center (Tsukuba city, Ibaraki pref.)
  - Onlie (Zoom)
- Lectures, practical work and presentation by five teams.
- Staying in the AIST's accommodation and coding endlessly every night :-P.

RT-Middleware Contest

- Held as an organized session in SICE SI conference
  - Various prizes
  - Entry deadline: Sep. 23rd
  - Software registration : Oct.
  - Paper submission due: Oct. 26th
  - Online examination : from end of Nov.
  - Presentation and award ceremony: Dec.
- Record of year 2019
  - Number of applications : 11
  - SICE RT-Middleware award x1
  - Product supporting award x2
  - Company supporting award x9
  - Personal supporting award x10
- See more details: openrtm.org
  - Menu: community -> events

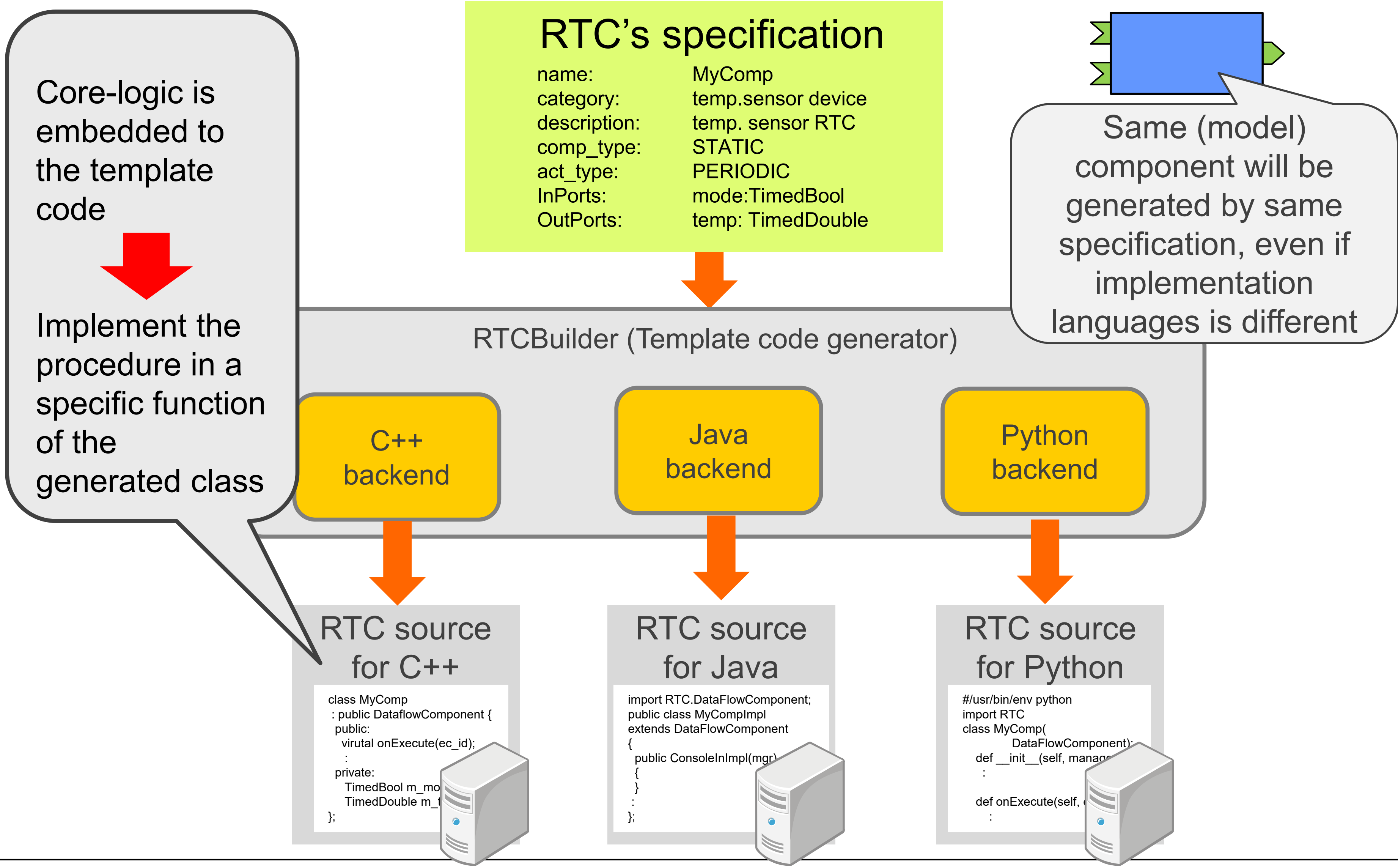
RTC development overview

Framework and core-logic

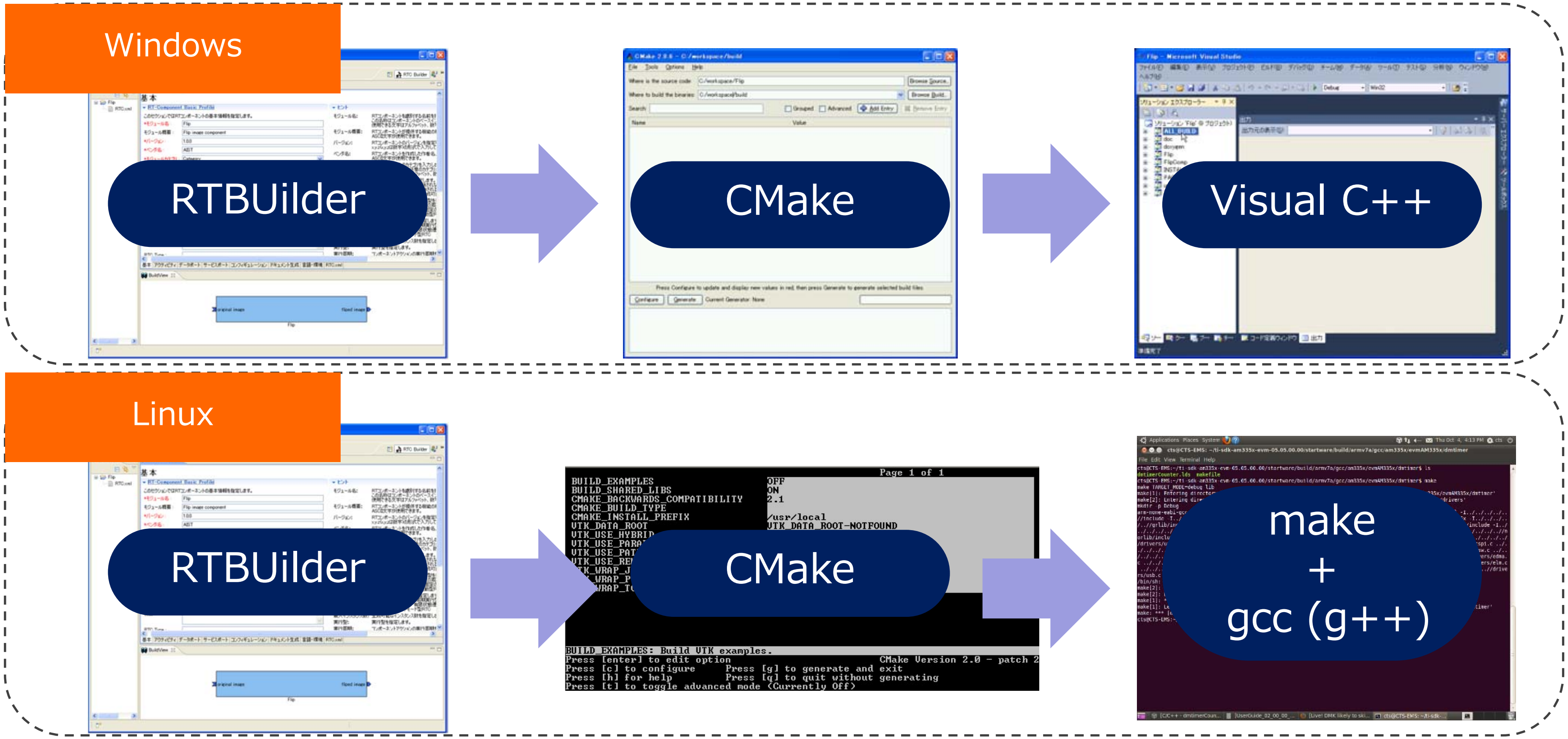


RTC framework ＋ Core logic ＝ RT-Component

Code generation by model



RTC development flow



Input spec of RTC

Generating VC project or Makefile

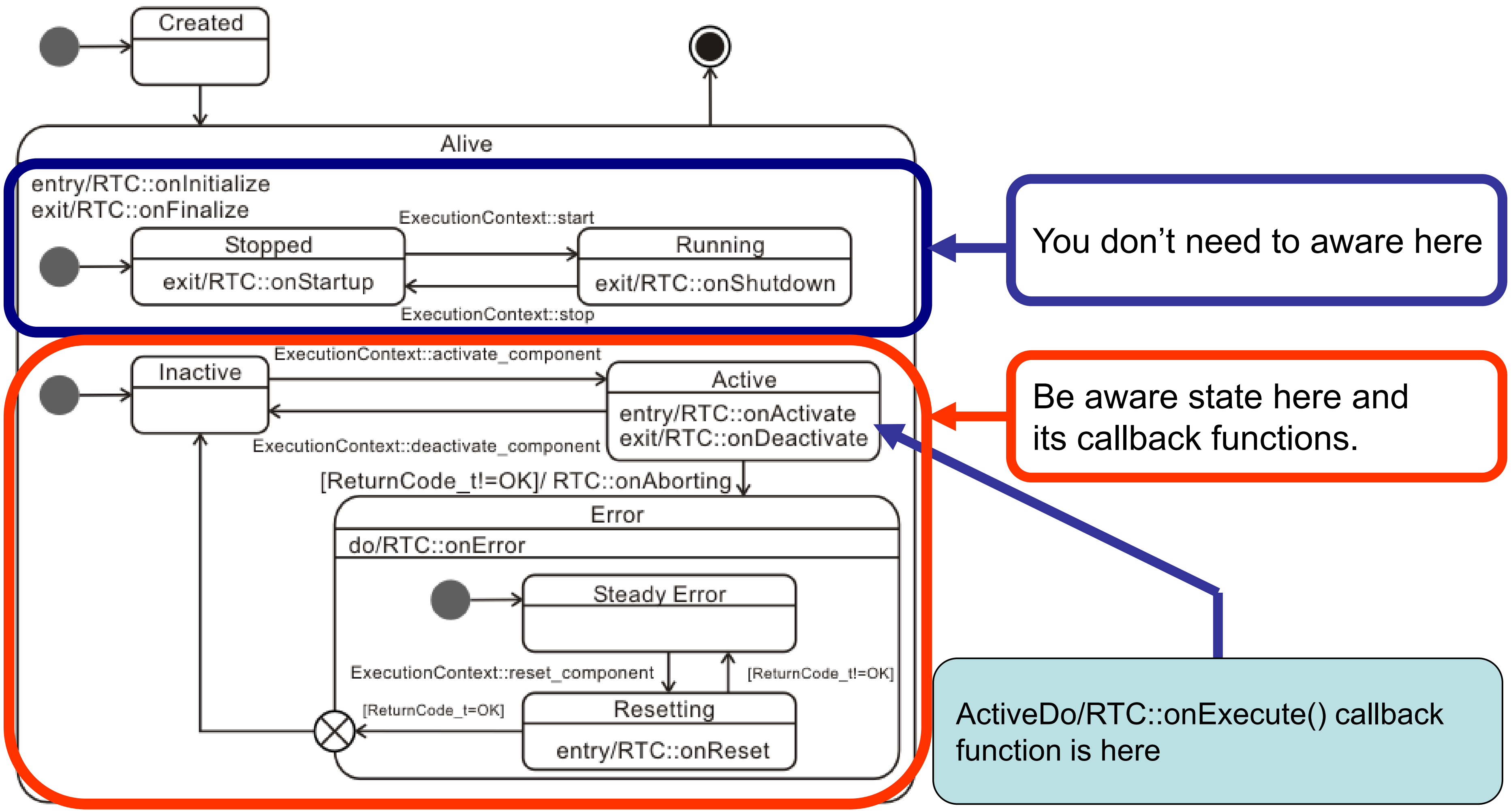
Implement logic and compile

Almost all steps are the same, except compiler

CMake

- Open source software for compiler-independent build automation
- Can generate build files for different development environments on different operating systems
- Generate Makefile on Linux
- Generate VC (Visual C++) project file on Windows
- Most of the recent open source software is built with CMake.

State machine and lifecycle of RTC

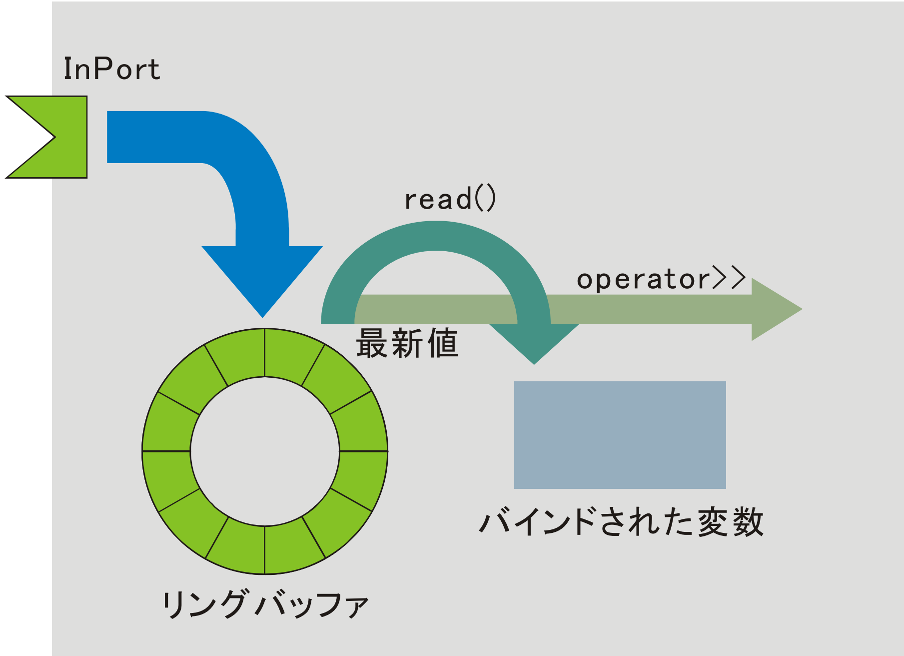


Activity (Callback functions)

Callback functions	Meanings
onInitialize	Initialization
onActivated	Called once when RTC is activated
onExecute	Called periodically when RTC is in the active state
onDeactivated	Called once when RTC is deactivated
onAborting	Called once when entering ERROR state
onReset	Called once when resetting
onError	Called periodically when RTC is in the error state
onFinalize	Called once when finalizing RTC
onStateUpdate	Called after onExecute everytime
onRateChanged	Called when ExecutionContext's rate is changed
onStartup	Called once when ExecutionContext starting
onShutdown	Called once when ExecutionContext stopping

InPort

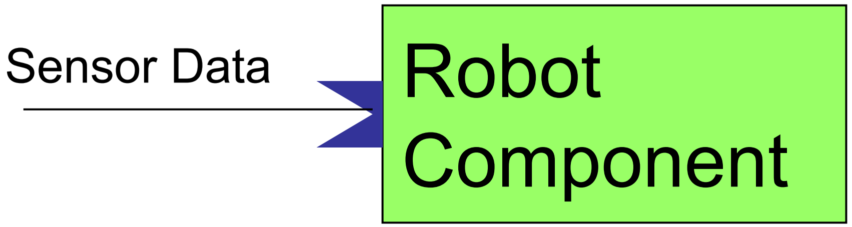
- InPort
  - Input port for data flow type communication
- Methods of InPort class
  - isNew(): check if new data arriving
  - read(): retrieve data from InPort buffer to the variable bound to the InPort
  - >> : same as above



Basically paired with OutPort

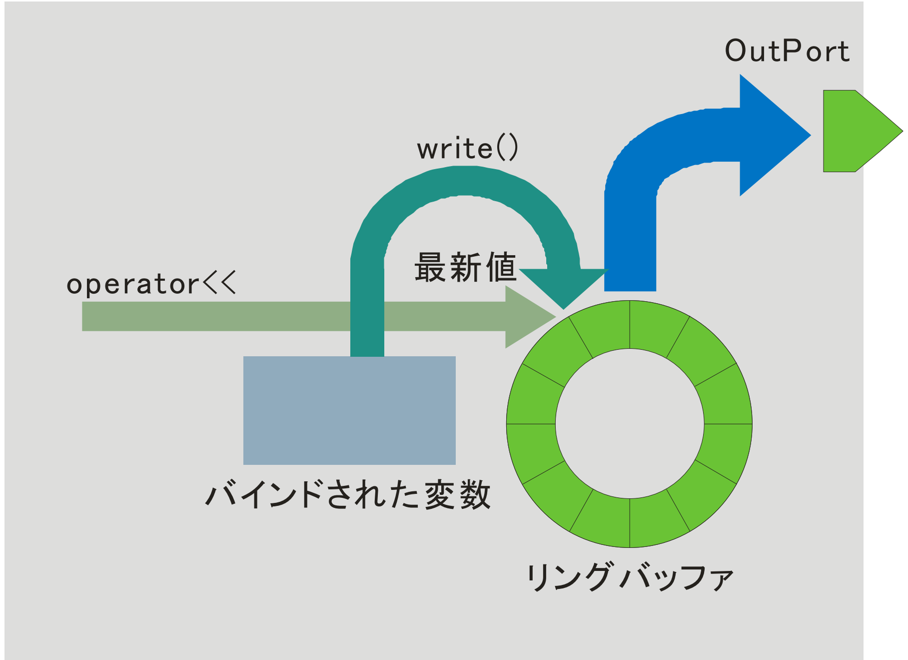
Data ports (InPort/OutPort) must have the same type

Example



OutPort

- OutPort
  - Output port for data flow type communication
- Methods of OutPort class
  - write(): push data from OutPort's variable into OutPort's buffer to be published to the remote InPort
  - << : same as above



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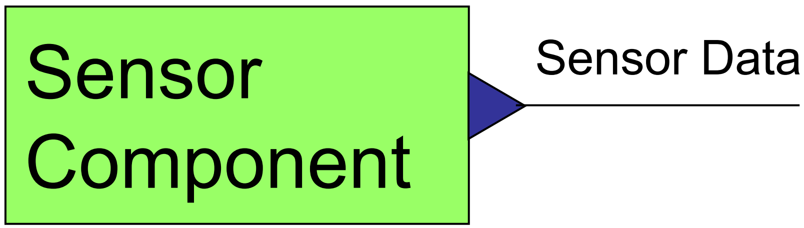
例



Recommendation

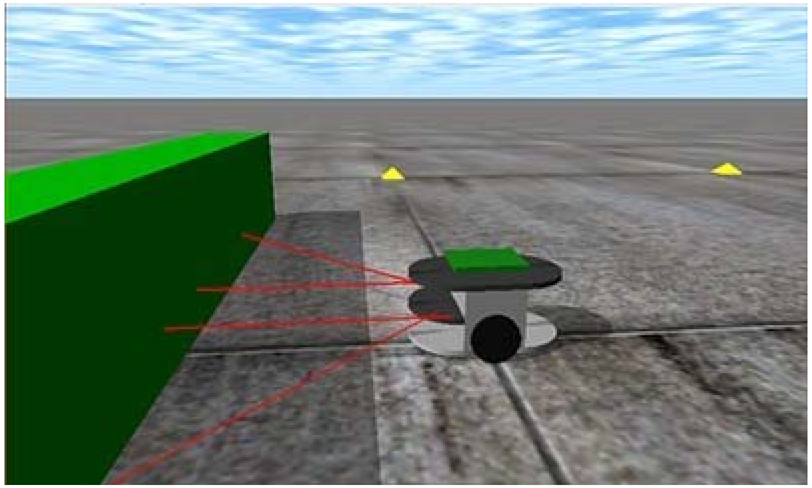
- Let’s stop reinventing the wheel!!
  - Code that has been executed thousands of times by different people works better than your code from scratch!!
  - Let's write the code you really need to write and borrow the other non-essential part for you.
  - A program released by someone is a program that has worked once!!
  - Other persons code is hard to read, but you shouldn't throw it away for that reason!!
- Commit to open source projects!!
  - Don't hesitate to ask questions on ML and forums!!
  - No matter how rudimentary a question is, it is valuable information for others.
  - Let’s complain to the project!! (good feedback grow the project)
  - Debug and send patches if you can!!

Conclusion

- Basic concept and overview of RT-Middleware
- Comparison with ROS
- Activities of RT-Middleware community
- RTC development overview

NEXT

- Part2: Introduction to creating RT-Component
  - Lecturer: Nobuhiko Miyamoto
- Please check your development environment
  - Did you install OpenRTM-aist and other dependent software?
  - During lunch time, staffs support installation, if you do not install them yet.
  - If you have any question, please call us via Zoom's chat or Slack.



We will create a robot controller for mobile robot and connect it to Raspberry Pi Mouse mobile robot component in the simulator.