An Integrated Distributed Simulation Environment weaving by Hakoniwa and mROS 2

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We are TOPPERS/Hakoniwa WG!!

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  - ESM & Hakoniwa Lab
  - Tech Leader!!

- About TOPPERS Project (Toyohashi OPeN Platform for Embedded Real-time Systems)
  - NPO in Japan to promote embedded systems technology and its industry by developing and releasing high-quality open-source software, especially in real-time kernels and components
  - Hakoniwa WG: working group to establish simulation technology for the IoT fields
Agenda

1. What is Hakoniwa?
2. Our Past Achievements, especially for ROS Robot
3. Latest Update: hakoniwa-mros2sim
4. Fusion of Virtual and Real weaving by Hakoniwa and mROS 2
5. Wrapping Up
Agenda

1. What is Hakoniwa?
   • What’s the issue
   • Concept: HUB to Everything for Simulation!
   • Key Functions: Hakoniwa Core, Conductor and Protocol Data Unit
2. Our Past Achievements, especially for ROS Robot
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Issue and Background

- IoT system spans a variety of technical domains, so its development requires the collaboration of experts from different fields.
- Integration test and validation are so challenging due to these technologies’ diversity.
- When a problem unfortunately happens, investigating the cause and its path becomes intricate.
- Costs for conducting empirical experiments also increase significantly.
Let’s bring them into a BOX!!

- Arranging various technologies according to everyone's preferences
- Trying out various combinations as often we want
- Observing them according to everyone's preferences into the same box
- Bringing together things (e.g., software) from various tech fields to perform end-to-end integration, and verification on the desk!

-> Developing IoT/robot systems in a virtual environment Hakoniwa

BTY, why “Hakoniwa”?
- Hako(箱) = box
- Niwa(庭) = garden
  a miniature garden, one of the traditional JP cultures (like “Bonsai”)
Concept

- HUB to Everything for Simulation!
  - not just a simulator, but also a framework to construct simulators
- Hakoniwa Assets: the components of the simulation target
Hakoniwa Core

- Functions for the seamless integration of various assets

Visualization Tool
Microcontroller Simulator
Hakoniwa Asset

Asset Management
Synchronization & Communication
Scheduling
Time Management

Hakoniwa Core

Physics Simulator
Automated Testing Tool
**Hakoniwa Conductor**

- Mediate simulation between assets on Hakoniwa
  - gRPC based communication between the server and clients

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**Server-side**
- registration of Hakoniwa assets
- start/stop/reset of each simulation

**Clients-side**
- connect to the server as the Hakoniwa assets
Protocol Data Unit (PDU)

- Common data format to exchange in Hakoniwa
- Function design is separated to asset-dependent and -independent
- An example between Unity and ROS (topics)
  - Note: Unity and ROS are positioned as one of the "assets" in Hakoniwa
Distributed Simulation with Hakoniwa

- **Computer1**
- **Computer2**
- **Computer3**
- **Computer4**

- **Server-side Hakoniwa Conductor**
- **Client-side Hakoniwa Conductor**
- **Hakoniwa Proxy for PDU**
- **Hakoniwa Asset**
Agenda

1. What is Hakoniwa?
2. Our Past Achievements, especially for ROS Robot
   - 4 Prototypes to Ensure the Hakoniwa’s Concept
   - hakoniwa-ros2sim: ROS controlled Robot Simulation
   - Actual Use Cases
3. Latest Update: hakoniwa-mros2sim
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Hakoniwa Prototypes Previously Achieved

Microcomputer-controlled robot simulation

Collaborative simulation of multiple robots

Integration with reinforcement learning

ROS controlled Robot Simulation
ROS controlled Robot Simulation

- Docker for the platform
  - pre-built container image for building & executing ros2app
  - able to use on multiple environments (Windows/WSL2 as the default)
- Unity for physics and visualization
  - TurtleBot3 as the reference
  - ROS-TCP-Endpoint for assets communication
Actual Use Cases

• Athrill (micro-controller simulator) for ET-robocon https://www.etrobo.jp/
• Group exercises (PBL) in some Japanese universities
• Automotive software education for embedded engineers https://github.com/ncesnagoya/autosar_os_training
Agenda

1. What is Hakoniwa?
2. Our Past Achievements, especially for ROS Robot
3. Latest Update: hakoniwa-mros2sim
   - Introduction of mROS 2
   - [FYI] ROSCon JP 2023 Workshop
   - hakoniwa-mros2sim: Simulator for mROS 2 app by Hakoniwa Tech.
4. Fusion of Virtual and Real weaving by Hakoniwa and mROS 2
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What is mROS 2?

mROS 2 on EMB board
better perf. & mem. usage
partially compatible with rclcpp
only for Topic comm.,
and many unsupported features
such as QoS, Service,

https://vimeo.com/showcase/9954564/video/767140724
Currently Supported

mROS-base/mros2-aspi3-f767zi
reference implementation of mROS 2 for STM32 NUCLEO-F767zi with TOPPERS/ASPI3 kernel

mROS-base/mros2-esp32
reference implementation of mROS 2 for ESP32 boards

mROS-base/mros2-mbed
reference implementation of mROS 2 for mbed OS

mROS-base/mros2-posix
reference implementation of mROS 2 for POSIX layer

watch later!!

NEW!!

free RTOS

POSIX

ubuntu

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News!!

9月25日: 講習会: ROS 2の組込みマイコン向け技術の

ROS 2の組込みマイコン向け技術に関する講習会を実施いたします。組込みマイコン固有の

グ技、ワールドとのROS 2通信による移動ロボットの制御方法について学びます。

講習会は到着後で参加費が必要であり、ROSCon JPの参加登録時点で「9月25日」の

到着しておきたい（講習会のみの参加はできません）。参加人数は25人限定・先着順で

ください。

講習会の教材には、次のロボット・基板を使用します。

- PiCo Classic3 マイクロマウス（受講者に貸出）
- PiCo Classic 3専用 ESP32-S3マイコンボード（参加登録・持ち帰り可）

講習会では、下記スポンサーより提供するロボットを使用します。

- RT CORPORATION

講習会の受講者は、次の環境のPCを用意して持参いただく必要があります。

- Ubuntu 22.04 LTS（ネイティブインストールされたもの・Docker等の仮想環境は不可）
- ROS 2 Humble Huggable
- USB Type-Aポート1口
- 有線LANと無線LANの双方

対象者:

- 上記の環境を自宅で未得・持ちいただく方
- ROS 2 Huggableの公式チュートリアルの内容をIntermediate まで理解されている方
- 組込みマイコン向けのソフトウェア開発に興味のある方

講習会資料（一般公開版）

contents is public!!
(only in JP:D)

https://roscon.jp/
2023/#workshop
hakoniwa-mros2sim :D

• Target: mros2 app & robot

Pi:Co Classic3 (MicroMouse)

mROS-base/rcjp2023_mros2
https://github.com/mROS-base/rcjp2023_mros2

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3. Latest Update: hakoniwa-mros2sim
4. Fusion of Virtual and Real weaving by Hakoniwa and mROS 2
   • Hakoniwa’s Future Vision for Robotic Service
   • Expected System in the Future and its Architecture Design
   • Integration of mROS 2 into Hakoniwa Communication
   • Demonstration!!
5. Wrapping Up
Our Future Vision for Robotic Service

How to Integrate?

- AI Analysis Space
- Cloud Service

Coverage of ROS

Robot Controller

What to do?

- Generative AI Agent Space
- Gaming Space
- Virtual Service

How to Integrate?

Robot Service Networks

Micro Controller

A new trend!!

Challenges faced in the embedded systems domain

Challenges faced in the cloud domain

Coverage of ROS
Fusion of Virtual and Real

• Integration of Virtual and Real in Simulation

- Generative AI Agent Space
- AI Analysis Space
- Gaming Space
- Robot
Expected System in the Future

Virtual World
- AI Agent
- Virtual People (Digital Avatar)

Real World
- AR Agent
- People

Virtual Signal
- Virtual Robot (Digital Twin)
- Real Robot
Architecture Design: Overview

- Central Server (ROS)
- Wireless Network
- Cloud Network (MQTT)

Real World:
- mROS
- Infrastructure
- Sensor
- Real Robot
- Actuator
- AR Device

Virtual World:
- Virtual Robot
- Virtual People
- Virtual Signal
- AI Agent
- Virtual Service
- Virtual/Real Map
- Cloud Server
but Why mROS 2?

- Integration of mROS 2 communication into Hakoniwa!
  - lightweight but direct communication on RTPS
  - mros2-posix can run on general-purpose OSes (even on macOS)
  - support mros2 communication as one of Hakoniwa PDUs!!
Demonstration!!
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Wrapping Up!

• Introduction of Hakoniwa (箱庭)
  - HUB to Everything for Simulation!
    not just a simulator, but also a framework to construct simulators
  - hakoniwa-ros2sim: our past achievement for ROS robot
  - hakoniwa-mros2sim: new simulator for mros2 robot

• Fusion of Virtual and Real weaving by Hakoniwa and mROS 2
  - Integration of mROS 2 into Hakoniwa Communication
  - Expected System in the Future and its Architecture Design

• What’s Next??
  - Open up the future by increasing the adoption in actual development scenes
  - and, enrich documentation, especially in English ;(  

• TOPPERS