”ArkTwin: Distributed Heterogeneous Multi-Agent Simulation Platform” received the Noguchi Award at DICOMO2024(Multimedia, Distributed, Cooperative, and Mobile Symposium).

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Toyota Motor Corporation is developing ArkTwin: distributed heterogeneous multi-agent simulation platform that enables the simulation of a single world by allowing various simulators to exchange necessary information and work together. At DICOMO2024 (Multimedia, Distributed, Cooperative, and Mobile Symposium) organized by Information Processing Society of Japan, a demonstration of ArkTwin was conducted, and it received the first-place Noguchi Award, an honor given to outstanding demonstrations expected to contribute to the industry on June 28th.

Backgrounds

When considering the introduction of "new urban systems" such as smart cities, central urban redevelopment, and new transportation services, the potential impacts can be extensive. If stakeholders are concerned about increasing disadvantages from their respective perspectives, it can make consensus-building difficult. While forming consensus through pilot projects is valuable, it is difficult to implement so frequently because of the high costs involved. Therefore, to conduct multiple impact assessments, it is necessary to use simulations to recreate reality in a virtual space.

To consider the wide-ranging impacts, it is necessary to simulate various elements within the same space. However, constructing these as a single simulator is unrealistic for the following reasons:

- The high difficulty of software implementation
- In cases such as service systems, where there is a competitive relationship, internal flows may not be disclosed

Therefore, it is expected that multiple heterogeneous simulators will collaborate by exchanging state information, including location, to achieve the simulation of a single world.

Technical Overview

Architecture Requirements

Below are the requirements that the platform must meet to enable the collaboration of heterogeneous and multiple simulators.

・**Utilization of Existing Simulators**

To leverage existing, highly reliable simulators that are already widely used by many users, it is essential to connect them with minimal modification.

・**Ease of execution for Various Types and Scales of Simulations**

The types and number of simulators connected will vary depending on the simulation content, so flexible connectivity is required. Additionally, the platform must be capable of conducting large-scale simulations that cover entire cities.

Proposed Architecture

The architecture proposed to meet the above requirements is shown in Figure 1.

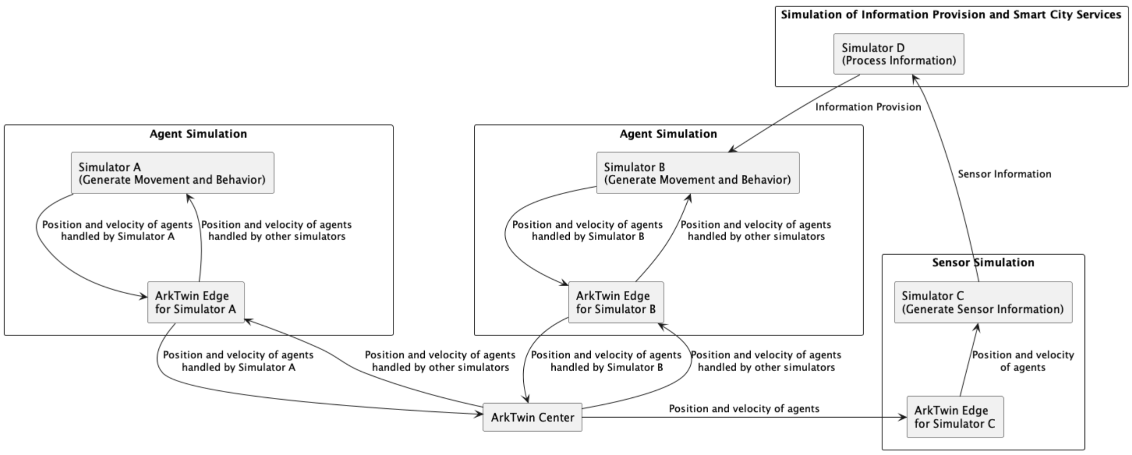

Figure 1. The fundamental architecture

The architecture consists of the following two components:

- **ArkTwin Center**: A central unit that collects and distributes messages output by each simulator.
- **ArkTwin Edge**: A unit that relays communications between a simulator and the ArkTwin Center.

Each ArkTwin Edge is dedicated to one connected simulator.

To enable communication of information from each simulator, all ArkTwin Edge units are connected to the ArkTwin Center. Any information that is not required by all simulators is communicated individually between the simulators themselves.

Figure 2 shows the communication details between a simulator and the ArkTwin Edge.

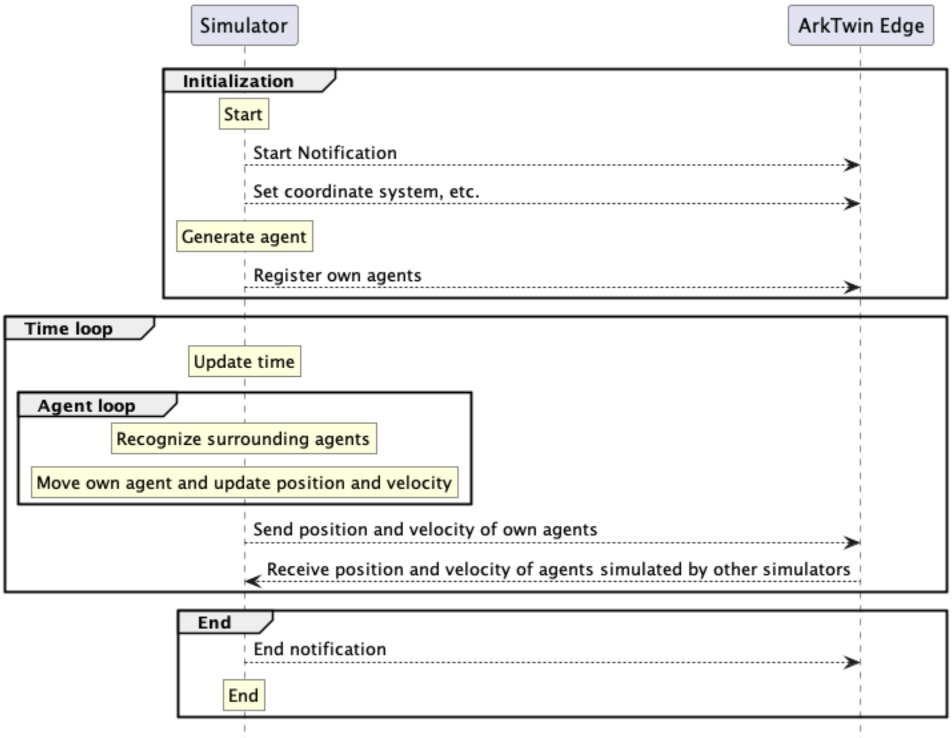

Figure 2. The communication between a simulator and ArkTwin Edge

ArkTwin Edge has the following functions in addition to controlling stream communication:

・**Agent Registration**

ArkTwin Edge registers the agents (individual vehicles, pedestrians, etc.) of the connected simulator with ArkTwin Center and obtain a unique ID. This prevents ID collisions between simulators.

・**Coordinate Transformation**

Each simulator may have different coordinate systems. Therefore, it normalizes the coordinate systems of the connected simulator (origin, coordinate axis assignment, rotation representation, etc.).

・**State Acquisition of Other Simulator Agents**

Each simulator is executed at individual time steps. Therefore, there is no guarantee that the state information of agents at a specific time you want to simulate in your simulator will be available. To address this, it provides a function to interpolate state information received from other simulators to the time step used in your simulator.

Demonstration

At DICOMO2024, we conducted a demonstration the interconnection of the following six types of simulators:

1. A simulator that simulates a single pedestrian operated by a demo participant using a VR device.
2. A simulator that simulates a single wheelchair user operated by a demo participant using a VR device.
3. A simulator that simulates a single vehicle operated by a demo participant using a steering wheel controller.
4. A traffic flow simulator that simulates multiple vehicles.
5. A pedestrian flow simulator that simulates multiple pedestrians.
6. A simulator that generates footage for fixed cameras.

Additionally, Figure 3 shows the configuration of the demonstration system.

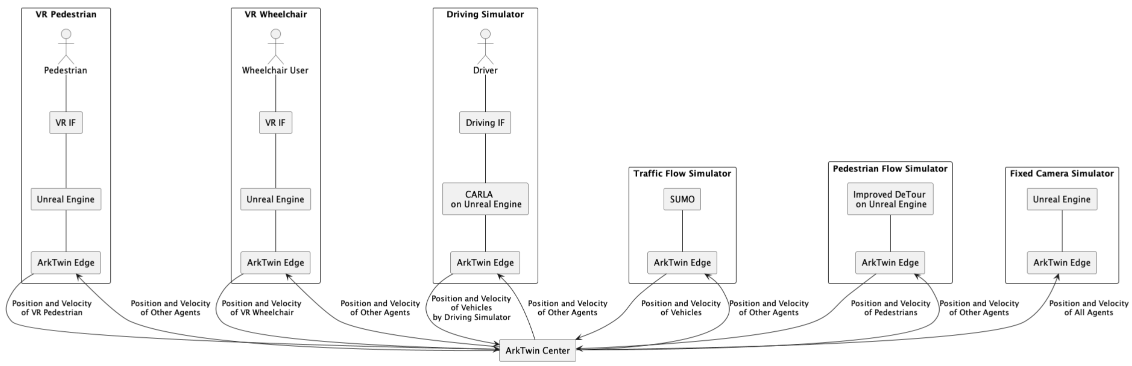

Figure 3. The configuration of the demonstration system

The demonstration conducted

Open Sourcing of ArkTwin

ArkTwin is available as open-source software. It is released under the Apache License 2.0, allowing for commercial use, modification, and distribution. We welcome any contributions, whether it's using ArkTwin, reporting bugs, suggesting new features, or improving the code. For detailed information and usage instructions regarding ArkTwin, please refer to https://github.com/arktwin/arktwin.