Extended Abstract

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Synchrono: A Multi-Agent Simulation Framework for Robotics and Autonomous Vehicle Applications

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Overview: Synchrono is a framework in which dynamic multi-agent simulations can be conducted to understand agent interplay and develop control algorithms in a safe environment. The end goal is to improve function and increase safety [1]. In scenarios in which the development of agents such as autonomous vehicle or robots is faced with testing constraints, an alternative, flexible, and safe environment becomes mandatory. Synchrono is designed to fulfill this desideratum. Synchrono consists of the following elements: i) synchronized geographically distributed participation within the simulation, ii) simulated local communication between agents, iii) physics based simulation, iv) sensor feedback from the virtual environment, and v) utilization of real world data in the virtual world setups.

Agent participation. In order to facilitate geographically distributed participation, the simulation of each agent is conducted on the client side drawing on a thin, efficient server for relaying data over a network that connects the participating agents. The state-sharing server enables agent participation, in which they can passively sense one another and interact with the environment. To this end, the server maintains a world-object, which contains the state representations of all connected clients. When clients update the server with their local agent states, the server responds in turn with the state representations of agents nearby in the world object. A second function of this server is to synchronize the clients' simulations, and remove clients if their simulations are too fast or slow, or if their communication patterns with the server are detrimental to the ability of other clients to simulate.

Agent communication. Synchrono also facilitates agent-to-agent communication that can be used for coordinating actions and data sharing. This message routing capability is used to represent various wireless communication protocols, such as 5G or DSRC. Synchrono facilitates this by routing messages between clients, which determine the receiving agents of these messages. This is a crucial function within this framework as it allows for development of collaborative robots and agents using specific protocols seen in practice.

Physics based simulation. In Synchrono, the physics-based simulation support are provided by Chrono [2, 3]. Chrono provides support for simulating rigid multibody systems with additional support, through modules, for fluid-solid interaction, multicore parallelism, finite element analysis, and vehicles, among others. Support for fully dynamic vehicles as agents within the Synchrono framework is provided through the Chrono::Vehicle module [4].

Sensor feedback from virtual environment. An important aspect of using Synchrono for robotic related simulations is to provide sensor feedback to the control algorithms. This is done through the development of a sensor support module. Basic models of LiDAR, GPS, and IMU are currently available for sensing purposes, which remains an area of active development in Synchrono. Note that lack of accurate sensing limits the capabilities when developing for, and testing edge cases. Further development in this area targets complex noise generation in non-ideal environments (i.e., rain, snow, fog).

Utilization of real world data in virtual world. This development ties in intimately with each aspect of Synchrono as it provides the virtual environment within which all other components reside. The world should include aspects that affect physics, communication, and sensors. For example, when trying to simulate a cluster of agents in the snow, the physics should be adjusted to correspond to falling or settled snow and sensors should perceive objects in the same way those sensors would react with physical snow. The target for this virtual space is to provide these other modules with data obtained from the real world. An example of this can be seen in Fig. 1, which illustrates a section of a virtual world generated from LiDAR, Camera, and GPS measurements on the University of Wisconsin-Madison campus.

Fig. 1: Mesh generated for Synchrono from LiDAR, camera, and GPS measurements, courtesy of Mandli Communications

Demonstration of technology. While there are various applications where Synchrono can be utilized, from collaborative swarm robots to disaster relief scenarios, the target of this demonstration of technology is within the development of self-driving vehicles. The first demonstration shown in the left of Fig. 2 is a "follow-the-leader" convoy driving through Madison. The first vehicle in the convoy is driven via a steering wheel game controller by a student while the other three are autonomous and directed to follow the vehicle in front. To this end, the vehicles rely on GPS, IMU, LiDAR and communication from the lead vehicle. The LiDAR data for the trailing vehicle can be seen plotted on the lower left corner of the image with GPS and IMU overlayed on a map for visualization. The full animation can be see at [5] as video #130.

Another autonomous vehicle simulation was conducted in Synchrono specifically to demonstrate the communication and agent distribution. This simulation, shown in the right of Fig. 2, had 30 autonomous vehicles interacting in the same environment. The vehicles, which are navigating the intersection of University Ave and Park St in Madison, WI, receive DSRC messages from the traffic light indicating the Signal Phase and Timing (SPAT). The autonomous vehicles use this information along with all their sensors (GPS, IMU, LiDAR) to decide when to continue through the intersection while avoiding collisions. Videos of this simulation can be seen at [5] as videos #131 and #132.

Fig. 2: Chrono::Vehicle Left: simulation of follow the leader convoy. Right: simulation of DSRC controlled intersection using 30 autonomous vehicles.

References

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