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Computer Standards & Interfaces 27 (2005) 149–161
COMPUTER STANDARDS & INTERFACES
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Smart Time Management—the unified time synchronization interface for the distributed simulation

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Received 20 January 2004; received in revised form 16 April 2004; accepted 29 May 2004
Available online 26 June 2004

Abstract

Distributed simulation is a widely studied technique for the networked virtual environment. Among existing technologies, High Level Architecture (HLA) establishes a common distributed simulation framework that facilitates the interoperability and reuse of simulation components. However, some HLA services are very low-level and difficult to use, especially when a simulation is designed using a particular time synchronization mechanism. This paper describes an agent interface called Smart Time Management (STM). STM is used to unify the time management services of the time-stepped, event-driven, and optimistic time advancement in HLA specification. The capabilities of the STM include the followings: taking over events timestamp tagging work, maintaining a look-ahead value, and unifying different time advance approaches provided by the HLA Run Time Infrastructure (RTI). In addition, it adopts the time warp mechanism for optimistic simulation. In summary, STM presents a unified and scalable middle layer to allow the user to construct an HLA federation with a unanimous time management interface when solving the synchronization issue. The presented middle layer enables the user to deploy the conservative and optimistic synchronization mechanisms in a unanimous way.

Keywords: Distributed simulation; High Level Architecture; Event-driven; Time-stepped; Optimistic synchronization

1. Introduction

Modeling and analyzing the timing behavior of the distributed simulation are of wide interests in the networked virtual environment. The parallel or distributed simulation refers to the execution of discrete-event simulation programs on a multiprocessor system or a network of workstations [1]. The researches of parallel/distributed simulation focus on how to achieve high-performance simulation while ensuring all events to be parallelly processed and still maintaining their causal relationships [2]. Over the years, two synchronization approaches for the parallel/distributed simulation have been proposed: the conservative synchronization [3,4] and the optimistic synchronization [5,6].

The High Level Architecture (HLA) specification was initiated by the Department of Defense, USA, to support interoperability among distributed simulators.

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0920-5489/$ - see front matter
doi:10.1016/j.csi.2004.05.008

It defines a standard architecture for modeling and simulation of a complex distributed simulation [7]. The HLA standard later becomes the international standard, IEEE 1516, for the distributed simulation. The implementation of the HLA specification [8] in the system side is called Run Time Infrastructure (RTI), whereas the application side is called the federate. Among the supported services of HLA specification, the synchronization mechanism was included in the RTI time management service to ensure the attributes/events sequence among distributed federates. In HLA terminology, each distributed node of a simulation is called a federate. To be more specific, the time management service provides both conservative and optimistic approaches to synchronize different federates within the federation [9]. In HLA terminology, a federation is a simulation that consists of a set of federates. However, it is not an easy task to use these synchronizing services to build a parallel/distributed federation. Even though RTI provides some synchronization interfaces for the distributed federates, several critical design issues must be carefully studied at the developing phase. Different types of federates require distinct synchronization schemes.

Furthermore, the application-specific characteristics of a time-based federate such as the look-ahead value, the communication patterns, checkpoints, etc., may profoundly affect the feasibility of using a specific protocol to simulate a given model. In any given federation, different federates may possess conflict characteristics. For example, a federate can only be effectively simulated by a conservative protocol whereas others may be more amenable to the optimistic method. When we design a synchronized federation, there are many critical federate design issues that must be carefully studied and evaluated, such as the time policies (time-constrained or time-regulating), message ordering definitions (receive-order (RO) and timestamp-order (TSO)), and logical time advance strategies (time-stepped, event-driven, or optimistic), etc. [10,11]. Hence, in order to make accurate design decisions, experiences in the RTI services and distributed simulation technologies are required.

This paper describes a mechanism called Smart Time Management (STM) that presents a unified and unanimous synchronizing scheme for the time management services that were defined in the HLA interface specifications. Furthermore, the STM extends the interfaces with the smart rollback, state-saving, and fossil-collection mechanisms for optimistic federates. This paper first discusses an approach to unify the use of conservative and optimistic time management methods. This approach integrates the conservative and optimistic schemes so that the federate developer can easily achieve the synchronization function regardless of the time policies, message ordering methods, and the logical time advance strategies.

The unified STM agent for the time management interface provided by the RTI is then presented. This agent smartly provides the rollback, state-saving, and fossil-collection management for the optimistic federates. Consequently, the STM agent helps the programmer to develop the optimistic synchronization mechanism like a conservative one.

2. Time management in HLA

The HLA time management service is concerned with the mechanism to advance the simulator's logical time. The time advancement of a synchronized federation is coordinated with the object management service of the RTI so that information is delivered to federates in a causally correct and ordered way.

2.1. Messages order and timestamp

The HLA time management service is strongly related to services of the message exchange, such as attribute updates and interaction exchange. In HLA, there are two general types of ordering messages, which are receive-order (RO) and timestamp-order (TSO). RO messages are simply placed in a FIFO queue, and immediately being eligible for delivery to the federate on their arrival. Whereas each TSO message is tagged with a timestamp by the sending federate and is delivered to the receiving federate in the order of nondecreasing timestamps. The incoming TSO messages are placed in a queue within the RTI and will not be delivered to the federate until the RTI can guarantee that no straggler TSO messages will be received by the receiving federate.

To ensure the received TSO messages are in order, the RTI must compute a Lower Bound of the Time Stamp (LBTS) of the future TSO messages that may be received from other federates. Several algorithms