Simulator X: A Scalable and Concurrent Architecture for Intelligent Realtime Interactive Systems

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ABSTRACT

This article presents a platform for software technology research in the area of intelligent Realtime Interactive Systems. Simulator X is targeted at Virtual Reality, Augmented Reality, Mixed Reality, and computer games. It provides a foundation and testbed for a variety of different application models. The current research architecture is based on the actor model to support fine grained concurrency and parallelism. Its design follows the *minimize coupling and maximize cohesion* software engineering principle. A distributed world state and execution scheme is combined with an object-centered world view based on an entity model. Entities conceptually aggregate properties internally represented by state variables. An asynchronous event mechanism allows intra- and interprocess communication between the simulation actors. An extensible world interface uses an ontology-based semantic annotation layer to provide a coherent world view of the resulting distributed world state and execution scheme to application developers. The world interface greatly simplifies configurability and the semantic layer provides a solid foundation for the integration of different Artificial Intelligence components. The current architecture is implemented in Scala using the Java virtual machine. This choice additionally fosters low-level scalability, portability, and reusability.

Index Terms: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual Reality D.2.11 [Software Engineering]: Software Architectures—Domain-specific architectures, Patterns

1 INTRODUCTION

Software technology is of central importance for real-time interactive systems (RIS), i.e., for VR, AR, MR, and computer games. Current technological challenges are hard- and software diversification as well as concurrency, from small scale parallelization to networking. Simulator X is an evolutionary platform for software technology research in the area of intelligent RIS. The current architecture (see Figure 1) incorporates some well known abstractions and good practices as well as some interesting experimental features:

- Unified concurrency model based on actors [14].

- Shared entity model using a distributed state.

- Component architecture using the concurrency model.

- Functional/OOP approach based on Scala.

- Semantic binding for the integration of AI.

- Generic support for multimodal interfaces.

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This paper concentrates on the first four aspects. After this introduction, we will first discuss related work. The following sections match the Simulator X architecture bottom to top, hence we start with the description of the core system followed by a description of the world interface. Each section includes discussions and reflections of lessons learned which will be summarized in the concluding section alongside some remarks regarding future work.

Figure 1: General architecture of the Simulator X platform. The core system is based on the actor model to realize a distributed state, state observation, and entity model. A semantic layer connects the core system with a world interface which provides a high-level event and component & configuration system as well as a general semantic access scheme.

2 RELATED WORK

A RIS middleware provides a software frame for recurrently required simulation tasks ranging from tracking, input processing, collision detection, physics simulation, Artificial Intelligence (AI), graphics, audio, and haptics rendering, to networking etc. The utilized coupling method is critical with respect to reusability and scalability [10, 25, 18]. Dedicated libraries for certain simulation tasks often require proprietary (1) data representations and (2) execution schemes. For example, a close coupling to scene graph libraries like OpenGL Performer™, Open Inventor, Open Scene Graph, OpenSG [24], or X3D is a source of several drawbacks [6, 2].

Data flow networks are a typical and well established RIS execution scheme, see, e.g., [7, 28, 1, 11, 9, 16]. They are simple to understand but they are also restrictive in their expressiveness [9]. Hybrid execution schemes which additionally incorporate, e.g., procedural elements [9], asynchronous events [16], or messages may cause severe consistency problems [9]. Still, a component-based or even service-oriented approach [5, 21] based on an event system provides reasonable decoupling and usually scales well in terms of networking [8, 13].

Execution scheme and data management are often strongly connected. Here, entity like models have proven to be a highly advantageous, reusable, and scalable representation [22, 16, 27]. Mapping of entities to objects in object-oriented programming (OOP) is straight forward [12] but often links data representation to a given execution scheme using the objects' method interfaces. Simulator X conceptually views entities only as sets of loosely associated

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