A Resolution Converter for Multi-resolution Modeling/Simulation On HLA/RTI

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ABSTRACT

Multi-Resolution Modeling (MRM) represents a real system as a set of models at different resolution in different abstraction levels from the view point of simulation objectives. The main problem for distributed simulation of multi-resolution models is resolution mis-matching in communication between simulators (processes) for different resolution models. Aggregation and disaggregation are methods for conversion of high-to-low resolution and low-to-high resolution, respectively. This paper describes design and implementation of a resolution converter in multi-resolution modeling of discrete event systems and distributed simulation of such models on HLA(High Level Architecture)/RTI(Run Time Infrastructure). A simple multi-resolution queuing model with multi-servers and multi-queues is developed and proved to be correctly behaved.

KEY WORDS: **Resolution Converter, Multi-resolution Modeling/Simulation, HLA/RTI**

INTRODUCTION

The DMSO on-line M&S (Modeling & Simulation) glossary defines resolution as "the degree of detail and precision used in the resolution real word aspects in a model or simulation."[4] MRM represents a real system as a set of models at different resolution in different abstraction levels from the view point of simulation objectives. The main purpose of such modeling is to save computing resources as well as to reduce simulation time at the cost of simulation accuracy. If resolutions of two communicating simulators are different resolution conversion should be made. Aggregation and disaggregation are methods for conversion of high-to-low resolution and low-to-high resolution, respectively.

This paper describes design and implementation of a resolution converter which manages data format converting and time synchronization in multi-resolution modeling of discrete event systems and distributed simulation of such models on HLA/RTI. It can be implemented either within one simulator process or as a separate process. In this paper, we assume that the resolution converter is implemented as a single process which is connected to the DEVS simulator via TCP/IP and it uses

HLA/RTI as a communication tool for data exchange.

Figure 1 shows the proposed architecture for MRMS on HLA/RTI.

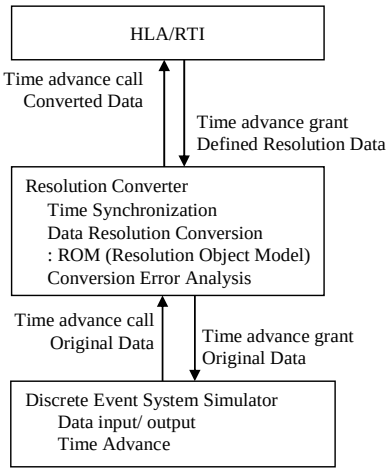

Figure 1 Proposed Architecture for MRMS on HLA/RTI

The paper is organized as follows: Section 2 briefly reviews multi-resolution modeling, High Level Architecture and the simulation interoperation layer [1]. The design of a resolution converter is described in Section 3. Section 4 presents the implementation of the resolution converter. Section 5 shows an example, a simple multi-resolution queuing model with multi-servers and multi-queues. Finally Last section concludes the paper and proposes the future work.

BACKGROUND

HLA & Simulation Interoperation Layer

The HLA is a specification for interoperation among distributed heterogeneous simulations. The standard consists of two parts; Federate Interface Specification and Object Model Template (OMT) [4]. Federate Interface Specification defines essential services. The RTI is an implementation of HLA Federate Interface Specification. OMT is a documentation format for shared objects and message types by which simulators exchange events. OMT is used to describe Federation Object Model (FOM) and Simulation Object Model (SOM).

The Simulation Interoperation Layer manages mapping between HLA services and DES simulation messages used in DEVS abstract simulation algorithm. [1] The main function of the Simulation Interoperation Layer is to provide communication interface between HLA and the DEVS simulator which is to be interoperated with other simulators through HLA services.

Multi-resolution Modeling

Multi-resolution Model is a simulation model which has various levels of resolution. The kinds of multi-resolution modeling can be divided two types when the simulators use resolution conversion: Static vs. Dynamic.

Static multi-resolution modeling is that the resolution level which the objects are simulated is fixed when the simulation is constructed [3]. It does not need resolution conversion because these simulators do not exchange the data when the simulation runs, so this paper will not consider this approach.

Dynamic multi-resolution modeling permits an object to switch levels of resolution during the course of the simulation [3]. This approach can be divided into two types. *Replacement* means that the whole data of one simulator with some resolution level is converted to a different resolution level data format and transferred to the other simulator with that resolution level. The both simulators are mutually exclusive at time.

Interoperation is the data exchange among simulators with different resolution level while the simulation is constructed. For one simulator, before data inputs are accepted from another simulator, it needs to be converted into the resolution level of simulator itself.

MULTI-RESOLUTION CONVERTER ON HLA/RTI

This section describes design of a resolution converter in multi-resolution modeling of discrete event systems and distributed simulation of such models on HLA/RTI.

Data Resolution Conversion

In a dynamic multi-resolution modeling, the data resolution of one simulator needs to be converted to different resolution level. What should be specified in the resolution converter? There are three categories: definition of resolution levels, registration of data with specified resolution, and converting rule.

Figure 2 shows the relation of three categories.

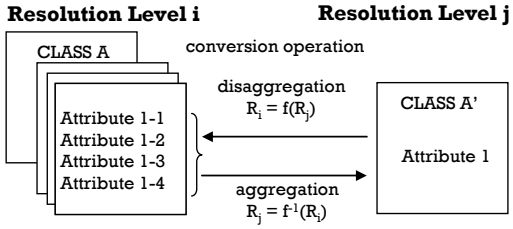

Figure 2 Data Resolution Conversion

For defining the static data format as a resolution level, this paper suggests the Resolution Object Model (ROM). ROM which is analogous to SOM, FOM approach, defines a resolution level, an object class name and attributes for each object group.

```
(Object Group
  (Resolution Level
    (Class Name
      (Object Group ID)
      (Attribute Name  Type  Default-Value)
    )
  )
)
```

Figure 3 Resolution Object Model (ROM) Format

Because the proposed architecture uses RTI as a communication tool, the objects of simulators are converted as a resolution level defined by FOM at first. The simulator of high resolution sends data to converter, and the resolution converter transforms the data to FOM and reverse. Therefore the proposed resolution converter assumes only two resolution levels.

Time Synchronization

In the interoperation, the simulators need to convert data resolution while simulation is constructed. A resolution converter supports time synchronization because simulators have different time resolution levels. Because the proposed architecture is based on HLA/RTI, a resolution converter is designed to manage time synchronization using RTI time management.

Conversion Error Analysis

A typical multi-resolution converting problem is the error which occurs while aggregation and disaggregation. A typical aggregation problem is to summarize various data into one or less data. The aggregated data contains less information; therefore the simulator looses some information in the aggregation process. Disaggregation is a reverse process, i.e. extracting information from low resolution level to high resolution level. In the ideal case, a resolution converter cannot generate error in these processes. The converting functions are defined as $R_i = f(R_j)$ and $R_j = f^{-1}(R_i)$, therefore $R_i = f(f^{-1}(R_i)) = R_i$. But in practical, f^{-1} cannot be the complete reversed function of f because of the information loss. Multi-resolution converting cannot avoid these errors. Developers analyze these error and determines whether within or without a permissible range.

Federation Management

Federation management includes such tasks as creating federations, joining federates to federations observing federation-wide synchronization points, effecting federation - wide saves and restores, resigning federates from federations and destroying federations. These services are usually not considered in each simulator. The multi-resolution converter needs to provide an easy way for users to use these services because it uses HLA/RTI as a communication tool.

IMPLEMENTATION: MULTI-RESOLUTION CONVERTER

KHLAAdaptor library is the implementati -on of core library for the Simulation Interoperation Layer. A resolution converter uses KHLAAdaptor library for supporting HLA/RTI managements, and adds a resolution converting component. A resolution converting component handles conversion among different resolution level.

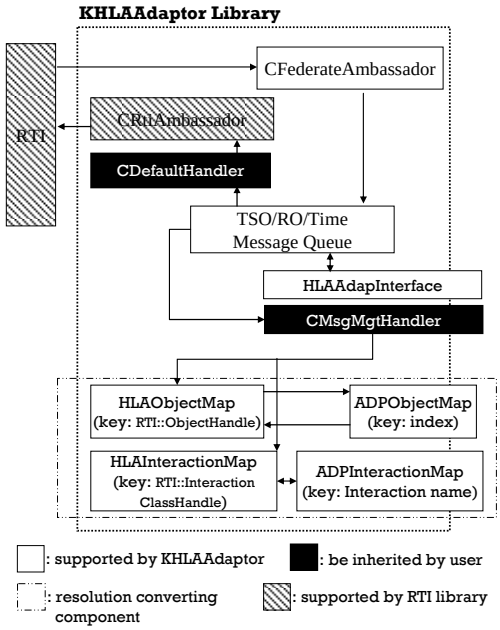

Figure 4 Architecture of KHLAAdaptor

Figure 4 shows the architecture of a multi-resolution converter. This section laid emphasis on the implementation of data resolution conversion. The implementation of time management is explained in [1].

Data Resolution Conversion

The resolution conversion component provides schemes for automatic conversion between two different resolution levels. HLAObject/interaction means the data format defined by FOM and ADPObject/ interaction is described in ROM. Developers need to implement actual conversion functions used in the library.

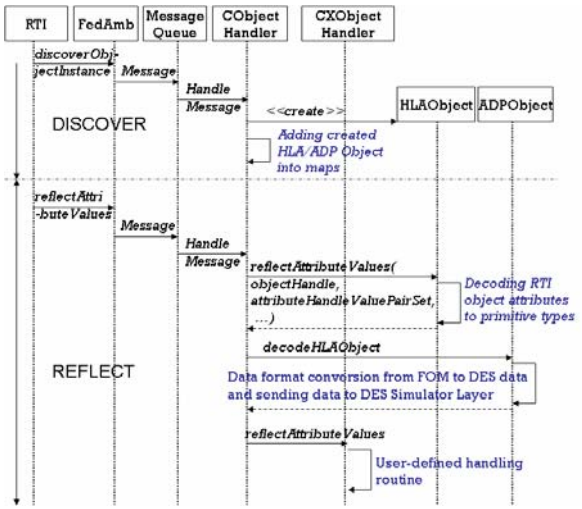

Figure 5 Discover and Ref lect Attribute Values

EXAMPLE: THE MULTI-RESOLUTION GENERATOR-BUFFER-PROCESSOR MODEL

The resolution converter is applied to development of simple multi-resolution queuing model with multiple queues and multiple servers as shown in Figure 6, called MGBP (Multi-resolution Generator-Buffer-Processor) model. The MGBP model is separated as two parts. The GB model generates customer by poisson distribution and sends it when the P model is idle. The P model calculates a waiting time of a customer

by poisson distribution and sends it to the result model.

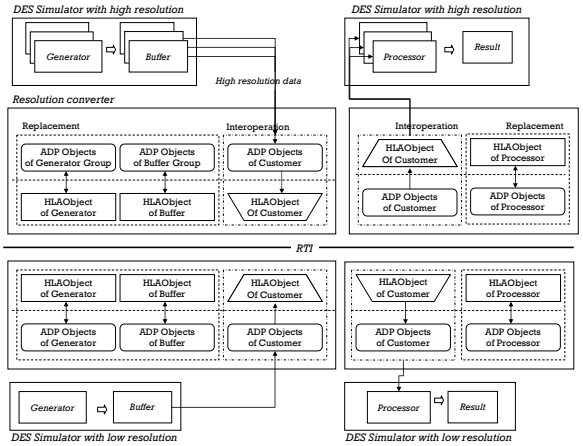

Figure 6 Multi-resolution Queuing Model

The GB and P Models convert resolution level while simulation is run. Figure 7 shows the number of generated messages and interoperated messages.

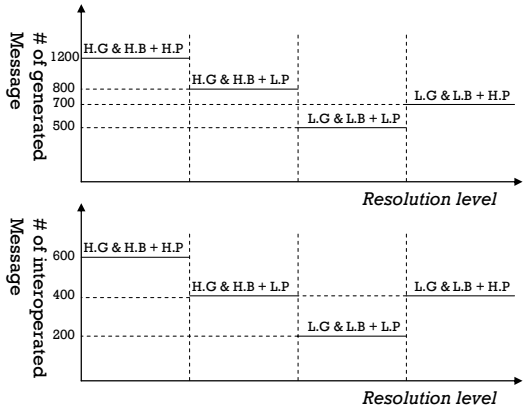

Figure 7 Multi-resolution Simulation Experiment

Because the simulation scale is too small, the MGBP example does not show predominant performance improvement. But the decrease of the message number can be surmised a speedup in the case of an enough large scale simulation.

In the resolution converting process, resolution converters execute resolution converting according as a mathematical equation. The mean parameter r of a low resolution generator is the sum of the mean parameters of high resolution generators. Reversely, the mean parameters m, n and p is equal to the mean parameter r. If m, n and p are different, they cannot be restored in aggregation and disaggregation. But as mathematical equation and experimental result showed, waiting times were identical.

CONCLUSION AND FUTURE WORK

A resolution converter for multi-resolution modeling/simulation on HLA/RTI was designed and implemented. A ROM format is defined for resolution definition of multi-resolution objects, which can be used by conversion functions. Implementation provides an automated environment of a whole resolution conversion process.

This paper only considers a resolution converter on HLA/RTI. But a fixed communication interface sets limits to the utility of a resolution converter. Therefore future research should be aimed at data resolution converting component independent from HLA/RTI.

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