Editorial Paper

FRAMEWORK DEVELOPMENT FOR WEB-BASED SIMULATION APPLIED TO SUPPLY CHAIN MANAGEMENT

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Abstract: The paper proposes a general framework for web-based distributed simulation using High Level Architecture (HLA). Alternative approaches are examined and compared in the context of Supply Chain Management, where effective Decision Support Systems (DSSs) are needed to improve collaboration among stakeholders and increase overall competitiveness. An industrial application is presented to illustrate the benefits of the proposed framework: experimental results show that the proposed approach highly reduces development cost and time, and supports the reuse of existing simulation tools.

Keywords: High Level Architecture, Supply Chain Management, Distributed Simulation, Model Re-Usability

1. INTRODUCTION

Due to the increased complexity of production processes, now involving multiple levels of suppliers and distributed production sites, supply chain management highly depends on the effective modelling of multiple and interdependent production processes. In particular, a new generation of simulation-based Decision Support Systems (DSSs) is needed to improve overall competitiveness and increase collaboration among the Supply Chain stakeholders. Many are the possible development alternatives based on different architectures and techniques. However, critical objectives for the success of the new DSSs are the reduction of development costs and time, and the reusability of pre-existing tools (Bruzzone and Giribone 1998).

Recent work in the Modelling and Simulation (M&S) community shows that High Level Architecture (HLA) is the key to the development of effective distributed simulation, and several ongoing projects support the use of HLA for non-military applications (i.e. Web Integrated Logistics Design, Intelligent Manufacturing System).

For such reasons the authors based their DSS development on the HLA standard. In Supply Chain Management applications decision makers mainly rely on tools developed using simulation packages (i.e AutoMod, Arena, Simple++) and often run their experiments as users with limited programming skills. Considering this characterization of the end-users, the authors performed an experimental analysis on the integration problems associated to the use/reuse of professional packages in HLA federations for the simulation of the supply chain logistic operations (Bruzzone et al. 1999).

The paper summarizes the results of this analysis and proposes an innovative approach for the development of distributed simulation frameworks supporting the HLA integration of new and existing tools. For the purposes of the analysis, the authors developed a set of HLA-based models of the supply chain using different integration approaches. Such models were used as demonstrators to assess and compare alternative integration approaches in terms of different performance indicators, such as, development time, Verification Validation & Accreditation (VV&A), robustness, efficiency, and scalability. The paper describes two of these demonstrators. The first demonstrator consists of a JAVA™-based application integrating an inventory management package and a simulation model developed using AutoMod™. In this application the packages are directly connected using sockets. The second demonstrator proposes an intermediate

structure interfacing HLA to the commercial packages; this latter approach is shown to significantly reduce development time and to simplify VV&A procedures.

The experimental results obtained during the integration and the federation execution tests are very important as they provide actual performance measures for the two approaches in different operating condition (i.e WAN versus LAN). Even more interesting are the experiments aimed at assessing the performance of the federation over a regular Internet connection, because the experiences reported in the literature are mostly related to the WAN infrastructure used for HLA military applications (Kuhl et al., 1998).

2. BUILDING A SUPPLY CHAIN DSS USING JAVA™ SOCKETS

Distributed production requires the integration of management support systems across different manufacturers and production sites to ensure coordinated inventory control and production monitoring (McConnell, 1996; Dewar et al., 1997).

Due to the growing globalization phenomena companies have significantly increased their production outsourcing, thus requiring detailed on line control of production in order to avoid time delays and lost profits. In response to this issue, the authors thought of using the Internet/Intranet resources available in the factory to build an integrated Decision Support System for the detailed control of the production processes.

Typical questions that managers are faced with include:

♦ Can current inventory levels meet the needs of the production schedule?

♦ Will the production deadlines be met?

♦ Can the Production process can be improved?

In a centralized production environment these questions may be answered linking the EDI to a simulation model of the whole production process. In a distributed production environment the relevant information needs to be retrieved from the production network first, and then used to update the simulation database (Geraghty et al., 1999).

Using JAVA™ Sockets the authors developed an integrated system capable of monitoring inventory

levels. Any variation in inventory levels is automatically uploaded into the simulation model of the production process (built in AutoMod™). The proposed architecture integrates a server tool, which monitors inventory levels as well as production scheduling parameters and makes this information fully available to the client application through an ordinary Internet/Intranet connection. The transfer of information over the Internet requires security procedures to protect the data from unauthorized users. Double password authentication and data encoding procedures were defined for this purpose.

The implemented system is currently in use in a company producing hydraulic devices for a locomotive manufacturer and shows great potential for the improvement of production performance. In this application the simulation process is still centrally located at the outsourcer's site, while the inventory management system is distributed over the Internet/Intranet.

3. HLA AS SUPPLY CHAIN MODELLING FRAMEWORK

Interoperability and reusability are important features of the simulation models developed in compliance with the HLA paradigms. In reality, the vast majority of the simulation tools currently in use are not HLA compliant, therefore it is practically impossible to reuse existing models as HLA federates. These considerations, along with a certain resistance to replacing existing tools, constitute major barriers to the development of HLA federations outside military application contexts. In addition, existing simulation models are usually difficult to integrate into a federation because they have often been implemented using different simulation languages or packages (i.e. Arena™, AutoMod™, Simul8™, Witness™). They may also have been developed at different times and thus they could be even more difficult to integrate.

To overcome these objective barriers, the authors propose an innovative approach based on sockets to make virtually any simulation model HLA-compliant, as long as the model can be accessed using the language in which client and server sockets are developed.

The integration of the system in the JAVA™ environment, based on the DMSO RTI1.3v7 run time infrastructure, is discussed in the paper along with its application to an industrial case.

4. INTEGRATING EXISTING SIMULATION MODELS IN HLA

Today's market offers numerous simulation languages defined HLA-compliant. However, none of them provides simple drag and drop features to develop simulation federates. Drag and drop simulation environments offer the unquestionable advantage of reducing development time and costs. Simulation tools such as AutoMod™, Arena™, Simul8, Witness, and ProModel™ offer such features and can be used to obtain quick-response simulation models in relatively short times.

The implementation of complex simulation models according to the HLA paradigms not only has the major advantage of dividing the implementation processes into the development of several self-contained simulation models, but also that of ensuring inter-operability among such models. This way, different stakeholders may develop their own federate models using their own tools and simulation languages. From a practical standpoint this represents the most important incentive for the application of HLA to supply chain management.

Let us consider, for instance, the situation in which the capacity of the main contractor does not absorb the entire production of the subcontractors. In this case the development of a single simulation model, integrating the production processes of both the contractor and the subcontractors, may force the subcontractors to share information about their production processes, which they would rather keep confidential. Specifically, the subcontractors may not want to reveal how the market shares are distributed among their customers or, more importantly, that there may be a privileged customer. HLA effectively addresses this issue because the different subcontractors can develop their models internally and share, as federates, only the information that they consider relevant to the federation. This way, the organisation of each subcontractor is entirely protected: information may be internally accessed under secure conditions, while only the "external behavior" is shared with the other federates.

At present, HLA ensures interoperability only for newly implemented simulation models that were specifically developed as HLA federates. With the innovative approach proposed by the authors, simulation models developed prior to the introduction of HLA can be reused and new models developed using simple drag and drop tools,

provided that they can exchange information through socket ports.

5. THE HORUS GENERAL ARCHITECTURE

Any simulation model can be linked to the HORUS package and transformed into a HLA federate, as long as the model is capable of sending and receiving messages over socket ports, and its time advancement mechanism can be controlled from an external routine. In fact, the HORUS package incorporates all the HLA specifications required to correctly execute the federation and map the entire life cycle of the HLA objects using socket ports.

Horus consists of an application developed in the JAVA™ environment and incorporates the DMSO RTI1r2v4567 technology. It also contains the specifications to act as federate ambassador, controlling the federation declarations and monitoring the federation execution.

The HLA specifications included in the HORUS package are highly general in nature, therefore, the integration of a simulation model into the federation is reduced to the definition of the socket ports needed to map the attributes of the HLA objects required by the simulator. The time advancement mechanism includes a scope window to be defined by the user and a socket port that can communicate to the model the time advancement authorization or the wait condition.
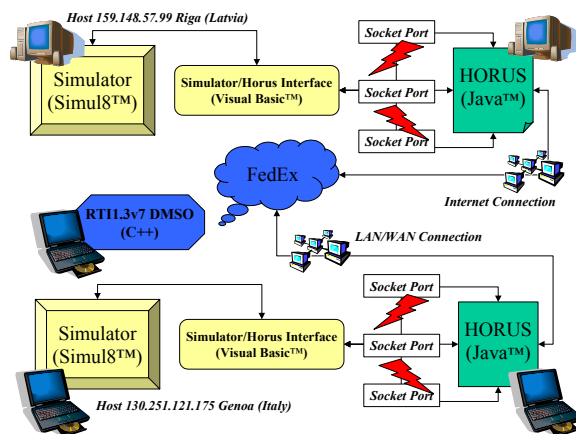

Figure 1: The General Architecture

Figure 1 illustrates the schematic of a HORUS application for the integration of simulation

federates. In this architecture the simulation tools exchange information with a module built in Visual Basic that, in turn, uses socket ports to communicate with Horus. The state variables of the simulation model are mapped onto a structure called the HLA object. Each simulation variable corresponds to an HLA attribute of this object. The state variables are first published by the Horus setup function and continuously updated during the simulation. These updates are sent to the Visual Basic module that records them on the Horus sockets. Writing on the Horus server sockets triggers the update attribute method on the RTI ambassador that will then call the reflect attribute method on the Horus federate ambassador. With the reflect attribute event, Horus decodes the value of the attributes and transmits them through the socket port to the VB simulation module.

This way, the simulator's time advancement may be controlled and the exchange of information between the simulation federates and the RTI, according to the HLA specifications, is ensured.

6. SIMULATION TIME MANAGEMENT

Strictly conservative time management (i.e. both time constrained and time regulating), controls the time advancement of each simulation model starting from the federation execution. The procedure is indicated in figure 2.
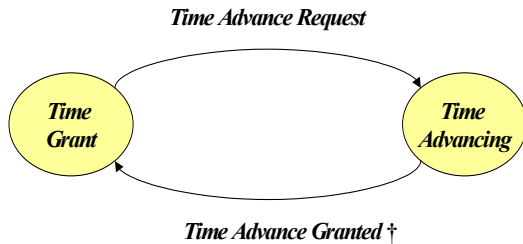
Figure 2: The HLA Time Advancement Process

This process may occur at constant time intervals or through discrete event management. Strictly conservative (i.e. both time regulating and time constrained) and event-driven time management is implemented at the individual federate level.

In order for Horus to harmonize the simulation times of the different federates, constant interval time

management was adopted based on user-specified time advancement steps. According to this approach, all the events occurring during a given time interval become effective at the end of that interval and only then they may be acknowledged by the federation. This way, multiple time scales are defined: one for the federation as a whole, and one for each single federate, as shown in the schematic of figure 3.
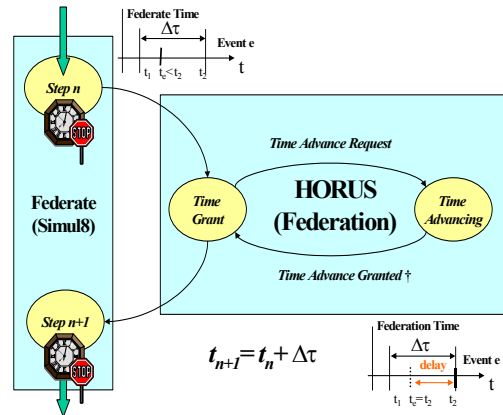
$$t_{n+1} = t_n + \Delta\tau$$

Figure 3: The HORUS Time Advancement Process

7. SHIIMA: AN INDUSTRIAL APPLICATION

The supply chain of an actual computer hardware manufacturing process, was used as an example application context to test the new methodology. This includes a PCs manufacturing company with two levels of sub-suppliers and 72 possible product configurations.
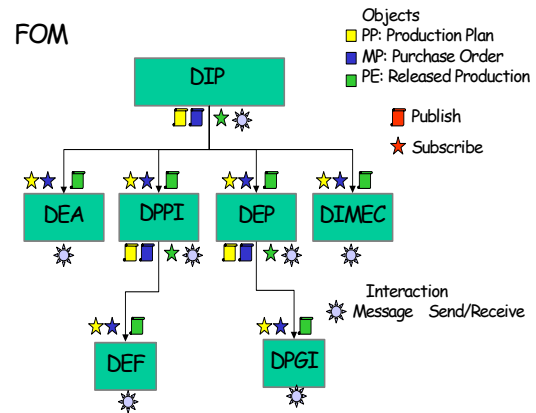
Figure 4: The SHIIMA Federation Objects

The model of each production unit was implemented using a simulation language suited for the representation of the M/M/1 conceptual model (i.e. Single Server Queue) with event-driven time management (Banks et al., 1996; Lorenz, 1993).

In order to ensure the secure transfer of confidential data over the Internet network, each communication is encoded using a simple substitution method.

The different federates are subscribers of different objects through an attribute, namely an identification code, which enables the decoding algorithm, if the code matches the one of the designated federate. The same way, federates may exchange messages with one-another in the form of encoded interactions secured by a receiver identification code.

The encoding system has multiple-level decoding keys to define messages and objects that can be accessed by a single federate or, alternatively, by several federates, if the information is relevant to a larger number of federates. It was decided not to let the publication/subscription procedure carry out message redistribution tasks directly, to prevent the federates from accessing attributes not directed to them and, thus, from obtaining confidential information.

Three classes of objects were defined for this application. These include: Production Plan, Purchase Order, and Released Production. The details of their attribute structure are defined in the following.

OBJECT: Production Plan
Attributes:
Code   [String]
Progressive   [no.]
Delivery Date   [Week]
Product Type   [CodeItem]
Quantity   [Number]
Price   [USD/Number]
Penalty   [USD/ Week Delay]

OBJECT: Purchase Order
Attributes:
Code   [String]
Progressive   [Number]
Delivery Date   [Week]
Product Type   [CodeItem]
Quantity   [Number]
Price   [USD/Number]
Penalty   [Week Delay]
Release Date   [Week]

OBJECT: Released Production
Attributes:
Code   [String]
Period   [Week]
Product Type   [CodeItem]
Product Quantity   [Number]
Product Difference [Number]
Delay   [Weeks]

8. SHIMA EXPERIMENTS AND RESULTS

The SHIMA federation provided the context for two sets of experiments: the first set of experiments was conducted integrating the federation (main contractor, 4 first-level suppliers and two second-level suppliers) on a LAN network in order to check, validate and test the federation itself. The analysis focused on the relationship between the simulated times and the wall clock times, for each federate considered as a stand-alone application and as part of in the federation, respectively (RSWSA- Ratio between Simulation time and Wall clock time in Stand Alone, RSWLA- Ratio between Simulation time and Wall clock time on LAN).

The second set of experiments involved the integration of the federation over the Internet network to link geographically distributed federates. In this case the RSWWA (Ratio between Simulation time and Wall clock time over WAN) relationships were measured. Such relationships are highlighted in the following formulas while the results are shown in table 1.

Table 1: HORUS Time Ratios

Parameter			
	RSWSA	*RSWLA*	*RSWWA*
n° PCs			
1	0.01	-	-
2	-	0.12	0.25
3	-	0.18	0.38
7	-	0.26	0.44

The tests were conducted on a 400 MHz PC using Windows NT service pack 5. The 2-PC configurations were obtained locating the RTIExec processes and the Main Contractor federate on one PC and all the other federates on the other one.

The 3 and 7-PC configurations were obtained assigning one computer to each level of the supply chain (Main Contractor, Sub- Level One and Sub-

Level Two) the first case, and one computer per federate in the second case. The Internet network was used to test the WAN integration with computers located in Riga (Latvia) and Savona (Italy), without particular routing requirements.

9. CONCLUSION

The paper proposed a methodology to integrate any existing or newly developed simulation model into a HLA federation, provided that the tool is developed in a language/package capable of exchanging information over socket ports. A demonstrator, the HORUS package, was developed to test and validate the methodology. Integration experiments involved simulation models developed using medium (ARENA™) and low-level (SIMUL8™) tools to demonstrate how easily small and medium-sized enterprises may implement and benefit from distributed simulation architectures. Horus has been extensively used in application to the detailed modeling of the supply chain for commercial vehicles manufacturing. Important results were observed in this application: both development costs and time to market were significantly reduced.

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