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TNO report

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Integrating Training Simulations and e-Learning Systems: The SimSCORM platform

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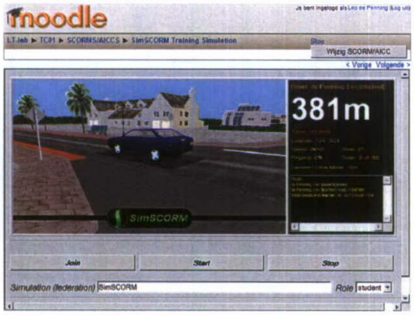
Integratie van Training Simulaties en e-Learning Systemen: Het SimSCORM platform

Een flexibel en generiek platform voor de integratie van HLA gebaseerde trainingsimulaties met SCORM gebaseerde e-learning systemen.



Probleemstelling

CLSK heeft TNO D&V, locatie Soesterberg, gevraagd om binnen het doelfinancierings-programma V406 na te gaan of het mogelijk is om op een gestandaardiseerde manier trainingssimulatoren te koppelen met e-learning systemen, iets wat tot nu toe een moeizame en kostbare zaak is.

Beschrijving van de werkzaamheden

Op basis van een analyse van relevante standaarden op het gebied van simulatie-systemen en e-learning systemen, is een benadering gekozen op basis van de standaarden HLA en SCORM om een efficiënte systeemkoppeling mogelijk te maken. Deze benadering is geïmplementeerd in een prototype platform, genaamd SimSCORM en getest middels een eenvoudige leermodule die draait in een SCORM compliant e-learning systeem.

Resultaten en conclusies

De gekozen benadering blijkt een dynamische en flexibele koppeling te bieden om elk simulatie- en e-learning systeem te koppelen dat voldoet aan de HLA en SCORM standaarden, zonder dat daarvoor aanpassingen nodig zijn. Dit maakt het mogelijk om middels het SimSCORM platform een virtuele taakomgeving (de simulatie component) snel en goedkoop te combineren met gedistribueerd leren en leerlingvolgfaciliteiten (de e-learning component). Dit bevordert onder andere het uitvoeren van gezamenlijke simulatieoefeningen (desnoods gedistribueerd), real-time evaluatie van leerprocessen, team training en de inzet van virtuele instructeurs.

Toepasbaarheid

De koppeling die middels technische standaarden in geïmplementeerd in het SimSCORM platform, maakt het mogelijk om de technische, onderwijskundige en economische voordelen van beide soorten systemen met elkaar te combineren.
Op deze wijze kan tegen minder kosten meer en beter opgeleid worden.

PROGRAMMA	**PROJECT**
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Programmaleider dr. J.E. Korteling, TNO D&V	Projectleider dr. E.W. Boot, TNO D&V
Programmatitel Innovatieve Opleidings- en Trainingsconcepten voor Defensie	Projecttitel SimSCORM
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Frequentie van overleg Met de programma/projectbegeleider werd 5 maal gesproken over de invulling en de voortgang van het onderzoek.	Projectteam ir. H.L.H. de Penning dr. B. Kappe

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Samenvatting

Vanuit een technologisch, onderwijskundig en economisch perspectief zijn trainingsimulatoren en e-learning systemen altijd twee gescheiden werelden geweest. Op dit moment is er een behoefte om deze werelden samen te voegen. Dit zou het mogelijk maken de onderwijskundige kennis en ervaring uit de e-learning community te combineren met de mogelijkheden van operationele training met simulatoren.
Tot nu toe is deze integratie nooit echt gerealiseerd, vanwege de hoge kosten en complexiteit van het koppelen van trainingsimulatoren en e-learning systemen zoals Leer Management Systemen (LMS). Door de recente, snel groeiende acceptatie van technische standaarden voor zowel simulaties (namelijk HLA) en e-learning (namelijk SCORM) wordt deze integratie echter eenvoudiger en goedkoper.

TNO heeft de integratie van simulatie- en e-learning systemen onderzocht en een benadering hiervoor ontwikkeld, gebaseerd op het gebruik van *de facto* standaarden HLA en SCORM. Om deze benadering te testen is het SimSCORM platform ontwikkeld. Dit SimSCORM platform biedt een dynamische integratie van beide soorten systemen. Hoewel meerdere partijen dit probleem bestuderen, heeft TNO gekozen voor een kenmerkende en flexibele oplossing. In TNO's benadering wordt elke leertaak in een LMS benaderd als een aparte simulatiecomponent, met een eigen relatie met de HLA simulatie. Deze aanpak maakt tweerichtingsverkeer van informatie, in real-time, mogelijk tussen één of meerdere simulatoren en de leertaak die actief is in de LMS. Elke willekeurig LMS, dat voldoet aan de SCORM standaard, kan gebruikt worden voor het bijhouden, evalueren en beheren van leerresultaten, evenals voor het maken en opstarten van simulatorscenario's. Het gebruik van het SimSCORM platform bevorderd het uitvoeren van gezamenlijke simulatieoefeningen (met deelname desnoods op afstand), real-time evaluatie van leerprocessen, team training en de inzet van virtuele instructeurs, zonder dat aanpassingen aan de simulator of LMS nodig zijn, mits ze voldoen aan respectievelijk HLA en SCORM standaarden.

Summary

From a technological, pedagogical, and commercial perspective, the world of training simulators has always been separate from the world of e-learning. There is a need, however, to merge both worlds. This would allow the pedagogical capabilities of the e-learning community to be combined with the operational training capabilities of simulators. Until now, this integration was held back due to the high cost and complexity of connecting training simulators with e-learning tools such as Learning Management Systems (LMSs). With the recent, rapidly growing adoption of standards for both simulation (e.g., HLA) and e-learning (e.g., SCORM), integration can now be achieved much easier and at a lower cost.

TNO has studied the integration of e-learning and simulation and developed an approach based upon integration by means of *de facto* standards in both worlds.
The SimSCORM platform was built as a proof of concept of this approach.
The SimSCORM platform provides a dynamic integration of e-learning systems and training simulators. Although not a unique effort, TNO has chosen a rather distinctive and flexible approach. In this approach, each learning task in the LMS is treated as a separate simulation component, which has its own direct link to the HLA simulation. This integration allows real-time, two-way interaction between one or more simulator(s) and the active learning task running in the LMS. The LMS, which can be any LMS as long as it is SCORM compliant, can be used for tracking, evaluation, and administration of training results, as well as for configuring and starting scenarios for the simulator.
As a result, the SimSCORM platform enables cost-effective reuse of expensive simulator features in e-learning settings, joint training simulations, real-time assessment using SCORM objectives, team training, and requires no adaptations to the simulator or LMS as long as they are respectively HLA and SCORM compliant.

Contents

1 Introduction

Today's simulators can provide learners with powerful and realistic learning environments; whereas e-learning systems provide them with interactive, mostly theory-directed lessons based on multimedia modules. Integrating both kinds of systems will have considerable advantages, from a pedagogical, technical, and organizational perspective. But what are exactly the differences between training simulations and e-learning systems?

1.1 Training Simulators

Training simulators are dedicated and immersive learning environments that provide a high level of realism in visualization and interaction. Examples are flight simulators that train pilots or process simulations of a plant for training operators. Mostly, training simulators have a built-in Learning Management System (LMS) for tracking interactions with learning content and providing instructional content by means of an Intelligent Tutoring System (ITS) or Virtual Instructor (VI) for assessment, feedback, and management of training results. A disadvantage, however, is that these LMSs are mostly built specifically for a certain simulator or simulation domain and therefore lack interoperability of learning and instruction content. This means both types of content will require a costly reengineering for each new simulator and/or LMS.

1.2 E-Learning Systems

E-learning systems are (mostly) web-based learning environments that provide distributed learning, independent of time of place. Based upon profiles of each learner, certain multimedia modules will be offered and the resulting learning processes and evaluation tests will be tracked, administrated, and reported. Mostly, e-learning systems are either LMSs for managing learning processes, Learning Content Management Systems (LCMSs) for managing learning content, or a combination of both. Note that these L(C)MSs are domain independent, and widely available as Commercial of the Shelf (COTS) or Open Source (OS) applications. Due to a widespread compliancy to e-learning standards, almost all e-learning systems are interoperable with each other.
A disadvantage, however, is that these e-learning standards are not really directed towards virtual environments, team training, and real-time assessment.

1.3 Integration benefits

Integrating training simulators and e-learning systems will result in a number of pedagogical, technical, and organizational advantages.

1.3.1 Pedagogical

With the introduction of new learning methods such as problem-based, competency-based or task-directed learning, the importance of meaningful integration of practice and theory, in both learning and evaluation, is becoming increasingly important. From a learner's point of view, a powerful learning environment should provide easy and seamless integration of practicing realistic learning tasks and studying theory that is supportive to that learning task.

1.3.2 *Technical*

Training simulators are traditionally strong in providing a fully interactive, multi-person (for team training), multi-modal task environment, with often excellent, real-time tracking of task performance. E-learning systems are traditionally strong in providing standardized and relatively cheap L(C)MS functionalities such as (a) managing interactions with learning content (e.g. tracking, administration, reporting) and (b) managing learning content (e.g. storing, delivery, maintaining) , and (c) providing instructional content (e.g. instructions, feedback, assessment), where and if necessary distributed in space and time. If training simulations and e-learning systems are interoperable and can make reuse of each others functionalities, significant design, development, implementation and maintenance time and costs can be saved.

1.3.3 *Organizational*

For both training simulators and e-learning systems, creating lessons (in the simulation domain often called scenarios or scripts) is labor intensive work typically done by highly specialized educational designers. A lesson will define the learning task by setting the parameters of the environment, roles, entities, and activities, but also the instructional assessment (in terms of timing, accuracy, safety, success, etcetera) on which a virtual instructor will operate. Although training simulation lessons and e-learning lessons may take place in the same curriculum and may adhere to the same pedagogical models, they are mostly built by different designers, using different editors and different design languages and implemented in different formats. Integration will improve the interoperability and reuse of these valuable lessons between training simulations and e-learning systems. Also, high level (and therefore less simulation domain dependent) lessons can be created before the actual training simulation is introduced, because generic e-learning editors can now be used instead of waiting for the proprietary simulation editors. Another benefit is the positive impulse it will provide towards standardization of user interfaces (e.g., same operation of editors for both types of systems) and technical and pedagogical terms (e.g., lessons versus scenario's, learning task versus case), providing more transparency for all stakeholders. Finally, performance evaluation can be standardized, as the same criteria, methods and technologies can be used for certifying and accreditation of training simulations, e-learning systems, and their learning content.

Integration, however, will not be simple. There are many different types of training simulators and e-learning systems, based upon different – often proprietary – technologies, structured according to different object-oriented approaches, embedded in different types of ICT infrastructure, and implemented according to different pedagogical models. And, last but not least, simulation and e-learning are separate communities with different origins, research interests and developers.

1.4 Integrating standards

To overcome this problem, several R&D efforts have been made to integrate the e-learning and simulation worlds via technical standards. The most relevant standards-based effort is made within the SCORM-Sim Study Group of the Simulation Interoperability Standards Organization (SISO, see http://www.sisostds.org), where several manufacturers and research organizations elaborate and explore the benefits of coupling SCORM [1] compliant LMSs with training simulations via widely used standards such as the HLA [2]. Both standards will be presented in Chapter 2.
The benefits of using these standards are the improved interoperability between different

simulation environments and LMSs and better reusability of simulation components and learning content. Furthermore standardized and well-defined interfaces will improve the way of working, since development and research effort can easily be divided between the learning content, LMS and simulation developer, and their supporting communities. It will also allow developers and researchers to focus on their area of expertise and integrate solutions with third party LMSs, simulators and or learning content. This is important because today's, powerful learning environments require the integration of realistic simulation, authentic task environments and typical e-learning capabilities such as managing learning content and learning processes.

The Royal Netherlands Air Force (RNLAF) has asked TNO to investigate the advantages and disadvantages of the integration of e-learning and simulation and develop a prototype to demonstrate the capabilities of such a combination.

In this report, a standards-based integration of training simulators with e-learning systems is presented. First, the SCORM and HLA standards, the standards on which the integration is based, are discussed. Then, existing approaches and the approach of TNO in integrating training simulators with e-learning systems is presented. In this context, the SimSCORM platform that is created to demonstrate this approach is introduced. This demonstration uses a learning task in the car driving domain as an example. Finally, conclusions are drawn with respect to the technical and pedagogical advantages of TNO's approach for both the simulator and the e-learning community, and recommendations for future research are described.

2 Standards for simulation and e-learning

This section explores HLA and SCORM, which are the de facto standards in the simulation and e-learning domains. These standards are the basis for TNO's approach in integrating training simulations and e-learning systems, and therefore briefly explained.

2.1 High Level Architecture (HLA)

The High Level Architecture (HLA) [2] is a general purpose architecture for distributed computer simulation systems. Using HLA, computer simulations can communicate to other computer simulations regardless of the computing platforms. Communication between simulations is managed by a Run-Time Infrastructure (simulation) (RTI).
The HLA consists of the following components:

- Interface Specification. The interface specification document defines how HLA compliant simulators interact with the Run-Time Infrastructure (simulation) (RTI). The RTI provides a programming library and an application programming interface (API) compliant to the interface specification.
- Object Model Template (OMT). The OMT specifies what information is communicated between simulations and how it is documented.
- HLA Rules. Rules that simulations must obey to be compliant to the standard.

Common terminology is used for HLA. A HLA compliant simulation is referred to as a federate. Multiple simulations connected via the RTI using a common OMT are referred to as a federation. A collection of related data sent between simulations is referred to as an object. Objects have attributes (data fields). Events sent between simulations are referred to as interactions. Interactions have parameters (data fields).

2.1.1 Interface specification

The interface specification is object oriented. Many RTIs provide APIs in C++ and the Java programming languages. The interface specification is divided into service groups:

- Federation Management.
- Declaration Management.
- Object Management.
- Ownership Management.
- Time Management.
- Data Distribution Management.
- Support Services.

2.1.2 Object Model Template (OMT)

The object model template (OMT) provides a common framework for the communication between HLA simulators. OMT consists of the following documents:

- Federation Object Model (FOM). The FOM describes the shared object, attributes and interactions for the whole federation.
- Simulation Object Model (SOM). A SOM describes the shared object, attributes and interactions used for a single federate.

2.1.3 *HLA rules*

The HLA rules describe the responsibilities of federations and the federates that join:

1. Federations shall have a HLA Federation Object Model (FOM), documented in accordance with the HLA Object Model Template (OMT).
2. In a federation, all representation of objects in the FOM shall be in the federates, not in the run-time infrastructure (RTI).
3. During a federation execution, all exchange of FOM data among federates shall occur via the RTI.
4. During a federation execution, federates shall interact with the run-time infrastructure (RTI) in accordance with the HLA interface specification.
5. During a federation execution, an attribute of an instance of an object shall be owned by only one federate at any given time.
6. Federates shall have an HLA Simulation Object Model (SOM), documented in accordance with the HLA Object Model Template (OMT).
7. Federates shall be able to update and/or reflect any attributes of objects in their SOM and send and/or receive SOM object interactions externally, as specified in their SOM.
8. Federates shall be able to transfer and/or accept ownership of an attribute dynamically during a federation execution, as specified in their SOM.
9. Federates shall be able to vary the conditions under which they provide updates of attributes of objects, as specified in their SOM.
10. Federates shall be able to manage local time in a way that will allow them to coordinate data exchange with other members of a federation.

2.1.4 *HLA Standards*

HLA is defined under IEEE Standard 1516 and consists of several substandards:

- IEEE 1516-2000 - Standard for Modelling and Simulation High Level Architecture - Framework and Rules.
- IEEE 1516.1-2000 - Standard for Modelling and Simulation High Level Architecture - Federate Interface Specification.
- IEEE 1516.1-2000 Errata (2003-oct-16).
- IEEE 1516.2-2000 - Standard for Modelling and Simulation High Level Architecture - Object Model Template (OMT) Specification.
- IEEE 1516.3-2003 - Recommended Practice for High Level Architecture Federation Development and Execution Process (FEDEP).
- IEEE 1516.4-2007 - Recommended Practice for Verification, Validation, and Accreditation of a Federation an Overlay to the High Level Architecture Federation Development and Execution Process.

Prior to publication of IEEE 1516, the HLA standards development was sponsored by the US Defence Modelling and Simulation Office. The final version of the standard was known as HLA 1.3. Other versions (including HLA's predecessor DIS) are described in the next sections.

2.1.4.1 *Distributed Interactive Simulation (DIS)*

This standard is the predecessor of the HLA standard and was developed over a series of 'DIS Workshops' at the Interactive Networked Simulation for Training symposium, held by the University of Central Florida's Institute for Simulation and Training (IST). The standard itself is very closely patterned after the original SIMNET distributed interactive simulation protocol, developed by Bolt, Beranek and Newman (BBN) for

Defence Advanced Research Project Agency (DARPA) in the early through late 1980's. In the early 1990's, funding and research interest for DIS standards development decreased following the proposal and promulgation of its successor, the High Level Architecture (HLA, initially entitled DIS++), in 1996. HLA was produced by the merger of the DIS protocol with the Aggregate Level Simulation Protocol (ALSP) designed by MITRE. A major advantage of HLA was the introduction of a flexible object model (defined by the OMT), whereas DIS uses a fixed object model.

2.1.4.2 STANAG 4603

HLA (in both the current IEEE 1516 version and its ancestor '1.3' version) is the subject of the NATO draft standardization agreement (STANAG 4603) for modelling and simulation: Modelling and Simulation Architecture Standards for Technical Interoperability: High Level Architecture (HLA).

2.1.4.3 DLC API

SISO has developed a complementary HLA API specification known as the Dynamic Link Compatible (DLC) API. The DLC API addresses a limitation of the IEEE 1516 and 1.3 API specification, whereby federate recompilation was necessary for each different RTI implementation.

- SISO-STD-004-2004 - Dynamic Link Compatible HLA API Standard for the HLA Interface Specification Version 1.3.
- SISO-STD-004.1-2004 - Dynamic Link Compatible HLA API Standard for the HLA Interface Specification (IEEE 1516.1 Version).

2.1.4.4 HLA-Evolved

The IEEE 1516 standard is currently being revised under the SISO HLA-Evolved Product Development Group. The revised IEEE 1516-200x standard is expected to include current DoD standard interpretations and the DLC API. Other major improvements include:

- Extended XML support for FOM/SOM, such as Schemas and extensibility.
- Fault tolerance support services.
- Web Services (WSDL) support/API.
- Modular FOMs.
- Update rate reduction.
- Encoding helpers.
- Extended support for additional transportation (such as QoS and IPv6).
- Standardized time representations.

2.2 Shareable Content Object Reference Model (SCORM)

The Shareable Content Object Reference Model (SCORM) [1], is a compilation of technical specifications for web-based e-learning. The SCORM standards are governed and published by the Advanced Distributed Learning Initiative (ADL). Among SCORM goals are to enable interoperability, accessibility and reusability of web-based learning content for industry, government, and academia. Where HLA has its focus on enabling simulators to be standardized and linked, SCORM has its focus on pedagogical aspects, and on sharing learning content.

SCORM consists of the following principal components:

- *Content Aggregation Model (CAM):* The CAM describes the types of content objects used in a content aggregation: how to package those content objects to provide successful exchange from system to system, how to describe those content objects using metadata to enable search and discovery, and how to define the sequencing rules for the content objects to complete the design of the learning experience. The CAM enables consistent labelling, packaging, storing, exchange and discovery of content objects.
- *Run-Time Environment (RTE):* The RTE specification describes the requirements that are imposed on a LMS to ensure the conditions that allow for interoperability of content across different LMSs (i.e., a standardized content launch process, standardized methods of effecting communication between content and LMSs and standardized data model elements used for passing information about the learner's interactions with the content). The RTE covers the requirements of SCOs and their use of a standard communication mechanism as well as the data that can be transferred to and from the LMS using this communication mechanism.
- *Sequencing and Navigation (SN):* The SN specification defines a method for representing the intended behaviour of a learning experience such that any SCORM conformant LMS will sequence learning activities in a consistent way. It also defines the required behaviours and functionality that SCORM conformant LMSs must implement to process sequencing information at run-time. More specifically, it describes the branching and flow of learning activities in terms of an activity tree, based on the results of a learner's interactions with content objects and an authored sequencing strategy.

Common terminology is used in SCORM. Assets are electronic representations of media, such as text, images, sound, web pages or other pieces of data that can be delivered using web technologies. *Sharable Content Objects (SCO)* are collections of one or more assets that represents a single launch able resource that can communicate with an LMS using the SCORM RTE. A SCO represents the lowest level of granularity of learning resources that can communicate with an LMS using the SCORM RTE.

2.2.1 *Run-Time Environment Data Model*

The RTE specifies an environment data model that defines the data that can be transferred to and form the LMS by a SCO, to track the learner's interactions and results. This data is also used by SN to determine the next learning activity that should be presented.

2.2.2 *Interface specification*

The interface specification for the RTE is defined by a simple set of JavaScript functions. These functions must be made accessible to the SCO by the LMS. The SCO uses these functions to pass information on learner interaction with the content. The functions are:

- *Initialize*: Used to initiate the communication session. It allows the LMS to handle LMS specific initialization issues.
- *Terminate*: Used to terminate the communication session. It is used by the SCO when the SCO has determined that it no longer needs to communicate with the LMS. The function also shall cause the persistence of any data set by the SCO since the last successful call to Initialize or Commit, whichever occurred most recently. This guarantees to the SCO that all data set by the SCO has been persisted by the LMS.

- *GetValue*: Requests information from an LMS. It permits the SCO to request information from the LMS to determine among other things: Values for data model elements supported by the LMS, version of the data model supported by the LMS and whether or not specific data model elements are supported.
- *SetValue*: Allows the SCO to send information to the LMS for storage. The API Instance may be designed to immediately store data that was set (to the server-side component) or store data in a local (client-side) cache.
- *Commit*: Requests forwarding to the persistent data store any data from the SCO that may have been cached by the API Instance since the last call to Initialize or Commit, whichever occurred most recently.
- *GetLastError*: This method requests the error code for the current error state of the API Instance. If a SCO calls this method, the API Instance shall not alter the current error state, but simply return the requested information.
- *GetErrorString*: Used to retrieve a textual description of the current error state.
- *GetDiagnostic*: Allows the LMS to define additional diagnostic information through the API Instance. This call has no effect on the current error state; it simply returns the requested information.

2.2.3 *Goals of SCORM objectives*

The goals that one can achieve with SCORM , the so-called '-ilities', apply to SCORM based LMSs and learning content and are:

- *Accessibility*: The ability to locate and access instructional components from one remote location and deliver them to many other locations.
- *Adaptability*: The ability to tailor instruction to individual and organizational needs.
- *Affordability*: The ability to increase efficiency and productivity by reducing the time and costs involved in delivering instruction.
- *Durability*: The ability to withstand technology evolution and changes without costly redesign, reconfiguration or recoding.
- *Interoperability*: The ability to take instructional components developed in one location with one set of tools or platform and use them in another location with a different set of tools or platform.
- *Reusability*: The flexibility to incorporate instructional components in multiple applications and contexts.

Furthermore, SCORM promotes the use of the Internet as the preferred communication medium to support these rules. In result, most SCORM compliant LMSs are web-based.

2.2.4 *SCORM Standards*

2.2.4.1 *SCORM 1.0*

The original version of SCORM, version 1.0, was a proof of concept only. It introduced the notion of Sharable Content Objects (SCOs) and the API model in which the burden of managing communication across the Internet is handled by the run-time environment, not by the content objects.

2.2.4.2 *SCORM 1.1*

The first production version of SCORM was version 1.1. It used a Course Structure Format XML file based on the AICC specifications to describe content structure, but lacked a robust packaging manifest and support for metadata. Version 1.1 was quickly replaced by SCORM 1.2.

2.2.4.3 *SCORM 1.2*

SCORM 1.2 was the first version with a real conformance test in the form of a test suite. It uses the IMS Content Packaging specification with full content manifest and support for metadata describing the course. Also allows optional detailed metadata tagging of the content objects and assets described in the manifest. Version 1.2 is no longer maintained or supported by ADL.

2.2.4.4 *SCORM 2004 (1.3)*

The current version of SCORM is version 1.3, also known as SCORM 2004 (see ADL Co-Lab, 2006). It includes the ability to specify adaptive sequencing of activities that use the content objects, new standards for API communication, and resolves many ambiguities. SCORM 2004 also includes the ability to share and use information about success status for multiple learning objectives or competencies across content objects and across courses for the same learner within the same learning management system. Several editions of this version have released. These are:

- 1st Edition (January 2004) - versioning changed so each book could be independently maintained.
- 2nd Edition (July 2004) - included improvements regarding Content Aggregation Model and Run-Time Environment.
- 3rd Edition (October 2006) - clarified various conformance requirements and of the interaction between content objects and the runtime environment for sequencing; added new conformance requirements to improve interoperability.

3 Integrating training simulations and e-learning systems

As can be seen in the previous chapters there are many similarities between the HLA and the SCORM standard:

- They both specify how to define content using a standard data model or template, such that content and information about that content can be shared between systems.
- They both specify a run-time environment that handles the sharing of content and information in a uniform way.
- They both enforce rules on the content and how information is shared.
- They both are the de facto standards within their domain and have large supporting communities.

This makes them a perfect match for integration, be it that there are several ways to do so. In the final report of the SISO SCORM-Sim Study Group Reference [3] several initiatives regarding the integration of simulation with SCORM based e-Learning have been listed. In essence these initiatives use two different approaches; using an external communication interface or using an embedded communication interface. Both approaches will now be discussed. After that TNO's approach will be presented.

3.1 External communication interface

In the approaches with an external communication interface a locally installed application handles all communication between the active learning content (i.e., a SCO) and a simulation (for example, see [4]). Often, the locally installed application is responsible for launching and stopping the simulation, monitoring the learner's actions in the simulation and providing results to the SCO that the SCO then can store in the LMS, see Figure 1.

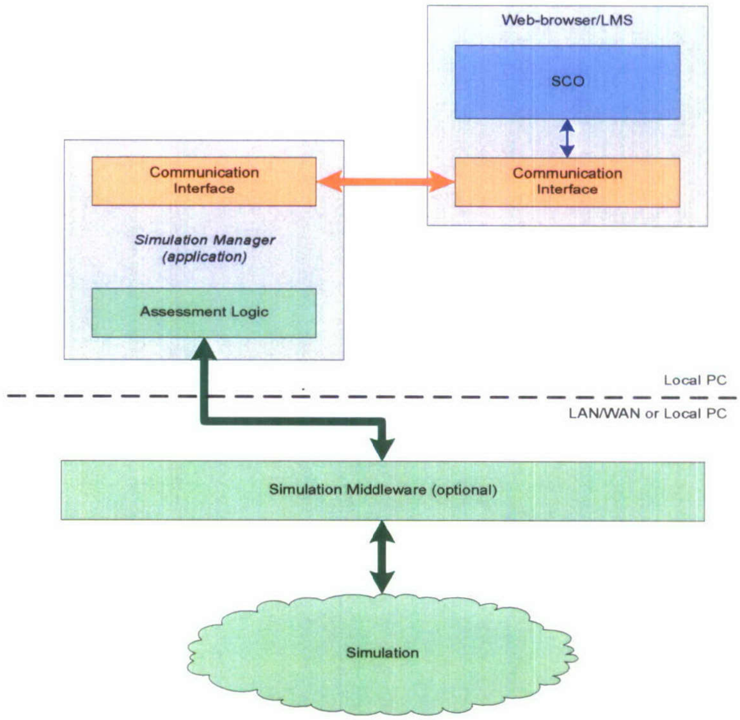

Figure 1 External communication interface with the simulation.

An advantage of this approach is that much of the communication and assessment logic is located in the application and not in the web-based SCO, as a web-browser has limited resources and uses a more restricted security policy.

A major disadvantage of this approach is that some kind of communication protocol between the application and the SCO is needed. This often leads to proprietary protocols and requires modifications to the LMS. Furthermore, the SCO will be highly depended on the performance measurement and the assessment that is performed by the application, and not by the SCO itself. This will restrict the interoperability of the SCO.

3.2 Embedded communication interface

In this approach, the communication with the simulation is handled by the active learning content (SCO) itself. Therefore, the SCO generally contains an asset that handles the communication with the simulation. In HLA terms this means the SCO can be treated as a HLA federate and has its own connection with the HLA federation, see Figure 2.

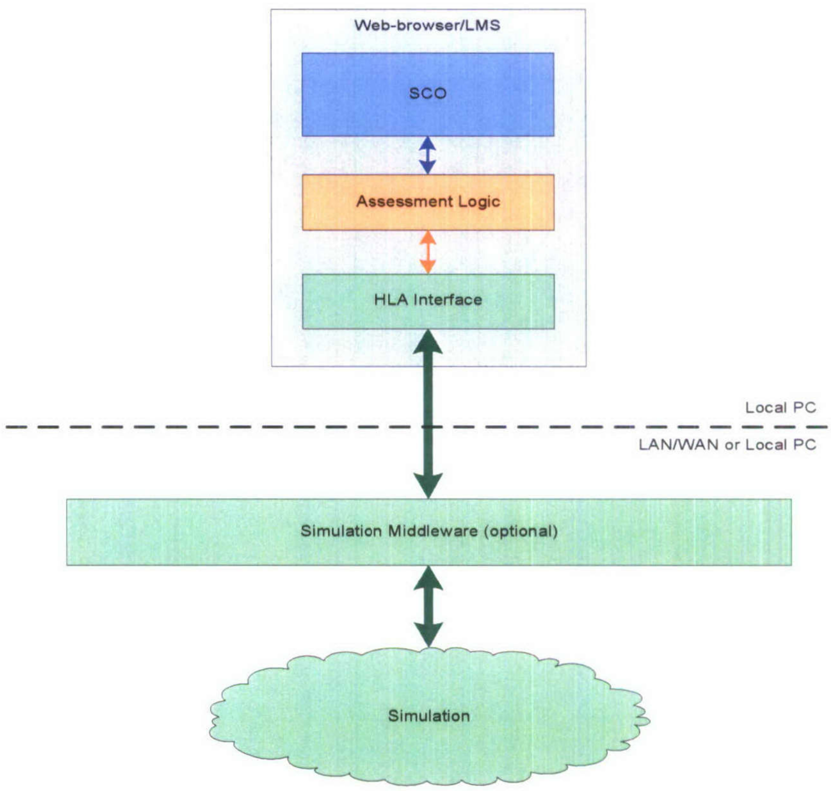

Figure 2 Embedded communication interface with the simulation.

Important advantages of this approach are that no other communication protocols then provided by SCORM and HLA are needed and that the SCO has its own link with the simulation. Therefore, the SCO is able to monitor and assess the learner's interactions based on the learning task it represents. This will lower the data exchange between the learner's PC and simulator and the development effort for the learning content, since the SCO only needs to deal with that part of the simulation data that is required to make an assessment for a specific learning task. Finally, the communication and assessment logic will be embedded in the SCO making the SCO more interoperable than the approach with an external communication interface.

A disadvantage is that the SCO requires more resources from the web-browser (memory and bandwidth) and a more flexible security policy (the SCO needs to access local resources outside the web-browser). But this may be acceptable when the learning task is not too complex and the simulator and the LMS are running in the same controlled environment (LAN/WAN). These conditions are often met, since a training course is usually divided into smaller learning tasks and the LMS is either connected to a dedicated high fidelity simulator via a company LAN, or is connected to a PC-based simulator running on the same computer as the web-browser.

3.3 TNO's approach

TNO has focused on an embedded approach. This allows the most flexibility and interoperability and has several advantages over the external approach:

3.3.1 Pedagogical

- All learning content related information, like training scenario description, assessment rules and learning objectives, are encapsulated in the content itself, creating a more holistic and interoperable perspective on the learning content.
- Support for real-time tracking and tracing of simulation interaction by the SCO itself, providing the content developer more control on what to train and how to measure performance.
- Support for multi-user training simulations, although SCORM is originally aimed at individual learning. This is because each SCO can operate as a participant in a joint simulation via the HLA connection and track individual training results. The tracking and tracing of team results is planned as future work.

3.3.2 Technical

- Integration of off-the-shelf LMSs and existing simulators, without any major modifications (only HLA and SCORM compliancy is required).
- Support for remote assessment via a standardized interface to reduce the complexity of the embedded assessment logic (and use of local resources). This will also provide a solution for the memory and bandwidth limitations typically associated with an embedded approach.

3.3.3 Organizational

- All learning content related information is encapsulated in the content itself, making it easier to create, manage distribute and reuse learning content.
- No additional maintenance effort is required for a separate application or any modifications to existing LMSs and simulators, only for the learning content.

To illustrate our approach, TNO has developed a software platform, called SimSCORM, and a small training scenario as a demonstrator. This platform and the demonstrator will be discussed in the next chapter. Also a Software Design Document Reference [5] is available that describes the SimSCORM platform, its APIs and the demonstrator, which can be used as an example SCO in more detail.

4 Results

4.1 The SimSCORM platform

The SimSCORM platform is build on the TNO Simulation Architecture (TSA, see Reference [6]) that incorporates its own HLA RTI, libraries, and supporting tools. Any HLA environment could be used, but the benefit of TSA is that many simulators currently maintained by TNO and its large, international group of customers are build on TSA. TSA also contains code generators to automatically generate an HLA interface according to a Federation Object Model (FOM = description of all objects, attributes and interactions in a simulation environment). This makes it easier to work with existing simulators.

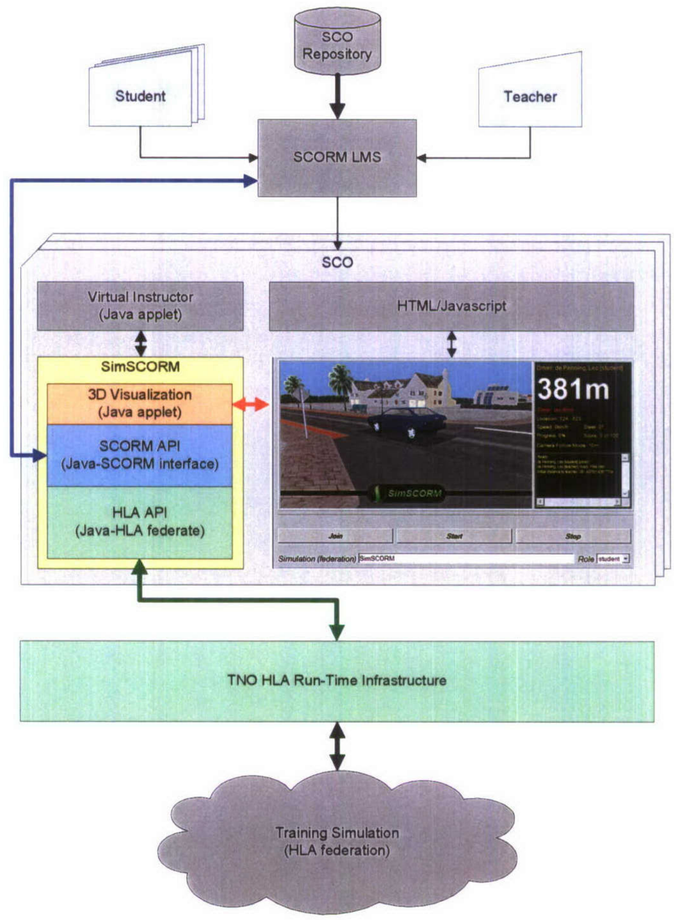

Figure 3 Context diagram of the SimSCORM platform.

The SimSCORM platform and its context are depicted in Figure 3. It shows that a user (student, teacher, etcetera) receives a SCO (stored in a repository) from the SCORM compliant LMS. This can be either requested by the user or directed by the LMS, based on SCORM Sequencing & Navigation (SN) rules. Basically, this SCO presents a learning task to the user via a HTML/JavaScript based user-interface in a web-browser.
The SCO can be regarded as a simple Virtual Instructor (VI) that runs a training scenario which contains learning objectives and assessment rules, that is specific to one learning

task. The VI uses the SimSCORM platform as an Asset to communicate with the HLA simulation, the SCORM LMS and the 3D viewer. It configures and monitors the simulation, assesses the student according to the specified SCORM learning objectives and reports the results back to the LMS. The LMS then decides which SCO to present next, based on the learner results and defined SCORM SN rules in the content package. Typically a SCORM content package (CAM) contains one SimSCORM platform as a resource that the SCOs in the package refer to as an Asset.

4.1.1 *Global Architecture*

As can be seen in Figure 4, the SimSCORM platform provides Java interfaces to the HLA RTI and the SCORM LMS. It contains several functions to join, start, stop, monitor and configure a simulation and read and write learner results in the LMS to support these training scenarios. Furthermore the platform contains a VRML interface to support visualization of the simulation or learner results in 2D and 3D.

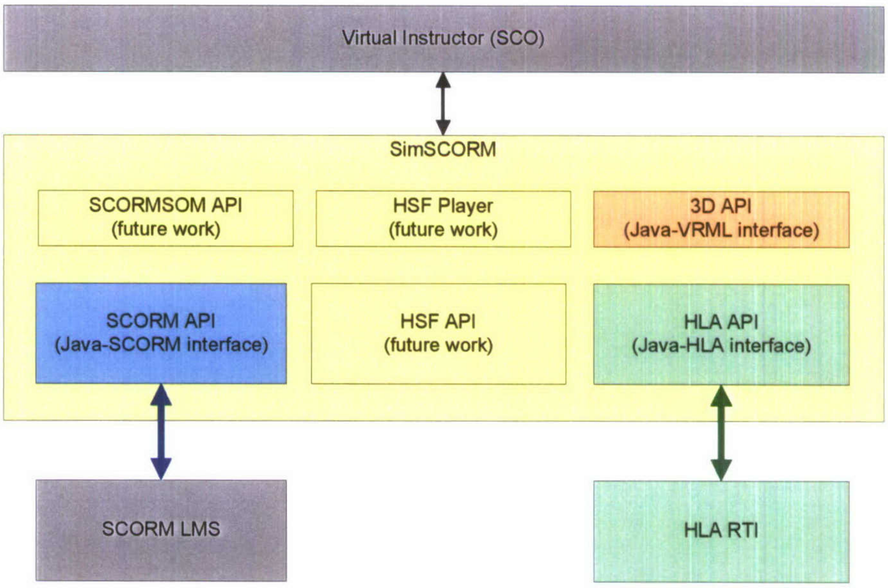

Figure 4 Global Architecture of the SimSCORM platform.

The SimSCORM platform itself is built as a modular and generic platform that can be applied in virtually any HLA and SCORM environment. Using this platform, a content developer can focus more on the learning content itself and does not need to worry about the technical details of a HLA and SCORM integration effort. Typically, the content developer will use the HLA API to configure and monitor the training scenario (context) and the SCORM API to monitor and report progress on the learning objectives (goals). On top of that, the VI needs to assess the learner's activities within that scenario and report back the results to the LMS. Currently, the VI is implemented as a Java applet for the demonstrator described in the next chapter.

4.1.2 *Scenario player*

In the future the SimSCORM platform will also provide a generic player (HSF Player) that supports the VI in playing training scenarios and doing assessment based on a standard scripting and/or data definition language. We have called this language the High-level Scenario Format (HSF) and is intended to be a result of TNO's standardization effort within the SISO SCORM-Sim Study Group. To support the HSF Player a HSF API will be implemented, enabling the use of external and/or SCORM embedded HSF data.

4.1.3 *Remote assessment and Team training*

Another future component will be a SCORMSOM API that will provide the platform with a means to communicate SCORM information between HLA federates and SCOs, providing support for remote assessment, team assessment and standardized simulator-based feedback and instruction. The support for remote assessment will also reduce the complexity of the embedded assessment logic (and use of local resources).

4.1.4 *Supporting tools*

Since the SimSCORM platform is based on TSA it benefits from the existing tools in the TSA, such as a Java code generator, which assists and simplifies integration with existing HLA simulations. With this code generator a HLA interface to a simulation can easily be generated based on an existing FOM.

4.2 Demonstrator

To demonstrate the capabilities of HLA-SCORM integration, a small SCO has been developed on top of the SimSCORM platform. In this SCO, the student's task is to find the teacher's car as fast as possible by driving in a virtual environment. The demonstration supports multiple students and teachers driving in the same virtual world. Figure 5 shows a student's SCO in an open-source LMS, called Moodle (http://www.moodle.org).

Figure 5 The HLA compliant driving simulator with the student interface (left) presenting the student SCO in Moodle which presents a 3D visualization and the control of the lesson (right).

The student in Figure 5 drives a scenario in the driving simulator. This scenario, a 3D real-time visualization of the student's performance and the control of the lesson, are all contained in a SCO that is managed by Moodle. Results are stored automatically in Moodle, and both students and instructors have access to all the typical LMS functionalities from Moodle.

The same SCO can also be used by the teacher to monitor the students driving around in the same simulation environment. To support this, the concept of roles was introduced. To maximize the SCO's reusability this concept was implemented on the HLA side only, but further investigation will be required to result in a standard solution (either SCORM, HLA or HSF-based).

The demonstrator can run standalone, where the vehicles are controlled via the web-browser using keyboard and mouse, or connected to external driving simulator which controls the vehicles via HLA. Also the virtual world is visualized via the graphics interface of the SimSCORM platform.

4.3 Projects and Standardization

The first results from the demonstrator and the SimSCORM platform are positive. The demonstrator has been easily integrated with existing high fidelity simulators, and provides a real-time 3D visualization of the student's performance inside an off-the-shelf LMS for both teacher and student. We are currently investigating the possible use of SimSCORM in a F16 maintenance trainer, to support web-based training for maintenance procedures with detailed tracking and tracing using a SCORM compliant LMS. Until now, our experience is that both development effort of the training tasks and the integration effort with existing LMSs and simulators will be minimal.

TNO is participating in the SISO SCORM-Sim Study Group to further support the standardization effort on integration of simulation and e-learning. One of the aimed results is a conceptual reference model, where HLA and SCORM will be the most important pillars. Besides that, a third pillar is needed to standardize the definition of training scenarios, learning objectives and assessment rules. With HSF TNO may contribute to the development of that standard.

5 Conclusions

The SimSCORM platform provides a standards-based and dynamic integration of training simulators and e-learning systems. SimSCORM is a flexible multi-user platform that can be used to connect to virtually any HLA-compliant training simulation with a SCORM-compliant LMS. As it requires no adaptations to the simulator or LMS, as long as they are respectively HLA and SCORM compliant, SimSCORM allows cost-effective development of the learning task and simulation environment at hand.

The current advantages of SimSCORM are:

- Support for development of SCORM-based learning content for simulation-based training results in less development effort.
- Use of interoperable standards HLA and SCORM results in less integration effort.
- Real-time and two-way interaction between the simulator and the active learning task in the LMS.
- Simulation configuration and control.
- SCORM-compliant tracking and tracing of simulation interaction and learning processes.
- Real-time assessment of training using SCORM objectives.
- Dynamic learning content via SCORM Sequencing and Navigation.
- Team training (including instructor views).

TNO has successfully implemented SimSCORM in several projects and is participating in the SCORM-Sim Study Group to contribute to their standardization effort on the integration of simulation and e-learning.

5.1 Future work

The current SimSCORM platform proves to be a good base for integration of simulation-based training in standard e-learning systems, but there are still some open issues that needs to be addressed in the future. These issues will mainly be solved in future projects and the collaboration with the SISO SCORM-Sim Study Group. The main issues are:

- Distribution of individual training results to other users to support team training, simulator-based feedback and remote assessment (SCORMSOM API).
- A (SCORM-based) standard for defining training scenarios, learning objectives and assessment rules (HSF). This will further increase the interoperability of the training content.
- A generic scenario player for playing, monitoring and assessing training simulations according to SCORM objectives (HSF Player).
- A generic SCORM-based editor for training scenarios (HSF Editor).
- Logging and playback of training scenarios via a HLA logger, which logs all HLA communication. This allows a complete after action review of the entire training scenario.
- Research and implementation of a standard solution for the definition and handling of roles.

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7 Signature

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15. ABSTRACT (MAXIMUM 200 WORDS (1044 BYTE))

TNO has studied the integration of e-learning and simulation and developed an approach based upon integration by means of *de facto* standards HLA and SCORM. The SimSCORM platform was build as proof of concept of this approach. This SimSCORM platform provides a dynamic integration of both types of systems. Although not a unique effort, TNO has chosen a rather distinctive and flexible approach. In TNO's approach, each learning task in the LMS is treated as a separate simulation component, which has its own direct link to the HLA simulation. This integration allows real-time, two-way interaction between one or more simulator(s) and the active learning task running in the LMS. The LMS, which can be any LMS as long as it is SCORM compliant, can be used for tracking, evaluation, and administration of training results, as well as for creating or starting scenarios for the simulator. Furthermore, the SimSCORM platform promotes improved execution of joint training simulations (if necessary distributed), real-time assessment of learning processes, team training, the use of virtual instructors, without adaptations to the simulator or LMS provided they are respectively HLA and SCORM compliant.

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