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The scenario management tool SMARTFED for real-time interactive high performance networked simulation

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ABSTRACT
The National Aerospace Laboratory NLR is the central aerospace research and development organization in the Netherlands, and is actively involved in international simulation projects. In the HPCN project SIMULTAAN, NLR developes a generic scenario magagement tool named SMARTFED for real-time monitoring and control of networked simulations. The scenario management tool also offers functionalities to define and execute scenarios. A faster than realtime option of SMARTFED facilitates the use of HPCN visualisation tools for evaluation purposes. This paper describes the tool SMARTFED and its use in networked high performance simulations. The envisaged use of SMARTFED in aerospace applications is further illustrated for NLR's DELTA federation.

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The scenario management tool SMARTFED for real-time interactive high performance networked simulations

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Summary

The National Aerospace Laboratory NLR is the central aerospace research and development organization in the Netherlands, and is actively involved in international simulation projects. In the HPCN project SIMULTAAN, NLR developes a generic scenario management tool named SMARTFED for real-time monitoring and control of networked simulations. The scenario management tool also offers functionalities to define and execute scenarios. A faster than real-time option of SMARTFED facilitates the use of HPCN visualisation tools for evaluation purposes. This paper describes the tool SMARTFED and its use in networked high performance simulations. The envisaged use of SMARTFED in aerospace applications is further illustrated for NLR's DELTA federation.

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(10 pages in total)

The Scenario Management Tool SMARTFED for Real-Time Interactive High Performance Networked Simulations [1]

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Abstract. The National Aerospace Laboratory NLR is the central aerospace research and development organization in the Netherlands, and is actively involved in international simulation projects. In the HPCN project SIMULTAAN, NLR developes a generic scenario management tool named SMARTFED for real-time monitoring and control of networked simulations. The scenario management tool also offers functionalities to define and execute scenarios. A faster than real-time option of SMARTFED facilitates the use of HPCN visualisation tools for evaluation purposes. This paper describes the tool SMARTFED and its use in networked high performance simulations. The envisaged use of SMARTFED in aerospace applications is further illustrated for NLR's DELTA federation.

1 Introduction

The world of builders of training or engineering simulators is a complex one. Firstly, a simulator for real world sceneries must provide an accurate approximation of part of the real world. Secondly, a simulator must be delivered on time, on budget, and satisfy stringent performance requirements. The ICT community actively pursues and promotes international standards, and simulators need to comply with these standards.

In the Netherlands, industry, institutes and a university collaborate in the SIMULTAAN [1] project to achieve a common view on the development of training simulators using state-of-the-art technology. To take full advantage of simulators located at different sites in one simulation, both a network and a central supervising capability must be present. This supervising capability should enforce collaboration between simulators and provide means to execute a shared scenario. The communication architecture that has been chosen is based on the High Level Architecture (HLA) standard ([2], [3] and [4]).

SIMULTAAN deals with federations. A federation is a unity of federates, i.e. simulators that work together in a simulation. Within a federation, each federate remains responsible for its own internal affairs. It is evident, however, that monitoring and control of a federation is essential for successful cooperation of federates in that federation.

Figure 1 illustrates the central role that is played by scenario management and its monitoring and control capabilities in a federation. The federation depicts one of the SIMULTAAN architectures for vehicle training simulators that involve several trainees. In this federation, a number of federates is involved, among which NLR's full-flight simulators NSF and RFS [5]. This illustrates that a federation can contain sophisticated high performance federates.

[1] This work has been carried out in the framework of the SIMULTAAN project, which is partly funded by the Dutch Foundation for High Performance Computing and Networking (HPCN).

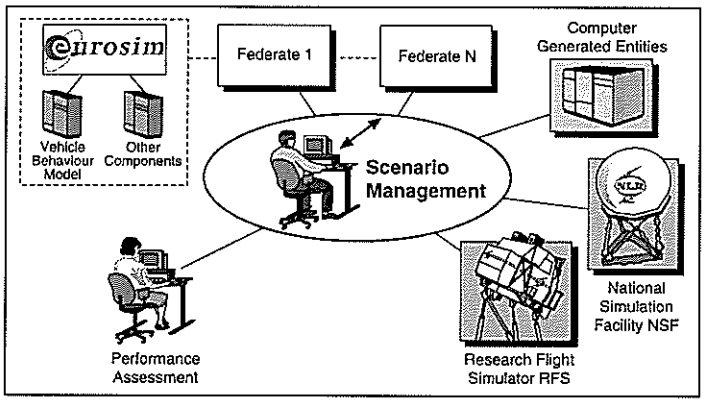

Fig. 1. An example of a networked simulation

Within SIMULTAAN, federates are composed of components. A component can be considered as a basic building block. Any component may require HPCN techniques. For instance NLR's computationally demanding Behaviour Model Component, see also figure 1, is able to participate in real-time training simulation of road-vehicles on rough terrain [6] where the actual mock-up of the vehicle is located elsewhere. The Behaviour Model Component resides in the real-time simulation environment EuroSim [7], which is a software tool that offers a generic environment for the construction, execution and evaluation of non-real-time and real-time engineering and training simulators.

This paper describes one of NLR's contributions to SIMULTAAN: the Scenario Management tool SMARTFED [1]. With SMARTFED, all federates within a federation are forced to co-operate in the execution of a particular scenario, i.e. a plan of actions and events to be performed during a simulation run with the federation.

The remainder of this paper is organised as follows. Section 2 gives a global description of SMARTFED and its communication with the federation. Section 3 describes in more detail the federation management tasks. Section 4 focuses on the monitoring task and section 5 describes the scenario definition and execution tasks. In section 6 the envisaged use of SMARTFED in the so-called DELTA federation at NLR is described. Section 7 contains the concluding remarks. Acronyms can be found in section 8 and references in section 9.

2 Overview of SMARTFED capabilities

Networked simulations consist of a number of federates that collaborate to achieve a common goal. These federates are located at geographically different sites and are connected through networks. Within the SIMULTAAN project NLR is tasked with the development of the generic Scenario Management tool SMARTFED. An important benefit of SMARTFED is that it allows engineers to concentrate on specific aspects in a project while ensuring reuse of available technology in the Netherlands. For instance, SMARTFED paves the way to incorporate existing federates in complex training scenarios.

Control over the execution of a simulation is desirable for a number of reasons. It is needed to ensure cooperation between federates that participate in a simulation. Another reason is that the same scenario may need to be performed more than once. For example, in training simulations the environmental conditions must be the same in multiple runs to ensure that trainees practise under similar circumstances.

In a networked simulation, SMARTFED controls and monitors all federates that participate in a particular scenario run, and executes the scenario. This is illustrated in Figure 2.

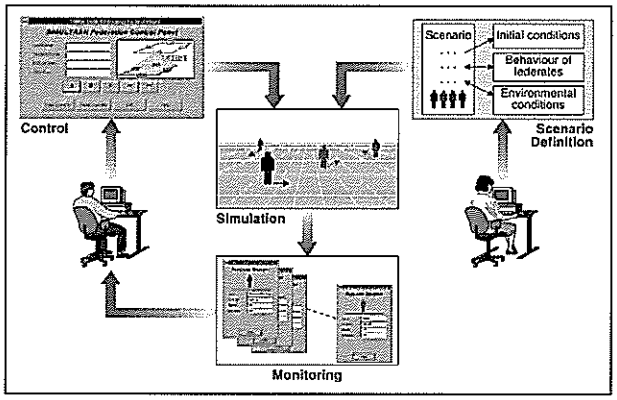

Fig. 2. Tasks of the Scenario Management tool

SMARTFED performs three tasks. Firstly, there is the control task. In SMARTFED this is realised by the Federation Manager. The Federation Manager controls the execution state of all federates in the entire simulation. Secondly, an operator (e.g. the supervisor or instructor) needs to be able to monitor the federation. This task is realised in SMARTFED by the Federation Monitor that enables him/her to watch the entire simulation on a screen. Different views on the federation and participating federates are provided. The third task concerns definition and execution of scenarios. In SMARTFED this is realised by Scenario Definition and Execution Manager. In the following sections we discuss in more detail how SMARTFED realises the above mentioned scenario management tasks.

SMARTFED communicates with all federates in a federation through a communication layer that is based on the Run-Time Infrastructure (RTI) of HLA. Data is made available through a publish and subscribe mechanism. All tasks of SMARTFED make extensive use of the Management Object Model (MOM) data provided by HLA. The MOM provides global information about the federation (e.g. the list of participating federates) and about the federates (e.g. the hostname of the federate) in the federation.

Each federate can subscribe to and publish two types of data, namely (portions of) the internal federate state, and interactions between federates. An example of internal federate state data is engine information in a vehicle simulator. Examples of interactions between federates are a collision between two vehicles and the interaction between a fighter plane and a tank by means of a missile.

SMARTFED also manages simulations that run faster than real-time. This option has been made available to support the use of dedicated HPCN facilities especially in the pre- and postprocessing phase. This makes it possible for a user to have access to computationally demanding visualisation facilities located at other sites. The fast-time option can also be used during replay to skip less important parts of a simulation.

3 Federation Manager

The main functionality of the Federation Manager is to provide central control over the networked simulation. The Federation Manager is operated by a supervisor. The supervisor decides when certain commands are sent to the federation. As depicted in Figure 2 the supervisor can react on signals displayed by the Federation Monitor (see section 4). The Federation Manager and the Federation Monitor will usually be used by one and the same person.

A general state-transition diagram has been designed for SIMULTAAN federates [8], see Figure 3. In principle each federate must comply with this state-transition diagram. However, federates may well possess an internal state-transition diagram that differs from the one depicted in figure 3. The main issue is that from a scenario management point of view, a federate complies with the depicted state-transition diagram. The Federation Manager sends state-transition commands to the federates. Federates in turn send success or failure notifications to the Federation Manager.

The user of the Federation Manager (e.g. the supervisor) decides whether a scenario shall be executed or not and when a scenario execution will start and stop. The Federation Manager subscribes to the federate data and federation data provided by HLA's MOM in order to know the states of federates that are present in the federation. The Federation Manager may only send a state-transition to the federation when all federates are in the same state. State-transition commands are made available to the supervisor by means of a graphical user interface. Also a message window is available to notify the supervisor of warnings or errors that occur during the federation execution, for instance loss of a network connection of a federate to the rest of the federation.

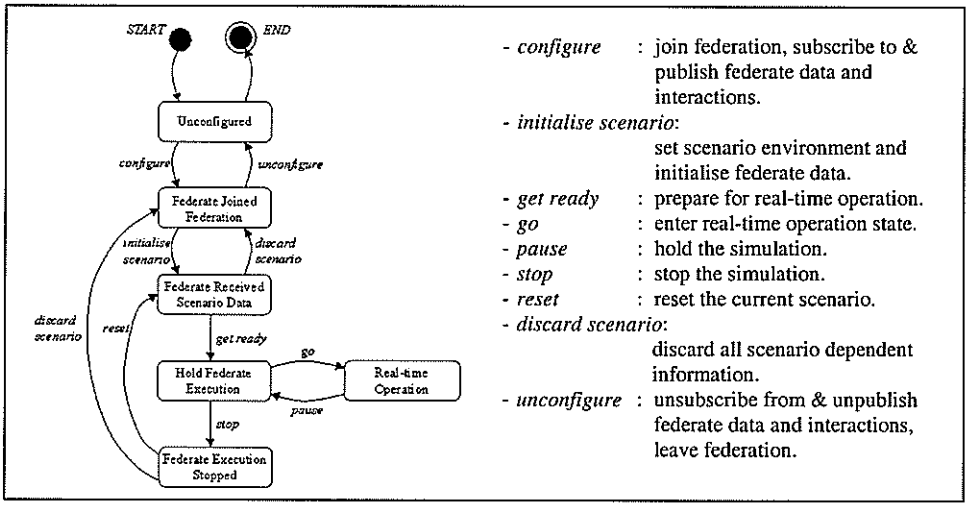

Fig. 3. The state transition diagram of a federation

Another functionality of the Federation Manager is the initiation of snapshots. A snapshot contains a dump of the entire internal state of a federate. Of course this is only possible if a federate itself is able to take a snapshot. Snapshots can be generated only when a federate is in the 'Hold Federate Execution' state. The same holds for restoring a federate by means of previously created snapshot.

It is also possible to register bookmarks during a scenario execution. During After Action Reviews, parts of the scenario can be replayed and analysed. The registered bookmarks serve as easy to find starting points for the review. A supervisor adds a bookmark at a point in time during the scenario run that might be of interest to the evaluation of the scenario afterwards.

4 Federation Monitor

The Federation Monitor provides the user with a view of the entire federation. This includes both a graphical overview showing the positions of the simulated entities with respect to each other and a textual view of the federation containing detailed information of the participating federates.

As mentioned earlier a federate can publish and subscribe to two types of data: federate data and interaction data. Published data can be viewed using the Federation Monitor. As soon as data from a federate is updated by its owner, the Federation Monitor will receive the new values. The data attributes are viewed in textual format, in addition numerical attributes can be viewed graphically.

The data collection that contains the information of all data and interactions available in a federation is called the FOM (Federation Object Model), conform HLA terminology. A FOM is composed of the collection of available federate data and interaction data. The data and interactions subscribed to and published by a single federate is called the SOM (Simulation Object Model). The FOM is used as a basis for the implementation of the Federation Monitor. For HLA a Backus-Naur Form notation of a FOM is defined, see [4]. FOM files that comply with this notation can be read by the Federation Monitor. The Federation Monitor will enable the user to browse graphically through the FOM. With this browser the user can subscribe and unsubscribe to federate data and federate interactions whenever he/she wants.

When new data is published by a federate, it will appear as an icon in the Federation Monitor using information contained in the FOM. Detailed information on federate data and its attributes will be displayed. The Federation Monitor will subscribe to federate interactions and display those incoming events that the user is interested in. A separate interaction view provides the user with an overview of all interactions that have occurred during the federation execution. For each interaction the detailed information on its parameters are available.

The application of the High Performance technology is closely related to the development of high-capacity networks. Since in principle, the Federation Monitor can subscribe to all data that are made available in the federation, network congestion may occur when a user actually does so. The level of accuracy of the monitoring depends on the network load and may decrease as the number of monitored objects increases, see also [9]. It is expected that the use of SMARTFED will make evident new requirements for capabilities of high-capacity networks.

5 Scenario Definition and Execution Manager

The Scenario Definition and Execution Manager obviously has two main tasks: scenario definition and scenario execution.

Scenario Definition enables the user to specify a scenario. A scenario is defined for a particular federation. A scenario consists of the following parts:

- composition of the federation: what is the name of the federation and which federates participate in the federation for the scenario.
- definition of environmental conditions: in which geographical environment is the federation operating (e.g. European airspace) and what are the meteorological conditions.
- definition of initial conditions of federates: what are the initial values of the attributes of the data of a federate (e.g. position, speed).
- definition of stimuli during the scenario: which events shall occur at what time during the scenario (e.g. engine failure at t=10:30:00).

Scenario Execution reads a predefined scenario and sends the initial conditions to the federation when the 'initialise scenario' command is generated by the Federation Manager. During the 'Real-time Operation' state (see Fig. 3) the Scenario Execution component will send events to the federation at times specified in the scenario.

The implementation of the Scenario Definition and Execution Manager is based on the implementation of the Federation Monitor. While the Federation Monitor only allows the user to *watch* the federate data and interactions, Scenario Definition allows the user to *set* the values of federate data available in the FOM and generate interactions during the scenario definition phase.

6 The DELTA federation

The realisation of SMARTFED is currently driven by SIMULTAAN requirements, especially with respect to the tailoring to HLA as a communication standard between networked simulators. In the near future it will be studied how SMARTFED can be extended to include other communication protocols, among which communication protocols used in aerospace.

As the central aerospace research and development organization in the Netherlands, NLR operates a number of advanced facilities, among which are the Full Flight Simulator NSF, the Cessna Citation II aircraft, the Air Traffic Control Research Simulator NARSIM, and the Tower Research Simulator TRS.

Figure 4 depicts the DELTA concept: the unification of part of NLR's facilities in a joint simulation. Use of SMARTFED will effectively result in a DELTA federation proper. The use of SMARTFED for scenario management in the DELTA federation will require a number of extensions. Since not all communication is digital, for instance a voice link between the pilot and an Air Traffic Controller must be supported.

In order to appreciate the complexity of scenario management of these real-time high performance facilities, a brief description of each facility is given.

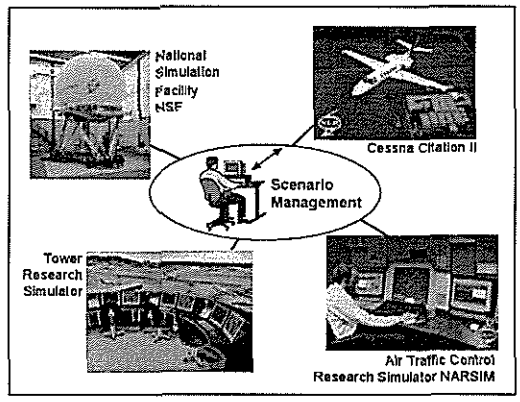

Fig. 4. Using the Scenario Management tool in the Delta concept

The National Simulation Facility NSF is NLR's versatile flight simulation facility. The simulator equipment consists of many modules, such as cockpits, visual, motion and computer systems, and a large set of simulation software modules and tools. With NSF virtually any vehicle can be simulated and its modular and versatile set-up enables efficient interchange of aircraft models, equipment, etc.

The Cessna Citation II PH-LAB is one of the research aircraft operated by the NLR. The Citation II is a twin jet certified in accordance with FAR Part 25 airworthiness standards and may be operated in known icing conditions. The PH-LAB can be used amongst others, for testing a variety of high-accuracy sensors and other equipment or complete systems in actual flight conditions

NARSIM simulates in real-time the Air Traffic Control (ATC) process, having both the air traffic controller and the pilot in the loop. NARSIM is concerned with approach/enroute ATC activities. In the past several years, NARSIM has been used in research programmes for a variety of customers. The NARSIM facility is also used in projects within European Commission's Fourth Framework Programme.

A Tower Research Simulator (TRS) is currently under development. The TRS will be capable of simulating the tower/ground ATC activities at an airfield, in real time and in a realistic operational and visual environment. This environment will contain a 360° field-of-view projection area where visual cues are simulated highly realistically. A key item in the research applications of the tower simulator is the role of the human controller, both the pilot and the air traffic controller, in the automated environment. At present, parts of the future Tower Research Simulator are already applied in various projects of the European Commission.

In the DELTA federation at least four persons are involved that may use the federation for training purposes. These persons are a pilot in the Cessna Citation, a pilot in the simulated aircraft in NSF (or RFS), and one (or more) air traffic controllers using NARSIM and/or the TRS. A possible scenario would include interaction between air traffic controllers and pilots, where the supervisor uses SMARTFED to sent stimuli to the trainees. The DELTA federation can be used to guide pilots all the way from the gate at one airport to the gate at another airport. Several interactions are possible, for example the transfer of an aircraft from one air traffic controller to another, since each air traffic controller is responsible for a particular area only.

NLR provides its services also to foreign aerospace industries, operators and other industries. Clearly, SMARTFED will stimulate the use of available facilities and simulators, both inside NLR and outside NLR, in a combined simulation, where each facility or simulator remains responsible for its own internal affairs.

7 Concluding remarks

In this paper we have presented the generic Scenario Management tool SMARTFED as developed by NLR in the SIMULTAAN project. SMARTFED paves the way to incorporate existing federates in complex real-time high performance training scenarios using networked HLA compliant simulators. SMARTFED consists of three main parts: the Federation Manager, the Federation Monitor and Scenario Definition and Execution Manager. Each of these parts can be accessed via graphical user interfaces. SMARTFED supports both real-time and fast-time simulations. The latter can be used for example for off-line replay and visualisation purposes, making possible the use of dedicated HPCN tools. It is envisaged that SMARTFED is an important asset to secure the Dutch contribution in international projects on high performance networked simulation.

8 Acronyms

ATC	Air Traffic Control
FOM	Federation Object Model
HPCN	High Performance Computing and Networking
ICT	Information and Communication Technology
MOM	Management Object Model
NLR	National Aerospace Laboratory
NSF	National Simulation Facility
OMT	Object Model Template
RTI	Run-time Infrastructure
SMARTFED	Scenario MAnager for Real-Time FEderation Directing
SOM	Simulation Object Model

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