Simulation Framework for Collaborative Fusion Research

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Abstract - *This paper presents a case study of a Modelling and Simulation (M&S) Testbed Framework that has been proposed to facilitate research activities in sensor technology, fusion and decision support. The framework facilitates research activities through the creation and sharing of common resources like scenario generators, simulation engines, sensor/target models and visualisation tools. With this framework, common resources can be reused in a "plug and play" manner and to facilitate the development of larger demonstrators. Two research institutes collaborated in the development of this framework, which consists of a suite of modular components and a standardised interface between them. The simulation testbed was successfully tested using a common scenario and fusion federates for tracking and classification of targets. The fusion federates consist of ground sensor networks (or network of fusion nodes using ground sensors) built independently from the two research institutes.*

Keywords: HLA, modelling & simulation, interoperability, ground sensor networks, data fusion.

1   Introduction

In the area of data fusion R&D, it is common for data fusion techniques and algorithms to be developed and tested in a simulation environment before they are being deployed in an operational system. Simulation will also enable testing of different scenarios, which commonly will be too expensive or too time consuming to be tested in a real operational environment. Thus, dedicated simulation systems are developed to support data fusion research, albeit in a stove-piped manner. This approach requires additional effort to develop a simulator for each new project, and efforts are needed to integrate the available models and results from previous projects due to lack of reuse and non-standardised interfaces. This prompted a rethink of the development approach for simulators and to design a common framework to facilitate "plug and play" mode with minimal integration effort, and reuse of common resources.

In 1998, DSO National Laboratories started a project to develop a common simulation testbed to facilitate scenario generation and testing of data fusion systems. This testbed has since transited from a DIS (Distributed Interactive Simulation) based architecture to an HLA (High Level Architecture) framework. Similarly, FOI has

also been examining the need for a simulation testbed for their requirement in early 2000. With this common interest and desire to collaborate on research activities in sensor, fusion and decision support technologies, both parties have agreed to work on the common M&S testbed framework to facilitate the collaboration.

As part of a pilot demonstration, both parties agreed on a common problem, that of the agent-based ground sensor network. Work in this area has already started in the two research institutes. This presents a good problem domain to be tested using the common simulation framework as well as enabling both sides to exchange information and share results of their respective solutions.

2   Common M&S Testbed Framework

Most of the current M&S testbed architecture consists of different simulation and utility components with the HLA as the primary integrating framework. The HLA is an IEEE standard [1] that specifies a standard technical architecture that facilitates interoperability and reuse of simulation systems. The HLA provides a common simulation framework which offers a set of basic simulation services that are object-oriented, modular and scaleable. The HLA RTI (Run-Time Infrastructure) enables data exchange between distributed simulations and manages the simulation execution.

The HLA integration framework enables reusability of simulation components by providing a means to define a Federation Object Model (FOM), interface specifications for communication between simulation components and offering a set of rules defining how simulation components should behave. The simulation setup enabling the scenario discussed in this paper is shown in Figure 1. The FOI and DSO testbeds are designed to enable easy integration of other types of platforms, sensors and fusion components, and is able to support more complex scenario involving higher number of vehicles and sensors.

Though both testbeds share similar structure, each employs a different suite of applications for the various components.
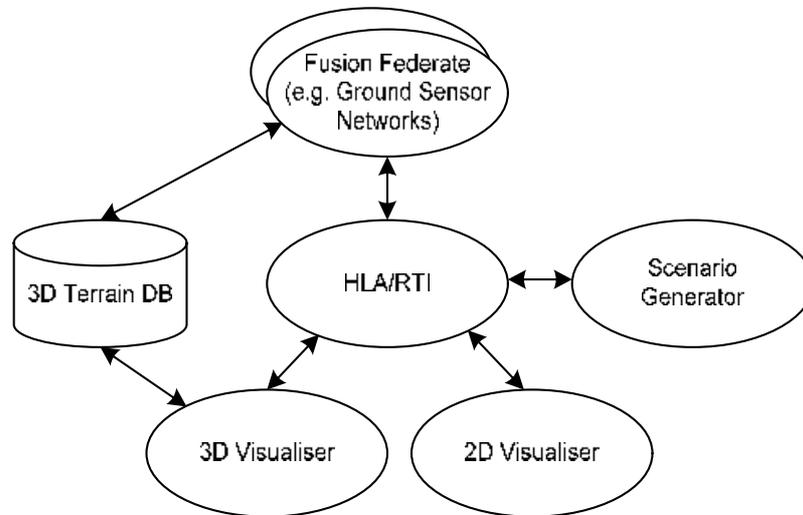
Fig. 1. Simulation setup.

2.1 DSO Simulation Testbed

The DSO simulation testbed is developed based on the suite of commercial products called VR-Forces from Mak Technologies. The Mak RTI and VR-Link HLA middleware are used to provide the underlying HLA framework. The Scenario Generator and 2D Plan View Display are provided by the VR-Forces CGF (Computer Generated Forces) package, and the 3D visualisation is provided by the Mak Stealth software. These applications provide object-oriented libraries of C++ API functions that enable the developer to add in customised models and features. All the components are running on the Microsoft Windows 2000 platform.

2.2 FOI Simulation Testbed

The FOI simulation testbed is mainly developed within FOI using a mix of software technologies. The DMSO and Pitch RTIs were used together with an in-house developed HLA middleware called the "HLAKit", both providing the HLA infrastructure. A Java-based Scenario Generator was developed and work to integrate the FLAMES simulation framework is in progress. The in-house developed MIND system [2] was adapted to the testbed for 2D visualisation. The 3D visualisation was provided by adapting the VEGA commercial software. The HLA Kits are available for both C++ and Java and are platform independent. The visualisation tools run on the Microsoft Windows platform.

2.3 HLA as Integrating Framework

Given that the two simulation testbeds at FOI and DSO employ different implementation approaches for the simulation components, the only thing common is the use of HLA as the testbed architecture and communications framework. Thus, it was agreed that both sides will work towards finding a common ground regarding the HLA components such as the FOM and RTI. This will be elaborated later in section 4.

3 Data Fusion Federate for Ground Sensor Network Domain

Both research institutes have been working on the problem domain of data fusion for a ground-based network of Unattended Ground Sensors (UGS). The UGS networks perform tracking and classification of ground targets. The institutes have been testing their ground sensor network modules using their respective simulation testbeds. The ground sensor network comprises of fusion nodes. Each fusion node is linked to simulated acoustic sensors. Each acoustic sensor has a detection range of approximately 200m. The fusion nodes are linked via communication means to form a network, hence also known as sensor networks. The fusion nodes are assumed to be non-mobile. Agent technology has been employed to manage the sensor networks. However, the agent management scheme for FOI and DSO are different and are briefly explained in the following subsections.

3.1 FOI Sensor Network

At FOI, the ground sensor network consists of acoustic sensors and fusion nodes. Mobile track agents are used to track each target. The sensor data from different sensors are sent to the fusion node where the track agent resides. In this case, more than one sensor might be attached to a single fusion node. The track agents are mobile and can move from one fusion node to another following the path of the target. At any given time, each target is tracked by a single node using polygon tracking. [3]

3.2 DSO Sensor Network

In the DSO sensor network implementation, co-operative agents are used to manage the tracking of targets. The agents will negotiate dynamically to form teams among the fusion nodes necessary for exchange of useful data to track each target [4]. The data exchanged are fused together to form tracks from multiple targets. Each fusion

node internally uses a Kalman-like tracking scheme [5][6].

4   Integration Process

In order to facilitate "plug and play" of simulation and fusion modules developed by the two parties on both testbeds, specific HLA components such as the FOM and RTI have to be agreed between both parties. Below are some of the main issues that have to be addressed before the actual integration starts.

4.1   Choice of HLA RTI

Different RTI implementations are not network compatible. This implies that within the same federation, the federates have to use the same RTI implementation (e.g. Mak, DMSO or others) in order to communicate. This lack of interoperability between different RTI implementations imposes constraints when collaborators employ different RTIs. Assuming that both parties have adequate number of RTI licences to share, and since the DMSO and Mak RTIs are designed to be link compatible, no additional effort is required to the actual source code when changing RTIs.

4.2   Choice and Adaptation of FOM

A standardised Federation Object Model (FOM) was also required to enable interoperability between different federates. The HLA object models define the set of shared objects in a federation, the attributes and interactions of these objects, and the level of detail at which the objects represent the real world. A common FOM is a form of contract between federates and enables them to publish and subscribe to the same attributes and interactions. A common FOM was designed by extending the existing Real-time Platform Reference (RPR) FOM, with additional classes that describe concepts such as sensor networks, and sensor tracks. These classes are shown in figure 2, below. The classes that were added to the FOM are shown bold.
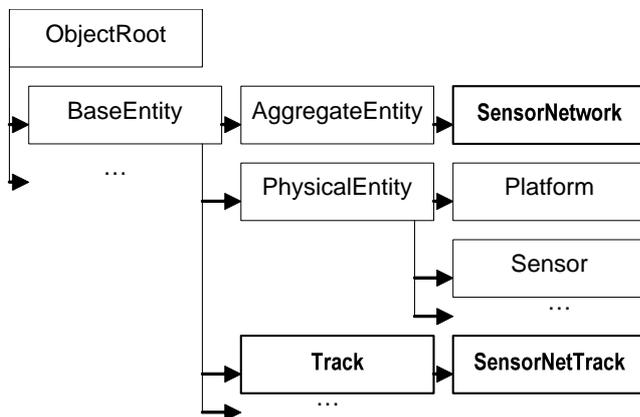

Fig. 2. Extended FOM used in the framework.

4.3   Time Management

Time management can also be an interoperability issue as different simulation systems may or may not use the time management services offered by the RTI. The DSO testbed does not use the HLA time management services but instead each federate is synchronised by the system clock, and RPR-FOM timestamping is used. The FOI simulation system can be configured to run with or without the HLA time management services as well as with or without RPR-FOM timestamping. Using HLA time management services will make the faster federates wait for the slower ones. Upon integration, the FOI federates were configured to run without time synchronization which enabled the federates to run together without issue.

4.4   Process of Integration

Both parties agreed on a common approach in the conduct and testing of sensor networks, prior to the final face-to-face integration and joint testing at one site. The sensor network modules were tested using the respective party's own simulation system. Then, integration tests for the sensor network module were carried out with a scenario generated by the other party's simulation system via the Internet to ensure that the interface issues were identified and resolved. After this was successfully done, there was an increased confidence in that there would not be any major integration hiccups when the parties met face-to-face for the final round of project reviews and demonstration. This integration approach ensured that most of the integration work could be completed before the two teams met. This was also facilitated via email exchange, videoconferences and Internet chat rooms. When the teams finally met, the integration of the respective modules could be done in a matter of days. This approach highlights the usefulness of performing distributed simulations through the Internet.

5   Distributed Simulations using Internet

Though the use of the Internet and Internet tools (email, chat, videoconferences) were used extensively to facilitate exchange of information, an additional use of the Internet was attempted, i.e. that of running a distributed simulation across the Internet, for the purpose of both integration effort as well as for actual simulation.

Initial Internet testing was performed to determine whether or not it was feasible to run a simulation over the Internet. The two primary issues were latency and bandwidth considerations. Though other issues such as security would be a concern if sensitive information was being shared, this issue was not considered for initial tests.

In order to test the latency issue a pair of simple HLA applications were constructed to send messages back and forth across the Internet. This 'ping federate' measured the latency of the HLA communication, helping to determine whether the simulation could be achieved. The initial set of results was promising, latency for a Sweden-Singapore

link was regularly approximately one second for a round trip. These results did depend upon the RTI used as well as time of day and general Internet traffic. As an alternative for an Internet link, the use of an ISDN direct link, or high speed Internet links were also considered. It was decided that this would not be followed up as the Internet tests provided satisfactory results.

Internet tests were performed both before and after the face to face meeting and integration of the two systems. Before the integration, the Internet was used as a platform both to discuss integration, as well as to attempt to integrate the code. After the integration was completed the actual simulation was tested when run in a distributed manner.

The Internet integration attempts demonstrated that it was not really feasible to perform the integration of two systems purely over the Internet. Though all of the integration planning was achieved remotely, the actual integration across the Internet was not as effective as during the face to face meeting. Therefore the Internet integration provided a good stepping stone to the final work, but could not achieve the goal.

After the systems were integrated, further tests were run across the Internet to determine whether the federation would perform the same across the Internet as it did when run in the lab. The test configuration is shown in figure 3.
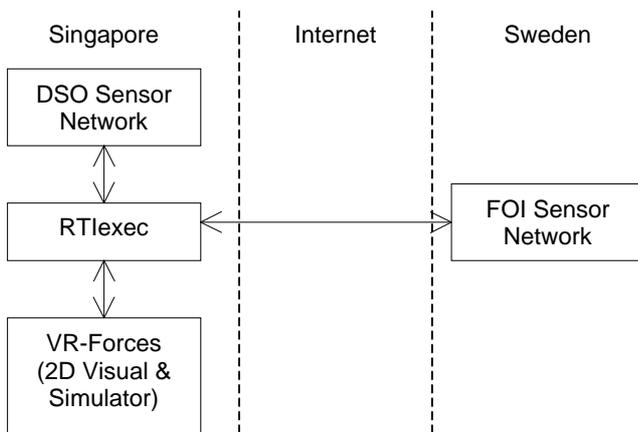

Fig. 3. Configuration for Distributed Simulation across the Internet

To help both systems to keep accurate information for the vehicles states, all the hardware was synchronised using Network Time Protocol (NTP) clients, and timestamping of all updates sent along the HLA. This enables the dead-reckoning algorithms to more accurately determine the location of the vehicles. The results of the Internet testing showed that the results were comparable to that of the lab tests.

6   Test Scenario

The integrated demonstrator was tested on the common scenario as shown in Figure 4. The two networks were deployed at the respective junctions to detect any hostile target that might be a threat to the power station or the mobile command centre. The simulation sees two groups of vehicles - one from the upper right corner and the other from the bottom right corner - travelling along predetermined routes towards the power station and command centre respectively. The first vehicle group was simulated to pass through both the FOI and DSO networks and move towards the command centre. The FOI network, on detecting the vehicle group, will alert the mobile command centre of the possible threat. The mobile command centre, on alert of the possible threat, will move to a safe location. The second vehicle group, coming from the bottom right route, will approach the junction about the same time as the first vehicle group. On detecting that the group is moving towards the power station, an alarm will be raised.

The scenario was generated on the terrain data provided by the Swedish side. The terrain data used was high resolution raw data with resolution of less than 1m. The data was captured using scanning laser radar and digital photo and included information on the topology, trees and buildings. In the simulation, a performance analysis tool written by the DSO team was also used. The analysis tool is an offline tool that takes in the log files of the fused tracks and ground truth. It then computes certain parameters for fusion federate performance analysis. The test scenario was successfully demonstrated in April 2003 at FOI in Linköping, Sweden; and subsequently in November 2003 at DSO in Singapore.
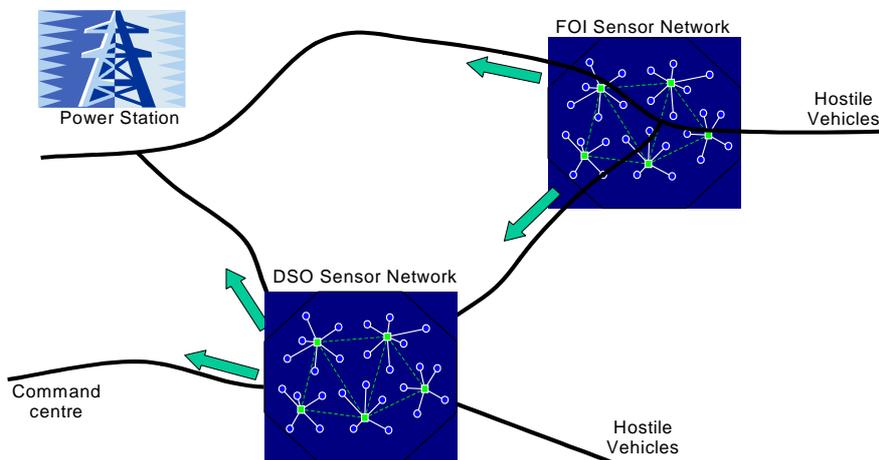

Fig. 4. Simulation testbed using a common scenario.

Figure 5 shows a pair of screen captures from the tests. The first is the simulator; the targets are in red, and the computed tracks in pink boxes. The second screen capture shows the display of the UGS position. The sensors are shown as triangles and the tracks as crosses with the uncertainly area and track history (the uncertainty area is small so it is difficult to see).
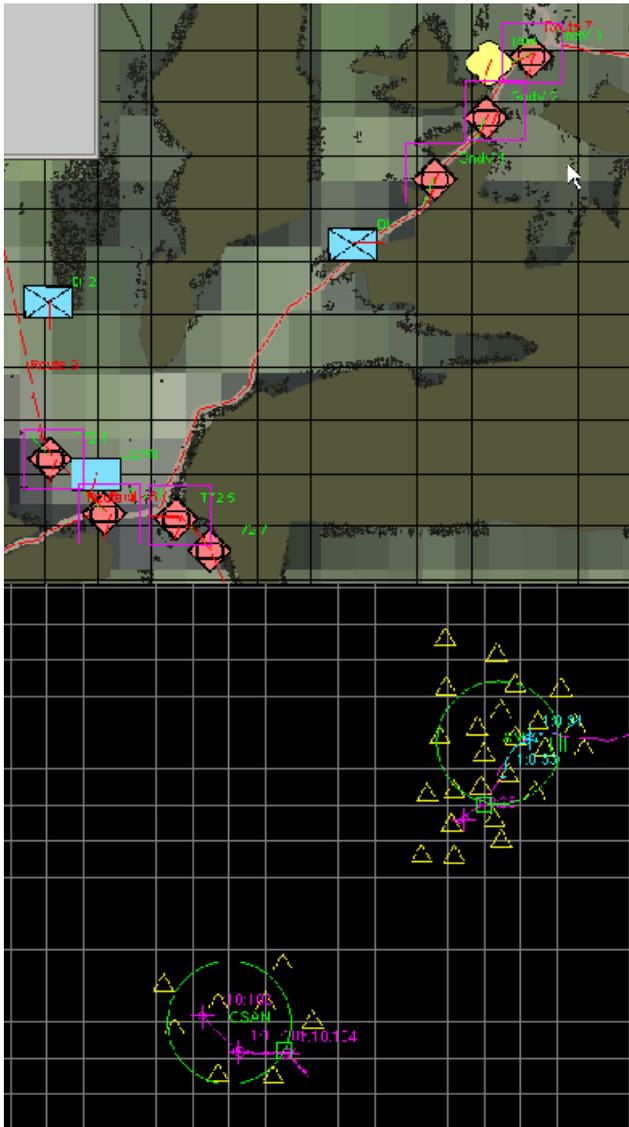

Fig. 5. Screen captures from the simulator and
the sensor network.

7   Conclusions

The success of the demonstration shows that the approach of building a testbed based on common specifications is feasible. The testbed provides an interface for "plug and play" of fusion federates such as ground sensor network modules. This approach also enables co-operation on fusion research between the different projects and different organisations. Both collaboration teams can share the different simulation modules such as simulation engines, visualisation tools, sensor models, environmental models and analysis tools. Each team can now leverage on each other in the development of different simulation modules.

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