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LONG RANGE ARTILLERY SIMULATION USING COMPONENT BASED DEVELOPMENT TECHNIQUES AND THE HIGH LEVEL ARCHITECTURE

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ABSTRACT

This paper describes the use and development of an artillery synthetic environment. This SE will be used to support system concept development and validation for long range and smart munitions. It will also be used for the development of operational concepts for these weapons including an investigation of ISTAR requirements. The SE is a force level analysis tool, representing artillery batteries and company level entities. It is capable of running with a human in the loop or in a closed Monte Carlo mode. The SE has been built using a component-based development approach. The HLA FOM/SOM mechanism is used to describe the interfaces between the component simulations. Each component simulation (federate) represents a different functional area – such as sensing, combat, and command and control. The component approach has allowed the development team to manage the level of complexity within each federate. This has resulted in a very rapid development cycle and a very flexible and extensible end product.

1 INTRODUCTION

1.1 Background

Interest in the use of synthetic environments as a tool for operational analysis (OA) has been growing over the last few years. In the UK community this has been stimulated by the development of the HLA and its free release in to the international simulation community. In 1998 the UK's Project FlasHLAmp investigated the applicability of the HLA to operational analysis (Colby et al. 1998). (This work also considered the DMSO Common Technical Framework.) It concluded that there was little immediate need for the HLA, largely because of the style of simulation development prevalent at the time. Simulation users called for small understandable models and required approximation and abstraction in preference to more detailed all-encompassing models.

More recently, initiatives in the UK such as Synthetic Environment Based Acquisition (SEBA) (UK MOD SE EPWG 1999) have raised the need for operational analysis techniques and simulations to be applied in support of acquisitions. Because of the purpose of these SEs many federates tend to be detailed entity level models provided by suppliers. It is usually necessary to augment these federates with others providing wider context and interactions in order to create a useable and valid operational analysis tool. This has reawakened interest in the HLA in the UK OA community.

1.2 Need for the Tool and the Approach

Late in 1999 a requirement arose to study the system requirements, concepts of operations and effectiveness of novel long range artillery munitions. These munitions were not well represented in the operational analysis tools then available and so it was decided that a new tool should be created.

At the same time, there was a desire within the analysis community to experiment with the use of synthetic environments as a tool. Two issues were of particular interest. Firstly, the tool would need to be flexible and easily expandable. The munition projects were in their early stages and the system concepts were ill defined. It was not possible to build a detailed simulation of the concepts simply because there was no detailed design for the concepts. It was therefore clear that the tool developers would need to be able to modify it quickly - and cheaply - as the understanding of the concepts evolved.

The second issue was software re-use. The simulation tool was being developed using private venture funding. There was a strong desire to maximise the value of any tools developed using this funding. The development team believed that this would come through re-use of parts of their simulation rather than re-use of the whole.

The software specialists within the development team recognised that a component based architecture could help them to make their software more re-useable. They recognised that the HLA could provide them with a mechanism to achieve this interoperability. They also realised that HLA compliance might allow their simulation – and its components - to play in one of the many other federations that would be developed in pursuit of the SEBA initiative.

1.3 Component Based Development and the HLA

Simulation re-use has been one of the promises of the HLA since it was released by the US DMSO. The early FEDEP (federation development and execution process) models (DMSO 1996) called for a 'resource repository' from which developers would pull components to create the federation that satisfied their users' needs. Even then this vision was recognised as overly optimistic. In a previous paper one of the authors (Colby 1997) drew an analogy between re-use using an HLA compliant resource repository and the growth of re-use using object-oriented software development techniques. He concluded that one could not pre-empt re-use; nothing is proven re-usable until it is re-used. Therefore, investing in making complex software re-usable is almost certainly not economically viable unless and until there is a real need to re-use it.

This view was developed as a counterpoint to the view that any simulation could be made HLA compliant and hence re-used. Whilst this may be strictly true, it is unhelpful. This is particularly true for the operations analyst because the behaviour of the resulting federation will be difficult to understand and is unlikely to provide a consistent and coherent model of a particular problem area. The analyst is more concerned to create a flexible tool that concentrates on particular important issues and that can be run quickly in response to changing questions and evolving understanding, rather than spending effort managing an all-encompassing megalithic federation. This view still holds true and, so far, has been supported by events.

However, whilst the view holds for re-use of large scale simulations, it does not necessarily apply to smaller scale systems. Over the last few years 'component based development' has become established as the key method of re-use in large projects. In this context components are software entities that perform a well defined set of functions and need not be standalone applications. In simulation terms, a component need not be a standalone simulation.

The component based development approach is reliant on the developer being able to draw on a set of components that are defined by their interfaces and a high level description of the functionality that they provide. The software engineer using a component need not be concerned with its detailed behaviour. This is somewhat analogous to the object-oriented concepts of encapsulation and (data) hiding. The HLA's interface specification method – Federation and Simulation Object Models (FOMs and SOMs) – provides just this encapsulation of functionality. Hence it is possible to use the HLA to support component-based re-use. The authors have created the Deep Attack Synthetic Environment (DASE) to explore the practicality of this approach.

2 LONG RANGE ARTILLERY STUDIES

2.1 Concepts Under Study

The DASE is to be used by studies supporting two new types of indirect-fire artillery ammunition.

The first is a new course correction fuze unit that corrects in range only, and reduces the delivery errors of standard spin-stabilised artillery ammunition, particularly for extended range weapons. This is LC3M (Low Cost Course Corrected Munition).

The second is a new fin-stabilised munition with on-board autonomous guidance and trajectory control, able to achieve greatly increased ranges with significant reduction in delivery errors which become independent of range. This is LCGM (Low Cost Guided Munition). This new munition will be a carrier type vehicle, capable of delivering Sensor Fuzed Munitions (SFMs), Unitary blast/fragment weapons and Bomblets, or other types of cargo as required.

LCGM trajectory correction capability will enable simultaneous delivery of successive rounds from the same barrel, or from different attack directions over the target to suit the particular payload/target scenario. The operational benefits of this new capability can be optimised in SEs.

2.2 Study Issues

Studies will investigate the concepts of operations for these munitions. This will consider lethality but will also address the optimum range for the munitions, including an assessment of the types of target that are likely to be engaged at each range, how those targets could be found and identified and how they should be attacked. As a part of this assessment the studies will assess the ISTAR system needed to support long range artillery and hence exploit the full capability of the LC3M and LCGM. Studies will also investigate the utility of specialist variants of LCGM carrying, for example, sensor packages to support recce or battle damage assessment (BDA).

In the longer term studies are expected to consider force mix and the balance between rocket and tube artillery. It could also address the numbers and organisational placement of battlefield Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) assets required to support artillery operations.

2.3 Study Method

The concept of analysis for the studies for LC3M and LCGM is being finalised. The outline presented below gives an overview of the likely approach.

The study team will use the DASE in real time mode with expert human operators to explore concepts for the munitions. These might differ in range, round to round accuracy, magnitude of course errors that can be corrected and so on. This activity will enable the team will select a small number of representative alternatives for each concept.

DASE will be used in real-time mode to record the actions of expert human operators in a set of operational scenarios that they have selected for detailed study. After the recording exercise the study team and expert operator will validate that the appropriate concept of operations has been followed and that the conduct of the operation is militarily valid.

The study team will then determine the sensitivity testing that they wish to conduct. This is expected to include variation of target location errors (TLEs) and variations in the accuracy of the guidance or course correction systems. They will then use the DASE in batch mode using a Monte Carlo approach to investigate the sensitivity of the results obtained from the human-in-the-loop runs to these variations.

3 DEEP STRIKE SYNTHETIC ENVIRONMENT

3.1 Architecture and Approach

The DASE is a federation composed of four HLA compliant federates. The federates are able to run in real time with human interaction or faster than real time (‘causal time’) in a closed Monte Carlo batch mode. This ability allows the user to undertake both types of run using the same simulation components thus removing the need for cross validation.

The DASE has been designed using a ‘composable’ or ‘component based’ approach. None of the federates are viable as standalone simulations. The utility of the DASE is provided by the emergent behaviour of the federation. This is a key feature of the component-based approach. The HLA facilitates the approach by enforcing rigid interfaces between federates. This has allowed the DASE development team to create complex federated behaviour using simple federates.

3.2 Federation Design

The four federates that provide the simulation capability of the DASE are shown in Figure 1. The federation also includes the DMSO DCT (Data Collection Tool) to log specific events for later analysis. This is used in both real-time and batch mode.

The HILAC (Human-In-the-Loop Artillery Commander) provides the user interface to the DASE. It allows the user to task artillery batteries with movement and fire mission. It allows the user to task ISTAR assets and displays the detection reports that they make. It also simulates the moving artillery targets.

The ISTAR federate models the detection performance and reporting by the ISTAR assets. Movement may be directed by the user or prescripted to simulate data feeds from assets that are outside of his control.

The Battery model federate simulates the response of the artillery batteries to the commands entered through the HILAC. It uses a state machine to maintain and control the behaviour of each battery. It models the movement and firing of batteries.

The damage calculator determines the effect of artillery fire from each battery. It reports the effect to the HILAC. This federate is separated from the battery model to provide for future scalability.

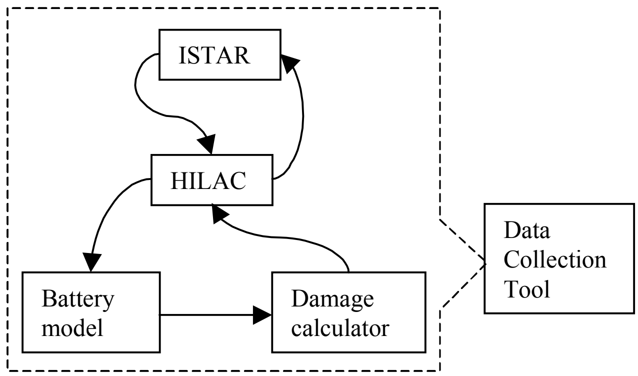

Figure 1: DASE Federation Architecture

3.3 Immediate Plans

The immediate plans for the enhancement of the DASE are predicated on the development of the LC3M and LCGM concepts. The most important plans are therefore to adjust and enhance the representations of the munitions and their effects as the concepts are developed.

In the short term the development team plan to split the target modelling from HILAC federate and move it to a new ‘battle model’ federate. At the same time the representation is expected to be improved to become two sided and to include simple direct fire combat (resolved using Lanchester equations) between the entities of each side. Movement will be user scripted as at present.

There also exists the potential to use elements of the DASE to provide a harness for artillery functions within other synthetic environments which model some of the detail of the direct fire combat, or the entity level interactions between some of the targets and sensors. This will probably require expansion to utilise the RPR FOM.

Other study teams are interested in the use of DASE in support of ISTAR tasking and coverage modelling. It is expected that they would require improvements to the modelling of the ISTAR systems and the communications between them. The development team is investigating the requirements of these potential users.

3.4 Longer Term Plans

As the understanding of the munition concepts evolve the system engineers will develop their own models. It is desirable that they are able to exercise these models within the wider context that the DASE provides. In particular, the team have already developed an approach that would allow detailed representations of specialist variants of the munition to replace the modelling in the damage calculator. This would allow the DASE to include federates modelling, for example, recce shells in the federation without modifying the damage calculator federate.

The development team plan to implement a command agent representation of the artillery commander for use in the closed (batch running) version of the DASE. This would allow the study team greater scope to investigate concepts without being dependent on the availability of expert operators. However, the feasibility of developing and validating an agent is dependent on the understanding that is gained from the expert human operators during the forthcoming LC3M and LCGM studies. In the longer term a command agent representation could also be used to replace the scripted behaviour in the proposed battle model federate.

4 SUCCESS OF APPROACH

The DASE team chose to use a component based approach both to promote re-use and to reduce the complexity of the software components whilst maintaining the complexity of the emergent behaviour of the federation. The approach has been successful on both fronts. Parts of DASE have been reused – not as whole federates but tailored to use. This has been a quick, cheap and relatively painless activity simply because of the relative simplicity of the federates. Furthermore, staff with no experience of the federates (or even the HLA) have become effective developers in only a few weeks, rather than the many months they would have taken with a large monolithic simulation.

Leaving staffing issues aside, it would not have been possible to apply a large monolithic model to the problems that we have solved with a few simple federates derived from one of the DASE set. The simplicity of components that has resulted from the composable approach has given us the ability to respond to requirements for new federates in different problem areas quickly and cheaply.

5 CONCLUSION

It is easy to conclude that achieving simulation re-use is easy. This is not true, and this has been amply demonstrated by in the past. The major problem has always been that the different users have different requirements and therefore have different views on the trade-offs that the developers have made. Whilst there are many example of large scale simulations that have a large user base, there are very few examples of simulations that have been re-used in simulations that satisfy very different requirements. This is largely due to the complexity of the larger models. Because the DASE federates are relatively simple we have been able to re-use derivatives of them in simulations covering other domains – federates providing, for example, air to ground weapons modelling and tactical air picture reporting.

We conclude that the component-based approach to simulation development re-use is practical and offers a viable way forward for simulation development. The approach should improve simulation software re-use. We expect, however, that it will be necessary to tailor components to meet the detailed requirements of a particular federation. However, because the approach requires that the components are relatively simple this should be a quick and relatively inexpensive activity.

The component-based approach should also reduce the overheads associated with staff training and replacement. Because simulations are formed from a number of components each developer only needs to be familiar with a few simple components. The developer of a new component does not need to understand internal functionality of the other components in detail, although an understanding of the interface and the externally visible behaviour that it provides to the federation is certainly required. Hence the learning curve for new developers will be significantly reduced when compared with that for developers of monolithic simulations. Our experience has proven the validity of this assertion. However, although the dependence on a few expert developers has been reduced the project is still dependent on a few expert architects who understand how the emergent behaviour of the meets the user’s requirements.

ACKNOWLEDGMENTS

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