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Simulation Reuse and Interoperability

A VISUAL TOOL TO SIMPLIFY THE BUILDING OF DISTRIBUTED SIMULATIONS USING HLA

Shawn PARR

Introduction

The High Level Architecture (HLA)[1] is intended to promote the reuse and interoperability of distributed simulations. While in many respects HLA achieves these goals, it unfortunately also adds additional cost and complexity to the development task, resulting in the need for specialist HLA skills.

This paper outlines the problems currently faced by simulation developers wanting to use HLA, and the way they are addressed by the Calytrix SIMplicity product.[2]

About HLA

Why Use HLA?

In an ideal world, a developer could write a component once and then reuse it in any simulation in which it played a part. This would have a variety of benefits:

- Simulations could be more quickly and easily constructed at a reduced cost.
- It would become easier to construct larger and more sophisticated simulations assembled from existing components.
- Component quality would increase, as more work would be focused on improving existing component functionality rather than rewriting components from scratch.
- Components from different developers and different projects (potentially in different parts of the world) could be combined in new simulations.

The High Level Architecture was introduced to facilitate simulation reuse and interoperability in order to realise the above benefits. HLA addresses a number of the limitations imposed by the data protocol approach associated with the earlier Distributed Interactive Simulation (DIS) standard. HLA has been mandated by the

U.S. Department of Defence, has been published as a standard by the Institute of Electrical and Electronics Engineers (IEEE)[3] and the Object Management Group (OMG),[4] and is being adopted by creators of simulation software worldwide.

The Problems with HLA

While there are good reasons to use HLA to develop simulations, there are also drawbacks. The learning curve for HLA is steep, and a lot of extra work and code is needed to build the necessary software infrastructure needed for HLA compliance. Specific problems that simulation developers encounter include:

- The HLA "glue" code required to bind a simulation component to the RTI[5] is often tightly coupled or intertwined with the simulation code. This makes the code unnecessarily complex and difficult to change and reuse.
- Due to the complexity of the RTI interface, specialist-programming skills are needed to write HLA compliant components.
- A number of cross platform issues introduce unnecessary portability and interoperability issues in HLA development (one example of this is the handling of "big-endian/ little-endian" conversion between hardware architectures).
- In a single simulation, all HLA components (known as "federates"[6]) must use the same data specifications as defined in the simulation's Federation Object Model (FOM). For example a location cannot be sent as 'latitude and longitude' in one component and received as 'eastings and northings' in another. This means that a component cannot be easily taken out of one simulation and reused easily in another unless they use exactly the same data types and format conventions. This problem is often referred to as "FOM Agility."
- Due to the complexity of HLA there is a tendency to maintain a relatively coarse granularity at the federate level in order to minimise the number of federates to develop (hence minimising the pain of RTI integration). However, it is often more desirable to build finer grained components in order to maximise the potential for re-use and extension.
- There are two incompatible HLA standards: DMSO 1.3 and IEEE 1516. Federates written for one standard cannot easily interoperate with those written for the other, thus undermining the key goals of interoperability and reuse.

SIMplicity solves the above problems, thereby making it easer for the simulation community to create large-scale, high fidelity simulations constructed from reusable and exchangeable simulation components.

Addressing the Problems with HLA

In order to address the problems described in the previous section, Calytrix has developed SIMplicity, which delivers an IDE for HLA development with the following attributes:

- Simple to use. Much of the work can be done through a visual interface so that specialist HLA skills are not needed.[7]
- Introduces a Simulation Component-Model (SCM) to HLA development.[8,9] This allows SIMplicity to decouple a component's simulation logic from its HLA "glue" or integration code, thus simplifying simulation development and making component simulation logic more reusable.
- Automatically handles the binding of the simulation code to the HLA infrastructure (by generating the FOM and federates infrastructure code), thus removing much of the "grunt work" associated with developing the RTI API.
- Handles transformations between simulation components. This addresses inter-platform issues (like "big endian – little endian"), and data translations between components created for different FOMs (FOM Agility).
- Allows developers to decompose a federate's functionality into a collection of finer-grained reusable components.
- Utilizes a Model Driven Architecture™ approach[10] to development that enables developers to easily transition and reuse their existing component's simulation logic with different RTI versions (including reuse between 1.3 and 1516 standards) and future simulation middleware.

An Introduction to SIMplicity

*A simulation developer should be concerned with **what** the simulation does, not **how** it integrates with the HLA infrastructure.*

Calytrix SIMplicity is an integrated development environment (IDE) that enables software developers and scientists to rapidly create component-based simulations from new and pre-existing components in a visual environment.

In this section we will introduce the underlying concepts and architecture of the SIMplicity development environment, as well as providing an overview of the component-model adopted.

Adopting an MDA Approach

Design and development within the SIMplicity IDE is based on the OMG's Model Driven Architecture (MDA) approach.[11] In summary, MDA provides a common approach for designing and building a system that remains decoupled from the eventual languages, platforms and middleware environments they will be used in. The key advantage to MDA is *future proofing*, as it provides a mechanism for an organization to design their systems once and then transition them over time when *the next best thing* comes along.

Following the MDA approach, developing simulations within SIMplicity is made up of the following phases:

Phase 1: The developer creates a *platform independent model* (PIM) for their simulation using UML[12] and specialized notation. The PIM remains independent of the eventual middleware infrastructure or RTI implementation that the simulation will be deployed into.

Phase 2: From the PIM the developer further refines the model to create a *platform specific model* (PSM). For example, in a simulation context a PIM can be refined for either an HLA 1.3 or IEEE 1516 PSM. It is important to note that the PIM and PSM remain separate, allowing a single PIM to be refined to a number of PSMs without having to re-implement the simulation logic.

In combination, the PIM and PSM provide a complete description of the simulation components and the infrastructure and services required to execute the system.

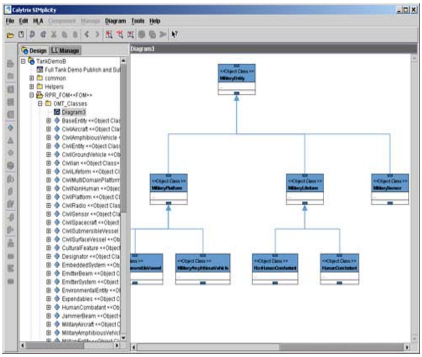
Phase 3: Based on the PIM and PSM meta models, a template based code generation engine can be used to generate the simulation's code, resulting in compilable federates that will execute on the targeted platform; all that remains is to insert the required simulation logic or behavior into the place holders created during the generation process (see the Simulation Component Model section below).

Lets now examine each of these phases, in relation to HLA and simulation, in more detail:

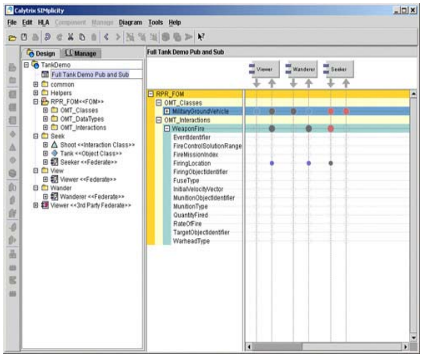
Phase 1 - Design your simulation

Central to the development process are visualizations to assist and simplify the design and specification of the simulation and its participant components. Starting from a blank canvas it is easy to model a simulation, from the base data elements and FOM to the federates and their relationship with each other.

SIMplicity employs a number of UML and specialized diagrams to allow the developer to rapidly construct a simulation model (see Figure 1).



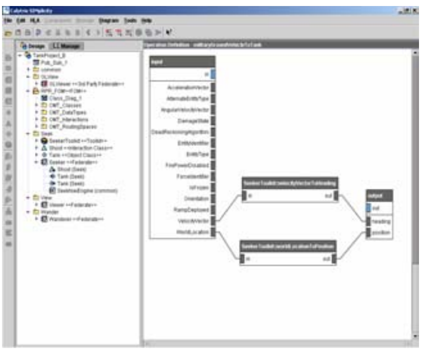
A UML Class diagram is used to model the simulation's base data elements and FOM.



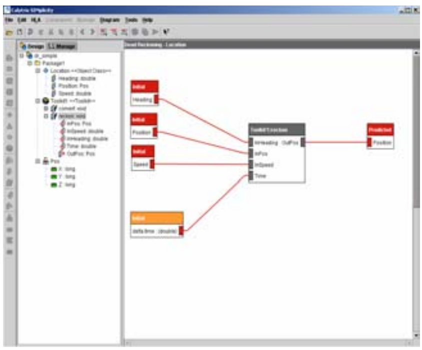
SIMplicity's Publish and Subscribe Diagram, relationships in the model.

Figure 1: Simplicity's Diagrams.

As part of the design process the developer will also define the relationships between the individual federates. This includes modeling transformations between semantically equivalent but syntactically different data items, allowing you to incorporate federates that use different SOM elements into your simulation's FOM (FOM-Agility). Similarly, dead reckoning and threshold values can be applied to published data objects through the IDE, reducing the amount of data traffic exchanged at execution time (see Figure 2).

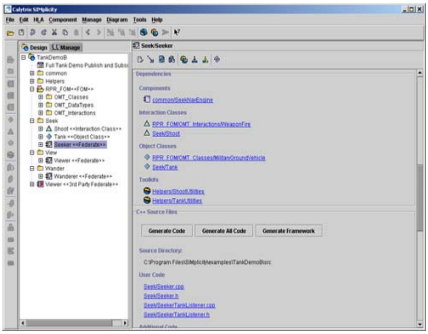


Connection diagrams allows the user to visual define complex data transformations between interfaces.

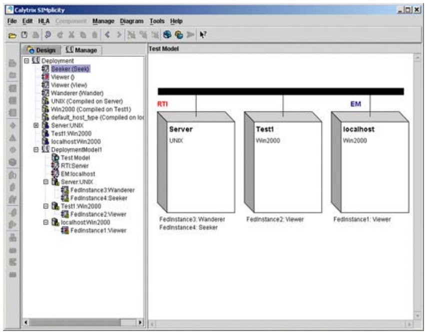


Link graphs are employed to easily capture complex dead-reckoning requirements.

Figure 2: Simplicity's Connection Diagrams and Link Graphs.



Property pages provide a way for developers to specialize their model.



UML deployment diagrams are used to specify how the system is to be deployed and execute across the distributed network.

Figure 3: Illustration of Property Pages and UML Deployment Diagrams.

By adopting a component model (see below) these types of integration refinements can be changed and regenerated seamlessly into a federate's integration code without having to revisit the existing simulation logic.

At the completion of this design phase the developer has specified their simulation's *platform independent model*.

Phase 2 - Refining your simulation

Following the high-level design phase the developer specializes or refines the simulation's PIM to the target environment to create a *platform specific model*. The PSM identifies key platform specifics such as the code generation language (C++, Java, VB) and target simulation architecture, including HLA vendor and version information.

As part of the PSM process the developer may need to model the physical deployment, via a UML diagram, of their simulation. Physical deployment will have an impact on issues such as byte ordering and host type, all of which needs to be taken into consideration during the code generation and compilation process. Figure 3 illustrates property pages and UML deployment diagrams.

Phase 3 - Generation and execution

Once the PIM and PSM are complete a template-driven code generation engine can be employed to create all the components and configuration files for the simulation. At the end of this process the developer has a compilable simulation that will execute on the targeted platform; all that remains is to insert the simulation logic or behavior into the generated components.

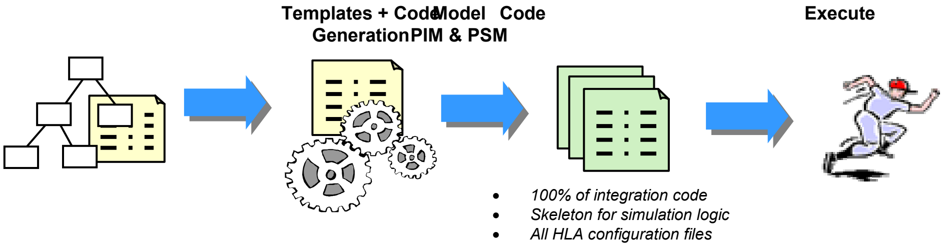


Figure 4: Simulation Life Cycle.

Local and remote compilations can also be managed through the same IDE, thus ensuring that the simulation is ready to be executed on the modeled network. Once the simulation has been built, tools can be used to package, deploy and execute the distributed simulation directly from the unifying IDE.

The diagram shown in Figure 4 summarizes the design, code generation and execution process used to manage the simulation life cycle.

Under the Hood

The Simulation Component Model

One of the core objectives of our work has been to insulate the federate developer from as much of the RTI infrastructure as possible, therefore lowering the barrier to HLA entry. Driving this objective is the ability to enable scientist and non-middleware programmers to develop simulation logic in their preferred component-based development language (C++, Java, Visual Basic .NET etc) with little knowledge of HLA and that these components can then be rapidly reused in any HLA simulation.

In order to achieve this objective we have created the Simulation Component Model (SCM),[13] which describes a programming pattern for developing federates based on the CORBA Component Model (CCM).[14] To help explain the SCM the diagram in Figure 5 shows the current programming responsibilities using just the RTI compared to that with the SCM.

As the above diagram shows, the SCM separates the HLA 'glue' code, which resides in the automatically generated integration code, from the simulation logic. In contrast, without a component model managing the developer would have to construct the main execution loop and the simulation ambassador from scratch, while using the RTI API to integrate the component into the HLA environment, as well as managing all the underlying plumbing issues like marshalling and un-marshalling of data to and from the RTI.

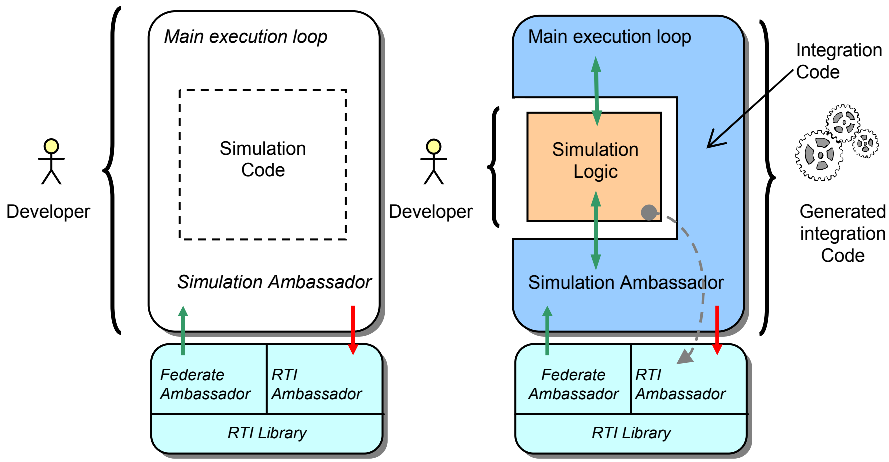


Figure 5: Developer Responsibilities with Just RTI (left)
and with the SCM (right).

When creating new federates, the developer defines their interfaces and relationships within the visual environment, which in turn can be interpreted and used by a code generation engine. By using customizable templates it is possible to ensure that the generated code exploits good OO techniques and design patterns, providing the developer with a well engineered and consistent code base (a simple class to provide the simulation logic in), as well as employing abstractions to insulate the developer from most of the generated HLA boilerplate code. Most common HLA functions, such as publishing and subscribing to data objects and interactions, and basic timing models, are seamlessly handled in the generated code, insulating the developer from writing any RTI calls.

In addition, the separation of simulation logic and integration code provides a mechanism to modify and transition a component between different HLA implementations without having to revisit or update a federate's tested simulation logic. For example, you can regenerate the integration code for different RTI implementations without impacting the simulation logic code (see Figure 6).

Architectural Overview

In order to create an extensible MDA based architecture that can support a range of varied and changing infrastructures, it is important to build a "pluggable" architecture that can accommodate change. To this end, the SIMplicity architecture can be broken into four key components:

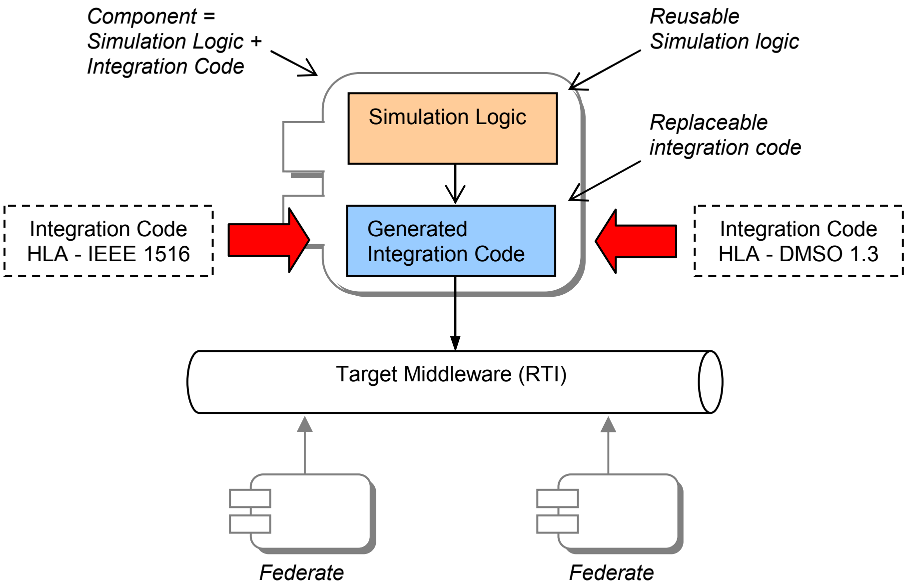


Figure 6: Separation of Simulation Logic and Integration Code.

GUI Layer: The GUI or presentation layer provides the user interface and manages the modeling and visual aspects of the system.

Meta Object Model: The Meta Object Model layer maintains the design internally, which is a highly customizable data structure for describing and storing all the PIM and PSM characteristics of a model.

Platform Engine: The Platform Engine is responsible for generating all the code for the simulation. This is achieved by mapping the characteristics held in the Meta Object Model to the corresponding code templates.

Plug-ins: SIMplicity supports a pluggable architecture for incorporating and updating PIMs, PSMs and code templates.

An *MDA Plug-in Developers Kit* will allow organizations to customize the design and code generation process to suit their particular requirements.

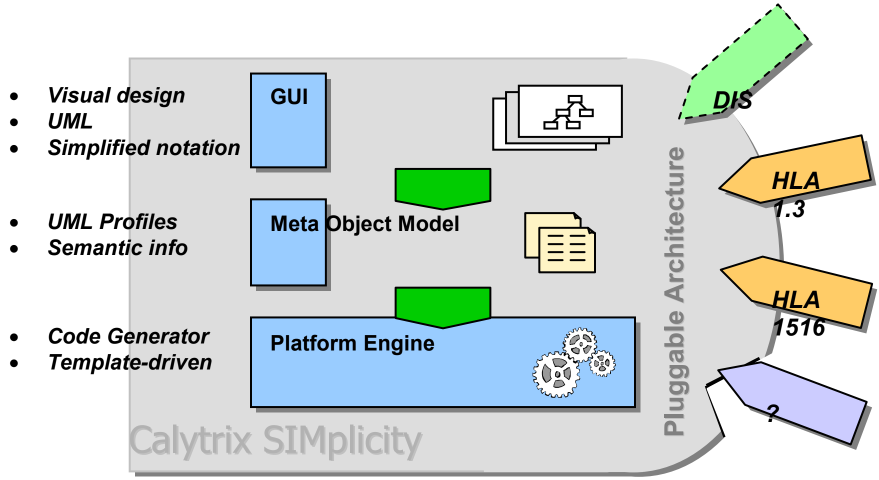


Figure 7: SIMplicity's Architecture.

The diagram shown in Figure 7 provides an overview of the SIMplicity architecture.

SIMplicity is working towards supporting multiple plug-ins, allowing the developer to define the following platform specific characteristics through the IDE:

- Simulation architectures: HLA (HLA 1.3 and IEEE1516 standards) and DIS;
- HLA platform transitions: from NG4 → NG5 → NG6; and
- Component languages: C++, Java and .NET.

Addressing Potential User Concerns

This section outlines concerns users may have and discusses how these have been addressed.

Can You Really Abstract the Developer from HLA?

The HLA integration code that SIMplicity generates contains a layer of abstraction that sits between the developer's code and the RTI interfaces, thereby directly shielding (not replacing) the developer from the RTI API. This results in a much smaller set of code to be maintained by the developer. In the end, the developer is only required to know about the simulation in general and not HLA specifically.

Using this method the developer is still able to directly access the RTI from their simulation logic code if required.

What about Timing?

SIMplicity provides the most common timing models used by simulation engineers. Should any advanced time management be required, such as optimistic timing, the developer is able to extend the generated code to support this.

Avoiding Vendor Lock-in

Users have expressed a concern about being too dependent on a single vendor. This is addressed by SIMplicity in a number of ways:

- SIMplicity is non-intrusive at the federate level, allowing SIMplicity created federates to be deployed and used in non-SIMplicity environments without requiring any additional or third party run-time services.
- SIMplicity provides the developer with all generated code. There are no proprietary APIs or runtimes required to use a SIMplicity HLA component in a running simulation.
- SIMplicity supports multiple RTI implementations and middleware infrastructure.
- Wherever possible SIMplicity utilises both existing standards (like HLA, XML, UML, MDA, etc) and component standards (like the CORBA Component Model (CCM)).

Increasing Federate Fidelity

One of the major concerns with increasing the fidelity of a simulation by decomposing federates into many smaller components is that of performance, as replacing one high-level federate with a composite of smaller federates which communicate via the RTI may adversely affect the simulation's performance due to an increase in RTI and network traffic.

SIMplicity overcomes this issue by providing a component-based solution within a federate. Here, entities are represented as independent reusable components that communicate through interfaces. These interfaces are subject to the same transformation facility as regular federate interfaces.

Limiting Power Users

With any visual or 'ease of use' tool there is the concern that it imposes limitations on power users. SIMplicity addresses this in several ways:

- Significant flexibility is built into the visual environment to accommodate a wide spectrum of users. This includes access to different timing schemes, data exchange, transformations, etc.
- SIMplicity works alongside existing technologies and methodologies. The use of SIMplicity will not prevent interoperability with components or

simulations created by hand or with other tools.

- The use of SIMplicity does not preclude the use of the original RTI API. Should any specific HLA behavior be required then the developer is free to provide this implementation.

Performance

Reasonable performance is recognized as a key requirement and SIMplicity is built to ensure it meets acceptable performance criteria.

The code generated by SIMplicity represents the code that the simulation developer would normally have to write. That is, there is no 'additional' code being executed – the developer is merely responsible for less of it.

Cross-Platform Support

Portability is seen as a key requirement. The follow platforms are currently supported with more to follow:

- Windows 2000/NT/XP
- Linux Redhat 6.2 and 7.2

Is Re-use Really Achievable?

Reuse is a core goal in moving to HLA based simulations, however there are some basic logistical issues that can prevent re-use goals being achieved. SIMplicity addresses:

- Storing and cataloguing components (pigeon hole problems)
- Finding components in a large repository (cataloguing problems)
- Configuration management of components (version control problems)
- FOM-Agility (incompatible component interfaces)

Sharing Binary Components (Protecting IP)

SIMplicity through the component repository provides the ability to distribute and share simulation components without releasing source code, thus protecting valuable intellectual property and meeting security requirements.

Conclusion

The adoption of HLA will provide an opportunity to realize the benefits of reuse and interoperability for those involved in developing simulations. However the complexity associated with HLA is hindering its adoption. SIMplicity solves many of the problems associated with HLA development, making it feasible for developers to create HLA simulations without specialist HLA or middleware knowledge.

Notes:

1 *IDL Application Programmer's Interface* (Defense Modeling and Simulation Office, 1998), <http://www.dmso.mil> (5 September 2003).

2 Shawn Parr, Alex Radeski, and Robert Whitney, "The Application of Tools Support in HLA," in *Proceedings of the Simulation Technology and Training Conference 2002 (SimTecT 2002)*, Paper ID 26 (May 2002).

3 *IEEE Std 1516-2000 - IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) — Framework and Rules* (Institute of Electrical and Electronics Engineers Inc, approved 21 September 2000), <http://www.ieee.org> (20 September 2003).

4 *Distributed Simulation Systems Facility v1.1 specification* (Open Management Group), <http://simsig.omg.org/> (20 September 2003).

5 RTI is an HLA term for "Run Time Infrastructure". The RTI provides the run time services needed to allow HLA components (federates) to interoperate.

6 A "federate" is an HLA component. Any number of federates can make up a "federation" which simulates a specific scenario.

7 Russell Keith-Magee and Shawn Parr, "Visualising Distributed Simulation Design And Deployment," in *Proceedings of the Interservice/ Interindustry, Simulation and Education Conference* (Paper ID 258, 2002) <http://www.iitsec.org> (29 October 2003); Parr, Radeski, and Whitney, "The Application of Tools Support in HLA."

8 Alex Radeski, Shawn Parr, Russell Keith-Magee, and John Wharington, "Component-Based Development Extensions to HLA," in *Proceedings of the 2002 Spring Simulation Interoperability Workshop*, Paper ID 02S-SIW-046 (SISO Spring 2002).

9 Alex Radeski and Shawn Parr, "Towards a Simulation Component Model for HLA," in *Proceedings of the 2002 Fall Simulation Interoperability Workshop,* paper ID 02S-SIW-079 (SISO Fall 2002).

10 *Model Driven Architecture* (Object Management Group), <http://www.omg.org/mda/ > (29 October 2003).

11 "Calytrix SIMplicity -- An MDA Approach to Distributed Simulation" (Calytrix Technologies Pty Ltd, August 2002), <http://www.omg.org/mda/mda_files/ Calytrix_SIMplicity_OMG_MDA_Release.pdf> (29 October 2003).

12 Grady Booch, James Rumbaugh, and Ivar Jacobson, *The Unified Modeling Language User Guide* (Addison Wesley, 1999).

13 Radeski, Parr, Keith-Magee, and Wharington "Component-Based Development Extensions to HLA;" Radeski and Parr, "Towards a Simulation Component Model for HLA."

14 *CORBA Component Model Tutorial*, ccm/2002-0401 (OMG CCM Implementation Group, April 2002).

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COMMON DATA ADMINISTRATION, DATA MANAGEMENT, AND DATA ALIGNMENT AS A NECESSARY REQUIREMENT FOR COUPLING C4ISR SYSTEMS AND M&S SYSTEMS

Andreas TOLK

Simulation Applications and C4ISR Systems

There is a strong necessity to solve the interoperability issue between information systems used for Command, Control, Computing, Communications, Intelligence, Surveillance, and Intelligence (C4ISR) and combat simulation systems. Interoperability is an operationally driven requirement in several application domains of combat simulation systems and it is stated in milestone documents such as the US DoD Modeling and Simulation Master Plan[1] and the NATO Modeling and Simulation Master Plan.[2]

- Within the simulation application domain of training and exercises appropriate simulation systems are used to create a synthetic environment for the trainees that is supplied to the C4ISR systems used by the soldiers in the field to "train them as they fight." Hence, the simulation systems used for computer-assisted exercises (CAX) have to be able to provide the necessary input to the C4ISR systems used by the trainees. Additionally, the orders given by the trainees to the simulated units have to be brought into the simulation systems as efficiently as possible, which implies that, as a minimum, the orders have to be transferable from the C4ISR application to the embedded simulated environment.
- Modeling and simulation (M&S) have also been applied successfully in simulation-based acquisition (SBA) for several years. Simulation systems are used to build a synthetic environment that dynamically generates test data for the C4ISR systems in the acquisition process. Furthermore, M&S is used to simulate new components to be introduced into the C4ISR systems. This application also leads to the requirement for interoperability between the

simulation and the embedded system to be tested.

- While the application domains mentioned above can be considered already well established, a relatively new domain is "bringing military operations research (MOR) methods back to war:" the simulation application domain of online support to real military operations. This new application domain uses methods of M&S to support the military decision-making and command and control processes. To achieve this, methods of M&S are integrated into the operational C4ISR systems to support the analysis of alternative courses of action, to check the consistency of operational plans, to control the development of operations, etc.

State-of-the-Art Solutions

However, the challenges that a system designer faces are still big. As a matter of fact, every integration effort establishes a new project with new or reinvented solutions, own – and often proprietary – methods and tools, etc. Surprisingly, to the decision maker these interoperability issues between C4ISR Systems and Simulations have the appearance of being pure technical problems, and thus are relegated to the backwaters of M&S policy. While the focus is on the reuse of components, we are still on the level of "home workers" that prepare them for the intended reuse. Although, under the aegis of the Simulation Interoperability Standardization Organization (SISO) a study group has dealt with the issues of interoperability between C4I and simulation systems,[3] such interface building efforts are still performed on a more or less ad hoc proprietary basis and rarely any real guidance exists, which leads to double work, reinvention of solutions, and last but not least rigid bridges between the systems. And instead of "system of systems" that we aim to build, nowadays we often face a "bunch of systems." This is especially true for C4ISR system to M&S system interface solutions.

On the other hand, integration has always been an issue where different legacy or in parallel developed information technology based solutions are brought together. The commercial, as well as, the academic worlds have arrived at some interesting solutions that are applicable to military problems. And, as the problem of integrating C4ISR systems and M&S systems during the actual first phase of the integration process is a problem of establishing information exchange over the interfaces developed between the respective systems, the ideas of federated databases can be successfully applied. The theory of federated databases deals with the challenge of merging distributed, heterogeneous, and autonomous data sources in such a way that they can be used by other applications. To this end, a rigorous common management process accompanies the technical solution. For a general introduction to this domain, a reference to the work of Sheth and Larson is recommended.[4] To author's knowledge, the most comprehensive introduction and overview is Stefan Conrad's book on federated database systems, which is written in German.[5] The applicability of respective solutions to military problems is described by the author of this paper in the Simulation Interoperability Workshop Paper on "Bridging the Data Gap" between C4ISR systems and M&S systems.[6]

A Necessity for Common Data Engineering

A common problem to all the different solutions is that the system designer responsible for the integration has to know *what* data is located *where*, the *meaning* of data and its *context*, and what *format* the data has to be transformed to so that it can be used in the respective distributed applications within the overall system. Generating answers to these questions is the objective of data administration, data management, data alignment, and data transformation, which can be defined as the building blocks of a new role in the interoperability process: the task of *data engineering*. The first three of these tasks can be standardized and used in a general manner. Only the task of data transformation is system dependent, but even for this task it will be shown that a general solution exists.

As already mentioned, these are the necessary first steps in a broader interoperability framework. Although this paper focuses mainly on the data issue of interoperability, a more general framework and the future work perceived by the author will be described as well.

In the context of this paper, the author defines the respective terms as follows:

- *Data Administration* is the process of managing the information exchange needs that exist within a group of systems, including the documentation of the source, format, context of validity, fidelity, and credibility of the data. Data Administration, therefore, is part of the overall information management process.
- *Data Management* is planning, organizing and managing of data by defining and using rules, methods, tools and respective resources to identify, clarify, define and standardize the meaning of data in terms of relations.
- *Data Alignment* ensures that the data to be exchanged exist in the participating systems as an information entity or that the necessary information can be derived from the available data, e.g., by means of aggregation or disaggregation.
- *Data Transformation* is the technical process – implemented often by the respective algorithms in gateways and interfaces – of aggregation and/or disaggregation of the information entities so that they match the information exchange requirements, including the adjustment of data formats.

In reality, the majority of work has been focused on data transformation, i.e., on programming or maintenance of interfaces. However, if such efforts are not accompanied by alignment of the respective control processes for data administration, management, and alignment, the result is at best only a temporary solution, effective until the next update of one of the involved systems. Therefore, the management processes of the participating systems must at least be harmonized. In the ideal case, the program managers will even use the same methods and support tools under a common, overarching approach.

Currently, the C4ISR and the M&S communities are in the process of establishing solutions that support these management efforts. In order to ensure continuous interoperability these processes have to be harmonized and coordinated, leading to a common approach.

Data Administration

The C4ISR community understands the process of data administration very well. For every field system a Command, Control, Communications, Computing, and Intelligence Support Plan (C4ISP) is required that describes the necessary information infrastructure needed to find the components' place in the overarching C4ISR architecture. The definition of the exact information exchange requirements is part of this plan, i.e., each information entity is defined by its syntax and semantics. The required methodologies can be found in the US DoD C4ISR Architecture Framework.[7] The NATO Consultation, Command and Control (C3) System Architecture Framework is the international version of this document.[8] In this respect, the M&S community has not yet reached such maturity. However, similar ideas are already part of the Common Technical Framework (CTF) included in the High Level Architecture as well as the respective Data Standards (DS) and Functional Description of the Mission Space (FDMS).[9] Within these concepts, especially the idea of using a Simulation Object Model (SOM) defined by means of HLA/Object Model Template (OMT, IEEE P1516.2) comes close to the definition of a general information exchange view on the respective systems. However, in reality there is no consensus on a common approach neither for C4ISR systems nor for M&S systems. It might not even be exaggerated if we say that the number of experts realizing the need for such a common method is still very limited.

Data Management

The process of data management is tightly related to the definition of a domain overarching ontology. The main objective is the development of a common understanding/view of the world. In this respect, the use of reference models has proven very useful. In the domain of C4ISR two models have to be mentioned explicitly, although this should not exclude other solutions. Within the US Army, the US Joint Common Database (JCDB) data model builds the kernel for all future Army Battle Command Systems (ABCS) versions.[10] Within NATO, the Land Command and Control Information Exchange Data Model (LC2IEDM) not only provides the kernel for future C4ISR systems, but has also been used as a reference model for the NATO Data Administration Group (NDAG) whose responsibility is data management for NATO's present and future C4ISR systems.[11] The main idea of data management using a reference data model is to find matching information entities in the data model being managed and the reference data model used for standardization. For each information entity in the data model under consideration, the data management agency defines a semantically equivalent standardized information entity or a semantically equivalent set of information entities including their relations. In this way, a set of standardized data elements (SDE), including respective mapping rules, is created. It is important that this process is performed following rigorous rules that extend the reference data model to insure that no redundancies or contradictions occur. It should be pointed out that the two reference data models – the JCDB and the LC2IEDM – have common roots in the NATO-hosted Permanent Working Group (APWG) of international experts in data modeling and management working over 10 years on the definition of the next generation of Allied Tactical Command and Control Information Systems (ATCCIS). The ATCCIS data model has been designed to meet exactly the required criteria for data management: the existing information exchange requirements are included and the extension rules allow redundancy and contradiction-free introduction of additional new information exchange requirements in future operations. The applicability to C4ISR and M&S systems has been demonstrated in the United Kingdom, Germany, and the US.

Data Alignment

It is often assumed that the data describing real systems in operations – as used by C4ISR systems – and the data describing simulated systems in simulated operations – as used in M&S systems – would not differ too much. Why should the state vector of a real system differ a lot from the state vector of the simulation of that system? This has led to the implicit assumption that there exist real-world data, which can be mapped to simulated data and vice versa, thus no management process seems to be needed. However, as has been shown recently in a study prepared for the US Department of the Army, Office Director of Information Systems for Command, Control, Communications, and Computer (ODISC4), the overlap between object and data models intended for work in the same or very similar domains is surprisingly small.[12] In this study, a mapping method has been developed enabling the comparison of relational data models (described using the standard IDEF1X) and object models (described by the Unified Modeling Language UML). Additionally, the study defines a method to measure the alignment ranging from 0% (no alignment) to 100% (total alignment). A very good overview of this methodology has been given during the first European Simulation Interoperability Workshop.[13] Without going into detail, alignment greater than 50% was rarely the case. Due to the surprising results from some alignment studies conducted last year, the US Army has decided to develop for the simulation community an Army Standard C4ISR Object Model that would represent the data structures to be used in operational C4ISR systems. In parallel to the US efforts, under the aegis of the German Army Office, the data models of various German simulation systems are harmonized with the LC2IEDM in an effort to initialize a common shared data model facilitating future interoperability issues. To support this, under consideration is a requirement to conduct relevant data alignment studies as a necessary step in the procurement process of all new military information systems.

Data Transformation

Programming of interface using knowledge for data translation is the last step. In addition, a great deal of configurable gateways enters the market facilitating the process of implementing the data transformation process. However, as is pointed out in the German findings on the applicability of data federation approaches, after having agreed on a common shared data model and mapping rules for harmonization are defined and distributed by a system independent data management organization, data mediation in the sense of automatic translation of system's data into standardized data elements and vice versa becomes possible. Using an appropriate toolkit, the results of data administration, data management, and data alignment can be used directly to configure a software layer interconnecting the data access layers of different systems with heterogeneous data interpretations. It has to be pointed out that this is not an isolated technical solution to achieve interoperability between different information systems, but the result of an integrated management process and the use of common standardized tools. The applicability of this solution to coalition interoperability of C4ISR systems has been demonstrated during a recent NATO workshop on new information technologies.[14] It could be concluded that the same technique, tools, and procedures can be used to ensure interoperability between C4ISR systems, as well as between C4ISR and M&S systems. In addition, the importance of the results of this study in operational systems and the applicability of the methods to operational analyses have been the topic of a paper presented at a NATO Studies, Analyses, and Simulation Symposium.[15]

A Framework for Interoperable Shared Solutions

As already has been stated, the integration of data is only one aspect of interoperability. Figure 1 shows the "House Diagram," which illustrates the complexity of interfacing M&S and C4ISR systems.[16] This holistic view emphasizes the interdependence of the five major factors in the effort to guarantee shared solutions for C4ISR/M&S interoperability: Architectures Alignment, Common Data/Object Models, Common Standards, Alignment Processes, and Reusable Component Interfaces.

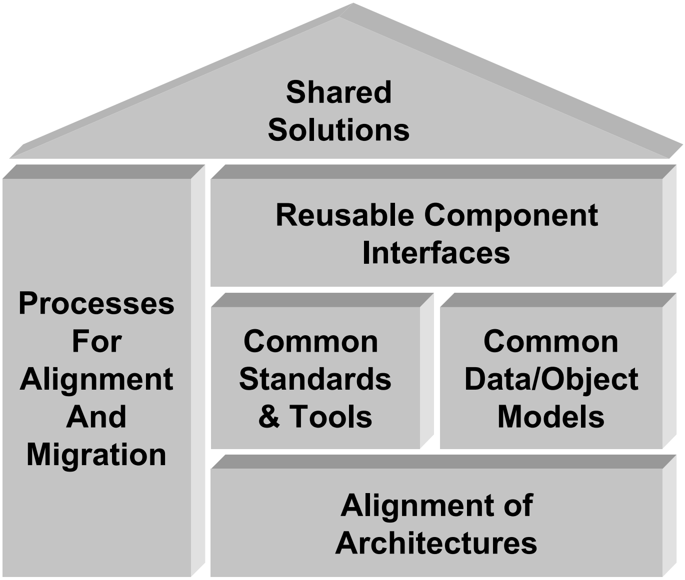

Figure 1: Components of Interoperability.

Architecture Alignment recognizes the fundamental need to align the framework architectures of the M&S and C4ISR domains. The US DoD C4ISR community under the aegis of the Defense Information Systems Agency (DISA) has developed the Common Operating Environment.[17] NATO uses the NATO Consultation, Command and Control (C3) Technical Architecture.[18] The M&S community has established the High Level Architecture.[19] These efforts build the foundation for interoperability between components of these two domains. Architecture alignment has to resolve the differences in the viewpoints or in the representation of the "problem space."

Within the M&S domain, the HLA Federation Object Model (FOM) methodology is used to align *Data Models* and *Object Models* among M&S federates. While this methodology works, it places a heavy burden on developers. When extended to the C4ISR domain, temporary (situational) alignment presents additional challenges: synchronizing development cycles, aligning domain ontology, and coordinating data standards. Actually, a data translation layer between C4ISR and simulation domains normally resolves these constraints. If, in the future, systems are aligned to the same or similar object or data model representations, performance increases due to the decrease of translation penalties and FOM alignment burden.

Common Standards are most effective when they are part of the system design. Integration of standards begins with the framework architecture for each domain and extends to support for common objects and data models. In other words, C4ISR and M&S systems have to work towards interoperability from the beginning, i.e., using the same architecture framework.

Reusable Component Interfaces sit atop, and, therefore, rest on the building blocks presented below. However, compared to architectures, models, or standards, interfaces have been a hotbed of activity. This apparent paradox stems from the ability to partition the problem space at interface level and thus provide short-term solutions for quick success. However, as these solutions are in general too shallow, one has to invest again for the individual solutions in terms of costs, time, and flexibility. By realignment of the underlying structures/components basic incompatibilities between the systems can be eliminated, thus leading to a large number of benefits.

To achieve the overarching goal, these technical processes have to be accompanied by harmonization of the *Management Processes for Alignment and Migration* of legacy applications and systems in order to keep the parallel developments on track. This aspect is very often neglected in articles proposing technical solutions to interoperability.

Finally, the top of the diagram envisions *Shared Solutions* between C4ISR and Simulation systems. This objective has to be supported by all the underlying blocks. In addition, it requires that the systems align or translate the included processes. For example, terrain alignment and object placement must be consistent between the components in the two domains. These shared solutions are the objective in mid term.

Future Work

In long term, however, integrated solutions are the objective. On the C4ISR side, initial ideas have been proposed with the vision of network-centric warfare where components of M&S and C4ISR systems work together within a common infosphere.[20] The application of these ideas to the domain considered in this paper is further suggested by the proposals for *one command and control system* based on *heterogeneous information techniques*.[21]

In addition, new developments in the sector of commercial information technologies offer very promising integration solutions, e.g., the Model Driven Architecture (MDA) developed by the Object Management Group (OMG).[22] The underlying idea behind the MDA is to use a common stable model, which is language-, vendor- and middleware-neutral. This model is a meta-model of the concept. With such a model in the center of the development and integration processes, users that have adopted the MDA gain the ability to develop code for various sub-levels. And, even if the underlying infrastructure changes over time, the meta-model remains stable and can be ported to various middleware implementations, as well as, to different platforms. This approach can also combine various other concepts used nowadays to increase interoperability, e.g., the Common Object Request Broker Architecture (CORBA), Sun's Enterprise JavaBeans, Microsoft's Distributed Component Object Model (DCOM), the Extensible Markup Language (XML) and the XML Metadata Interchange (XMI) Standards, and many others (e.g., the HLA used by the M&S community, as well as C4ISR solutions).

The time to realize these visions has come. On one hand, more military users formulate the need for operational support in an increasingly demanding military operational environment.[23] There are many operational challenges that can be tackled using algorithms and ideas borrowed from the M&S community, e.g., harmonization of operational images, aggregation and disaggregation, pattern matching, etc. On the other hand, the operational architectures being used by the C4ISR systems – the Common Operating Environment in the US and the NATO Consultation, Command and Control (C3) Technical Architecture for NATO nations – are reformulated so as to become object-oriented and open to technical solutions from other communities. The M&S community has to be very well aware of what happens in this field in order to be able to build operationally relevant solutions.

In summary, the methodologies and the operational needs for coupling, federating, and, finally, integrating M&S and C4ISR systems are present and ready to be applied in the near future in order to increase the overall efficiency of soldiers in military operations.

Notes

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A SMALL STEP TOWARD INTEROPERABILITY

Ronald J. ROLAND

Content Focus

Never forget, the lowest bidder made your weapons

Applying simulations to enhance jointness and to promote national and multi-national cooperation and interoperability. The theory is that this will help lead toward developing a Modeling and Simulation (M&S) Master Plan for emerging Democratic Countries and enhance military and crisis management interoperability. Advances that have occurred since the 1999 with issues of Information and Security and dealing with the increased capabilities and continued proliferation of the Joint Theater Level Simulation (JTLS), emphasizing the interoperability issues, and the inherent dangers in the proliferation and quick fix approach of a variety of simulations in the wake of the terrorist event of 9/11/01. There are no quick fixes. Simulation users are learning the hard way by being seduced into the "pit" of simulation tools.

A subordinate focus includes the extent to which one theater level simulation has increased its capabilities, functionalities and user base; and its' relationship with the National Military Command Center (NMCC) initiative. Caution is extended for the user to exercise due diligence and caveat emptor when selecting systems and system integrators.

Coverage

Tracers work both ways

This paper will address the critical issues that have been resolved toward meeting the NMCC requirements of providing a common simulation software environment for both crisis management coordination at the intra and international levels and a potential candidate that can be used for combined, joint and coalition training of combat and security forces. It will propose a common architecture for the NMCC concept and support the guidelines of North Atlantic Treaty Organization (NATO)

M&S. Information and guidelines will be provided concerning future enhancements programmed for JTLS and how each user can help guide continued upgrades and revisions. The proliferation of M&S related tools, use of the term M&S (and its image, S&M), technology developers and claims of value are discussed. Caveat emptor is defined to mean that simulation users should be technologically competent and use expert judgment in their selection and acceptance of simulation technology.

Preface

If you think education is expensive, try ignorance[1]

It seemed clear at the outset of this contribution that the focus should be on the dichotomy of what most simulation users think is meant by the term Modeling and Simulation, shortened to M&S, and the ensuing liberties taken by some software developers to pursue and market the analogous works of Smoke and Mirrors, fondly shortened to S&M.[2] Hence the original title selected was *Smoke and Mirrors (S&M) as the Antithesis of Modeling and Simulation (M&S).* As this research developed, it became apparent that the lack of interoperability at multiple levels, military as well as civil coordination, was a very key issue; and that a great deal of data indicates at least one M&S application was making a difference. The following is an effort to highlight some of the issues, respective players and define an opportunity to overcome the interoperability training shortfalls.

Introduction

When the enemy is in range, so are you

The international journal, Information & Security, volume 3, published in 1999, included an article on M&S techniques and their applications to security related issues including defense, internal security and international cooperation. Since then, the value of simulations to defense establishments has been repeatedly proven by providing readily available, operationally valid environments to (1) train jointly, develop doctrine and tactics, formulate operational plans, (2) assess warfighting situations, and (3) support technology assessment, system upgrade, prototype and full-scale development, and force structuring. The corollary to M&S is Smoke and Mirrors or S&M. S&M has proven a deadly counterpart to achieving cost efficient simulation capabilities.[3] Two key events occurred during preparation of this material. One was a memorandum by the U.S. Office of the Secretary of Defense that directed that development efforts on the Joint Simulation System (JSIMS) be funded only through Fiscal Year 2003 and follow on efforts be reviewed or discontinued[4] pending review by the Office of Secretary of Defense, the Joint Staff and the services. JSIMS had become almost a billion dollar, multi-year investment that continued to experience technical and management problems. Its termination was probably a very difficult political decision. The Joint Forces Command and the JSIMS program office have been instructed to capture the lessons learned (good and bad) for future simulation developers. The spiral approach for example was a key element of the JSIMS development. This relatively new methodology may not have been a sound methodology for such an undertaking. Was this M&S or S&M? We will not know unless and until the report is written and evaluated to be either a real lessons learned or an attempt to justify the expenditure of a huge sum of money on a catastrophe. We hope S&M is not the result.

The second event was a meeting of members from PEO-STRI, USJFCOM, NAWCTSD, USAF/ESC and MSIAC called the Enterprise Team, who reaffirmed their organizations' resolution to promote interoperability programs in the European and Balkan regions.[5] The USAF/ESC representative presented changes to the NMCC concept, which were included to promote interoperability from the tactical through the operational to the strategic leadership levels of cooperating nations.

The article titled *Applying Modeling and Simulation to Enhance National and Multi-National Cooperation* by the author of this paper provided a background concerning one effort, the USAF/ESC NMCC initiative. The focus was to proliferate a common architecture for crisis management, a history of simulation development and an introduction to a specific software application, the Joint Theater Level Simulation (JTLS). JTLS is used throughout the world to train senior staffs within simulated crises situations.[6] It focused on the potential use of simulations, and their scientific bases, for application to crisis management. The emphasis was on using simulation software that was widely available, currently in use by several U.S. and non-U.S. agencies, was an open system architecture, was well documented, configuration managed, could be (and generally is) used with LANs as well as WANs, and was database driven.[7] The recommended simulation, JTLS, met all these criteria in 1999 and currently exceeds them. It is used for Computer Assisted Exercises (CAXs) involving joint, combined and multinational training to include analysis of the training events and the capability to be used as an analysis tool independent of training. This paper describes the continued application of simulation technologies to enhance country-to-country, agency-to-agency and coalition-to-coalition cooperation and understanding. It describes a potential synergism between the proposed capabilities of the NMCC and the inherent features contained in the current release of the JTLS software.

The Chief of Initiatives, Joint Training Directorate, U.S. Joint Forces Command, U.S. Joint Warfighting Center, recently stated that training for joint military operations is the key for success on the battlefield and must be element in future military simulations. Colonel Ann Campbell was describing the establishment of a U.S. Joint

National Training Center. She further stated "*this training center will provide a seamless training environment across a broad spectrum of training requirements.*"[8] She emphasized joint training as a key to transformation to facilitate tightly coupled interactions among the training, operations and acquisition communities to meet their respective tasks. The need to enhance interoperability among the NATO Alliance Members, Partnership for Peace (PfP) Nations and the Mediterranean Dialogue Countries was articulated by Lord Robertson in his presentation, *The Transatlantic Security Agenda*.[9] He pointed out that part of the agenda include crisis management, regional issues, international terrorism, civil emergencies and disaster preparedness.

Mr. Young, U.S. Naval Postgraduate School, reviewed many of the issues facing C2 interoperability in the European theater.[10] Standard practices, policies and procedures headed the list. The increased use of command post exercises and computer-assisted simulations were at the top of his list of recommendations. An excellent example of this lack of operational capability was the challenges of Task Force Hawk, described by Gordon and colleagues.[11] They identified major failures in the integration of NATO ground and air forces. Achieving interoperability is a key element, where European member states are trying to further develop their capabilities as part of NATO's Defense Capabilities Initiative and trying to achieve the goals of the European Union's (EU's) European Security and Defense Policy. The spokeswoman for the NATO Military Exercise Branch, Ms. Karen Dehaes, stated, "due to the multinational and joint character of allied operations, coherence and interoperability between national forces contributions have to be enhanced."[12]

These same environments can support the implementation of a national command center for crisis management. One environment, discussed in 1999 is the Joint Theater Level Simulation system.[13] The architectural enhancements to the simulation software, the continued implementation of faster, cheaper and more available hardware and operating systems, the forthcoming delivery of a Web-enabled version, and its recent use in multi-national environments dealing with scenarios specifically focused on Operations Other Than War (OOTW), combine to provide a simulation environment that coincides with the NMCC concepts.

This command center, identified as the NMCC, would support both national civil and military crisis situations. It would also support regional collaboration in response to regional crisis situations because different national systems would be built on a common architectural platform, This NMCC concept is to be constructed from affordable, reusable components interoperating through open systems architecture to allow maximum utility and flexibility.

Dr. Warren Switzer provided an excellent example on OOTW and the use of simulations to mitigate the time lag between identifying a potential problem and being able to use the tools for either training or evaluation.[14] He described the need to be able to simulate interoperability among the various civil authorities as well as military organizations. The emphasis was the importance of information exchange at multiple levels throughout the decision-making hierarchy and the development of standard procedures to make it happen.

The National Crisis Management Command Center

Incoming rounds have the right of way

The demise of the Warsaw Pact in 1989, the continued growth of the European Union, NATO, and the Partnership for Peace (PfP) consortium, have changed the political landscape of the world. These changes, coupled with the continuing changes in military and political environments, threats, acts of terrorism, and natural disasters, continue to generate crisis situations within and beyond national boundaries. None of these events recognize political boundaries. Collaboration and interoperability with multi-national resources is essential.[15]

The recent NATO summit in Prague opened a new opportunity to transform NATO's role in trans-Atlantic defense industrial and technological cooperation according to Professor Gordon Adams.[16] NATO partners made substantial progress on a long-term agenda to change the role and structure of the alliance. A rapid-reaction force was identified as a critical element to support the alliance.

Eight key capability objectives, critical to future alliance interoperability, were identified. Five of the eight are associated with implementation of simulation capabilities within the previously discussed NMCC conceptual architecture. These are: (1) the rapid reaction force will depend on interoperable C^4ISR; (2) the alliance needs to develop coalitions that encourage the sharing of data and technology, engage in cooperative R&D, and increase joint procurement of weapons and communications; (3) the new transformation command in Norfolk, VA (Formerly SACLANT), must integrate transformational technologies into European forces; (4) a joint trans-Atlantic system will depend on linkages among radar and information technologies for more flexible information transfer; and (5) European allies must increase and integrate their spending on research and development, especially on technologies related to the Prague initiatives.

An important result of the meetings in Prague was that the alliance's command structure was altered, transforming the Atlantic Command into an allied transformation command, focusing on alliance-wide adoption of 21st century defense technologies.

There are at least three key fundamental requirements for civil and military components to be able to respond to crisis situations in an efficient manner: (1) the availability of information regarding crisis situations and military/civil resources readiness; (2) coordination among the organizations and agencies (intra and international) involved in crisis management; and (3) continued training and exercising of the resources so that they can respond effectively when needed. The U.S. Air Force has provided architecture to support the operational aspects of an information system intended to assist national Ministries of Defense (MODs) in arriving at a solution for these issues.[17] This proposed solution was discussed in the previous article and remains in the planning stage. The NMCC concept was presented to several nations in the spring of 1999 and met with favorable response. The presentation identified the Joint Theater Level Simulation (JTLS) as a potential baseline for training and analysis at the national and multi-national command and decision-making levels.[18]

The U. S. government formally introduced the new policy initiative to Partnership for Peace nations at a multinational conference in Sofia, Bulgaria, in June 1999. The U. S. keynote address at the conference, described the NMCC as an initiative to provide national command authorities with a modern, integrated command and control center to support decision-making in the event of civil or military crises. Further, the NMCC would be built on a NATO-compatible technical architecture platform and provide interfaces compatible with comparable NATO and U.S. command and control systems. Currently only two countries have agreed to become associated with this concept.

Simulation Support

The enemy diversion you have been ignoring will be the main attack

The previous article provided an extensive summary of modeling and simulation (M&S) agencies and activities including the High Level Architecture, Joint and Service efforts, various associations and current research. A variety of simulations were discussed. It included an in-depth discussion of the Joint Theater Level Simulation (JTLS) as an illustration of a joint war-gaming system.[19] The purpose was to illustrate a software capability that might enhance the NMCC concept and exploit a great deal of simulation software developed by NATO Consultation and Control Agency (NC3A). Figure 1 shows different scenarios in which the NMCC and JTLS combination could support.

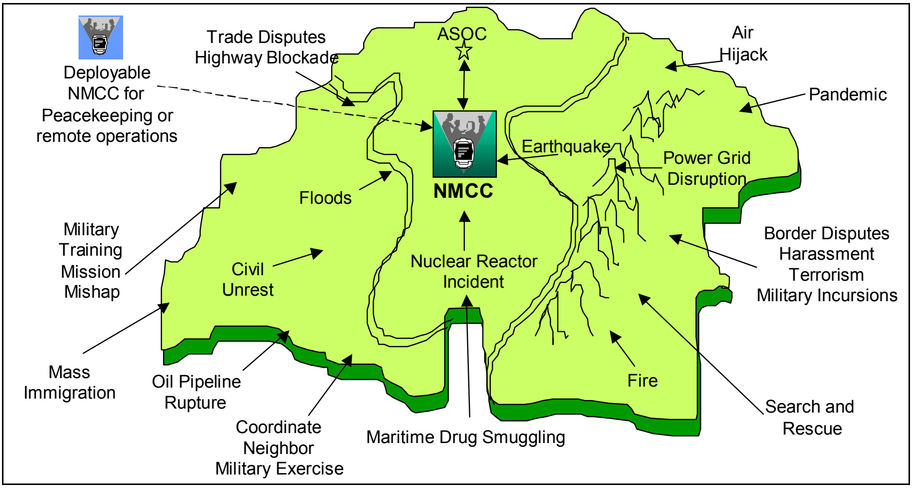

Figure 1: NMCC and JTLS Support to Crisis Management Operations.

JTLS since 1999

If your attack is going well you have walked into an ambush

There have been approximately eight minor releases and three major releases per year of the JTLS software since the first meeting in 1999. Each release is fully controlled by the JFCOM/JWFC Program Management Office and through a formal Configuration Control Board (CCB) and is accompanied by a complete suite of current documentation.[20] The simulation is used in approximately six major U.S. Joint exercises per year and about the same for International users of JTLS.[21] These International (non-U.S.) users include eleven current JTLS installations and six pending for 2003.[22] The JWFC/JFCOM commitment to the JTLS user community is administered through a support contractor and is designed to provide sufficient training so they can use JTLS effectively without continued external support. This does not mean to imply that the users are without recourse if they have problems or technical questions. A 24/7 help desk is available for all JTLS users. This particular support strategy has been very successful from the JWFC/JFCOM perspective.

Enhancements to the JTLS simulation engine are too numerous to mention in this article. A major revision is planned annually with intervening deliveries as needed. The help desk support and deliveries are accomplished via the web, email, fax or CD deliverers. Three recent training exercises, US Pacific Command's (PACOM's) Terminal Fury, NATO's CANNON CLOUD and US Central Command's (CENTCOM's) Internal Look, are examples of the capability of JTLS to support multiple users of various nationalities around the world simultaneously.[23,24,25] The exercises were two, two and one half and two weeks long respectively. All were 24/7. The simulation model downtime that the users experienced throughout any exercise was less than 40 minutes total.

The current enhancements to JTLS include porting the source code to the Linux operating system (OS). While the JTLS Player Stations have always included PCs as well as Sun workstations, the requirement for the SUN Solaris OS remained constant. JTLS Version 2.5, delivered to the JFCOM/JWFC JTLS Program Manager in January 2003 by their support contractor, includes object code for both SUN Solaris and Linux OS.[26] This version of JTLS has been tested and used in USPACOM's Terminal Fury CAX. Both laptops and desktop PCs were used for the very successful two-week effort. Integration with other systems, for example C4ISR capabilities, continues at each exercise. The NC3A exercise called CANNON CLOUD is an excellent example of a theater missile defense scenario where the theater level, missile and C2 simulations were exchanging data.[27]

Another enhancement to the JTLS repertoire is the current design/integration of the JTLS and Joint Conflict and Tactical Simulation (JCATS) simulations. JCATS is the only self-contained inherently joint simulation in use for entity-level training in open, urban, and subterranean environments. JCATS is an interactive, high resolution, entity level, conflict simulation that models joint-multi-sided air, ground, and sea combat on high-resolution, digitized, polygonal terrain. The uses of JCATS range from the joint task force level to tactical and operations other than war levels in scenarios including open, urban, and subterranean environments using aggregated and individual systems. JCATS' most unique features include the replicating of small group tactics in urban terrain to include enhanced multi-floor buildings with doors, windows, interior walls, day-night operations under differing visibility and artificial lighting to include an underground environment.

JCATS is being developed and maintained by the Lawrence Livermore National Laboratory (LLNL). However, its Program is managed and funded by the Director for Joint Force Training at JFCOM/Joint Warfighting Center. The integration of JTLS and JCATS will represent a breakthrough in simulations for many reasons. Both models are established world wide meeting user requirements. This combination will provide, for the first time, a single simulation suite that can be used at the theater and operational levels simultaneously. They are both High Level Architecture (HLA) compliant, both run on PCs, and are managed by a single U.S. agency, the JFCOM/JWFC, and they are both available to international users. JTLS may be obtained through FMS or commercially. JCATS can only be obtained via FMS. Delivery of this JTLS/JCATS HLA integrated system is scheduled in late 2003. There are ongoing studies to include other simulations as part of the JTLS/JCATS architecture, which will provide a more robust presentation in the training environment. These initiatives include logistics, intelligence, air defense enhancements and civil agencies.

Simulations have historically been developed with unique graphic user interfaces, also known as human computer interfaces. The concept of being able to use a common browser for such applications has evolved with the increasing speed of the Internet. JTLS has a prototype Web enabled capability in beta test. It has been used in parallel in one major U.S. International CAX with great success. This version of JTLS, most likely assigned Version 3.0, will include a Web capability in addition to the Linux and SOLARIS operating system instantiations. The ability of a PC to become a JTLS Workstation, (regardless of the PC OS platform being used) will greatly reduce the cost of standing up a simulation center by populating it with laptops and desktop PCs. Taking the simulation to the hands of the users in such a cost effective manner should greatly increase the number of experienced participants, thereby increasing the interoperability of the community of users.

Current Value

Never draw fire, it irritates everyone around you

The current value of employing simulation tools, such as JTLS, is obvious to those of us who are constantly in the field. This benefit to the interoperability issue is not so evident to others, so some amplification is appropriate. Using simulations is becoming a standard part of the training and exercise schedules of most modern armed forces and many civil agencies. In addition, simulations have been used for years to conduct analyses and experiments that where either far too dangerous to actually conduct or too expensive. Simulations also allow civil and military staffs to do almost real-time mission planning and rehearsal. The tradeoff is that a staff must be trained and available to support the myriad detail that is involved with maintaining the software, the hardware and the data.

The use of JTLS provides insight into many of the interoperability issues. For example, the Southeastern Europe Simulation (SEESIM) exercise that was conducted in December 2002 demonstrated the value of using such a simulation tool. SEESIM was mandated by the Southeastern European Defense Ministers (SEDM) to integrate initiatives through a series of simulation-based exercises to enhance SEDM coordination, prepare for emergency response, continue developing regional capabilities and enhance ties to Euro-Atlantic institutions.

Figure 2 illustrates the geographical scale of the SEESIM effort.

Figure 2: SEESIM 02 Participants.

The scenario developed, and used, for SEESIM 02 was a civil emergency scenario that quickly expanded to involve various agencies in all the participating countries, as illustrated in Figure 3. The close relationship between the concept defined by the NMCC architecture and the actual scenario developed and executed for the SEESIM exercise is evident by comparing these three figures. It is exciting to see the coalescing of these disparate organizations and nations into a single coordinated operation, even if so briefly. A small step toward achieving interoperability may be taking place, thanks to these various players. Another SEESIM exercise is planned for 2004. JTLS will again be used and the main process will be executed in the new Turkish War College M&S Center in Istanbul, Turkey.

It is important to note that the simulation software, selected to support the SEESIM efforts, is JTLS. The value of using software that is HLA compliant, highly distributable, a NATO and US standard and well documented has not been lost by the participants. Their ability to communicate and work together is further enhanced by the concept of being able to manage the design to accommodate individual C2 systems over time. The managers of the simulation software are aware of the commercialization of the Run Time Infrastructure (RTI) software and are closely monitoring the various vendors to ensure as much commonality as possible.

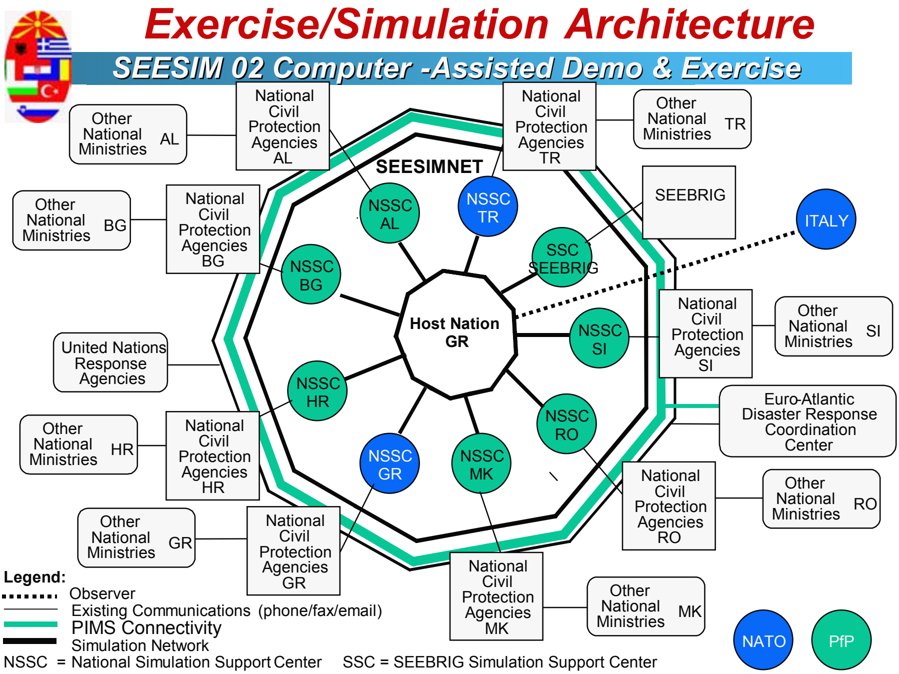

Figure 3: Exercise / Simulation Architecture.

The NATO/NC3A exercise called CANNON CLOUD was held at the US Armed Forces - Europe Warrior Preparation Center, Einsedlerhof, Germany, from 1-15 November. It used a scenario that involved planning and conducting joint operations for a collective defense situation. It was a very large exercise with hundreds of JTLS Work Stations, and illustrated the multi-national capability of this simulation being used in a purely combat support situation for training senior joint, combined and multinational staffs.

The analytical tool used for the STRATOS project is JTLS. This 2-year, $3,000,000 USD research effort was in support of the European Cooperation for Long-term In Defence (EUCLID) program. It required a strategic operational simulation to support research goals and JTLS was chosen as their research support tool. The consortium included Italy and Greece and two commercial firms, DATAMAT (lead company, IT) and INTRACOM (GR). The University of Genoa is developing plans to use JTLS in one of their follow-on research efforts in 2003/2004.

NMCC since 1999

Once you have secured the area, be sure to tell the enemy

JTLS has continued to mature since 1999. The NMCC program has kept pace with changes in the EU and PfP nations, and with applicable, current technology. It has suffered some delay due to bureaucracy, U.S. policies and changes in management. One crucial ingredient to the NMCC recipe is that they require a solid base of users before establishing their first site. This will change in the near future as more users are identified. The expanded capabilities of a proven theater level simulation system may be the added benefit that the NATO Members, PfP Nations and the Mediterranean Dialogue Countries will view as an added benefit to becoming part of the NMCC program.

Caveat Emptor

The recent ITEC and I/ITSEC conferences make it dramatically clear that the potential user of simulations must be well versed in the nature of simulations, their proven capabilities, and can match their agencies requirements with the capabilities of the tool. There are numerous vendors, with wonderful displays, that can capture your imagination. In some, perhaps too many, cases *"what you see is what you get."* The American phrase "look under the hood" is very apropos. Vaporware is another common term. In many cases the vendors have something that is special purpose, but they are advertising it as a general application. This is evident in many publications that are distributed worldwide and that include advertisements and articles praising various simulation techniques and systems that have little, if any validity: Some periodicals such as *The National Defense,* www.ndia.org, *MS&T, The International Defence Training Journal*, www.halldale.com/mst, and *I/ITSEC NTSA National Defense, Training and Simulation 2002 – Trends and Technology Review I/ITSEC Exhibits' Guide,* include many articles and advertisements that may be misleading. Consider the JSIMS advertising for example.

Some U.S. Service representatives have expressed their concern and dismay on numerous occasions about how the forces have allowed their simulations and training programs to decay.[28] One representative observed that some high tech gizmos look nice in the laboratory or classroom but that industry and some technologists, i.e. simulation providers, have lost the big picture and the environment in which the tools are to be used.

The Military Operations Research Society (MORS) publishes a monthly newsletter called the Phalanx, which recently included an article co-authored by Dr. P. Allen and Ms. A. Ratzenberger. They were involved in an experiment, called Millennium Challenge 2002 at the Joint Experimentation Directorate of the JFCOM. Dr. Allen and Ms. Ratzenberger described situations where they were assured by simulation software developers that their specific application would meet all the specifications defined for their particular part of the experiment.[29] The result was described in the article, and in part said, "The term 'buyer beware' is as applicable now as it ever was. There are many new models appearing that make many claims about capabilities and what they represent." Users must be astute enough to determine, through any means available, that the tools they intend to use really do meet specifications and are not vaporware. Caveat emptor.

Conclusion

The need for interoperability continues to be identified as a crucial element in providing more efficient and effective, multi-national and multi-agency operations. The ability to exchange information, coordinate resources, and understanding each participant's capability is paramount to meeting today's challenges on the military and civil battlefields. This paper has attempted to provide examples of the shortcomings. Joint, combined, multinational training is seen as one key to the transformation required to effect interoperability. The newly restructured Atlantic Command is one step of this transformation in the European Theater. The SEESIM demonstration and the CANNON CLOUD exercises are provided as two examples where a simulation engine was used to assist in executing interoperability strategies and tactics. A common architecture, tested and exercised on a regular basis will lead toward interoperability. The simulation engine, used for these and multiple other exercises and analyses annually and which is being upgraded and enhanced continually, is a proven value. It has become a worldwide standard for theater level simulations.

The need for a common simulation-training platform among nations and agencies is essential. There are a large number of platform combinations that may prove effective. A potential architecture to consider, presented herein as an example, is the USAF-ESC NMCC concept combined with the JTLS model. Caveat emptor is recommended throughout system selection to detect the nuances between M&S and S&M. A small step toward interoperability.

Appendix A. The JTLS International User Community

Current
The Commonwealth of Australia, Australian Defence Force Warfare Centre
United Arab Eremites M&S Center, via Coleman Research Corp., Huntsville, Alabama
France: College Interarmees De Defense
Greece: Hellenic National Defense General Staff
Italy: Comando Operativo Interforze (CIMSO), via Marconi, Ltd.
Japan: Japanese Defense Agency, via Mitsubishi Electric Corporation
Republic of Korea: ROK Air University, Taichung, ROK
Thailand: Royal Thai Supreme Command, Joint Staff College
Turkey: TURKISH War Colleges, Istanbul
United Kingdom: Defence Science & Technology Laboratories
NATO C3 Agency, The Hague, Netherlands
Scheduled for 2003
Taiwan MND
Spain
Malaysia MINDEF
Slovenia
Poland
Oman

Appendix B. Smoke and Mirrors Defined

Subject: Smoke and Mirrors, circa late 2002, prior to the U.S. SECDEF announcement that JSIMS funding was to be withdrawn.

First, I wanted to remind you that I had interacted with JTLS back when I was a RAND employee at the Warrior Preparation Center (1989-1991). You contacted me then regarding how much like my RAND Report on Evolution of Models at the Warrior Preparation Center: Problems and Solutions for Higher-Echelon Exercises, where one of the three primary recommendations was for the WPC to use JTLS for higher-echelon exercises. We discussed the strengths and limitations of various models, and how it was unfortunate that there was a certain amount of prejudice (and not-invented here) syndrome in the field. Later, when I was senior scientist for Cubic Applications Inc. we were trying to get JTLS into NATO/SHAPE exercises and the UK, although both of those immediate opportunities did not pan out. However, over time, you were still able to get JTLS into those exercises, which I believe was a good idea.

When JCM and UCATS were combined in their capabilities to form JCATS, I believe that was a step forward in the level of resolution that could be accomplished across both models. Connecting JTLS to JCATS sounds even more interesting. Now that JTLS is HLA compliant, I do believe the HLA-compliant JTLS-JCATS tool is worth looking into. Other models being examined include the Joint Integrated Contingency Model (JICM), which I helped develop when I was at RAND, but I do believe all viable opportunities should be examined. (I don't think I suffer from the not-invented-here syndrome, and can appreciate other approaches I did not happen to work on!)

Although I have since visited the JEXP to discuss ways to connect Operational Net Assessment tools with IO tools, I am no longer working Joint Experimentation support on a daily basis.

Let me also reply to the issue of legacy versus “new” models. I, for one, do not consider the term “legacy” to be a dirty word (and I hope the article reinforced that viewpoint). As the JWARS developers are finding out the hard way, the legacy algorithms solved a number of problems that they are rediscovering in JWARS and JSIMS, and have yet to be solved in those new models. In my opinion, aggregate model-designers are indeed a rare breed, and the entity-based-everything approach is disastrous for the industry. Entity based applications have their place, as do aggregate models. There is no “one-size fits all” model, in spite of some efforts to make that claim.

The two models we were referring to in the article were the older LEM-Space model out of USSPACECOM (the first case) and the Entropy-Based Warfare model (the second case). The smoke and mirror aspects were highly prevalent in those two, and it appears to be getting worse. A lot of money was invested in the latter, and it is now being touted as the Holy Grail--and few have noted when the Emperor has no clothes. Do I think JWARS or JSIMS are new or legacy? Since they haven't solved the aggregation problems that we solved many times years ago in the legacy models, then they are new but missing the old boat that got folks across the river before. They did not have experienced modelers helping on the design--moreover, they religiously believed entity-level was the only way to do any analysis, training, or experimentation. The community is suffering immensely under the DARPA-sponsored mentality where only entity-level through-the-window simulations mattered--and will continue to suffer for years. A picture may be worth a thousand words, but it can also be the simulation equivalent of an optical illusion. Graphics sells, regardless of what is behind it.

So is JTLS-JCATS legacy? Yes, and no. It has the benefits of being one of the legacy models that solved many of the problems that still plague the JSIMS/JWARS development efforts. Is JTLS-JCATS a new model? In that it talks HLA and runs on Linux, I believe it also has some new elements. So hopefully the JTLS-JCATS combination will get a fair hearing in these upcoming events. I am sorry that so much money was wasted on the JSIMS and JWARS efforts, when a small team of experienced modelers could have accomplished so much more with even a fraction of those funds. But that's politics. The voices in the wilderness warned of the coming train wreck, but the money-providers were enamored with the smoke and mirrors. That is one reason I am no longer in that field--good money continues to flow after badly expended money, and there seems to be a belief that unless all funds fill the one basket, the one basket will never succeed. (That's partly true, for if all the funds go to one basket, there are no alternatives left to compete for the future of modeling and simulation--but the win is by default and not based on success.) Due to my new field, I will not likely be at I/ITSEC this year.

Any way, I believe I have said my piece and "set the world to rights"--if only it were that easy! Good luck and best wishes on getting JTLS-JCATS marketed and used. As I mentioned in my previous e-mail, it is good to see that both you and JTLS are still alive and kicking. My contact information is below.

Author to remain anonymous.

Notes:

1 Unknown scholar.

2 Appendix B. Smoke and mirrors defined.

3 Patrick D. Allen and Annette C. Ratzenberger, "Outputs Should Not Equal Inputs," *Phalanx* 35, 3 (September 2002): 9.

4 Mr. Brian Gregg, JTLS PM, JW1910, Joint Warfighting Center, U.S. Joint Forces Command, Suffolk, VA, greggb@jwfc.jfcom.mil.

5 See Enterprise Team, <www.msiac.dmso.mil/enterprise/default.asp> (3 October 2003) or email the webmaster at webmaster@msiac.dmso.mil.

6 The list of International JTLS Users is included in Appendix A.

7 The database values managed the simulation process.

8 "Advance Planning Briefing to Industry," *MS&T Magazine*, Issue 6 (2002): 47.

9 Robertson, The Right honorable George Islay MacNeill, Lord of Port Allen, "The Transatlantic Security Agenda," *Joint Force Quarterly*, (Washington, D.C.: Institute for National Strategic Studies, U.S. National Defense University, Autumn/Winter 2001): 34-39.

10 Thomas-Durell Young, "NATO Command and Control for the 21st Century," *Joint Force Quarterly*, (Washington, D.C.: Institute for National Strategic Studies, U.S. National Defense University, Autumn/Winter 2001): 40-45; European Program Manager for the Civil-Military Relations, U.S. Naval Postgraduate School, Monterey, CA.

11 John Gordon IV, Bruce Nardulli, and Walter L. Perry, "The Operational Challenges of Task Force Hawk," *Joint Force Quarterly*, (Washington, D.C.: Institute for National Strategic Studies, U.S. National Defense University, Autumn/Winter 2001): 52-57.

12 K. Dehaies, *Defense News*, 26 November 2001.

13 *National Military Command Center, Concept of Operations* (Hanscom AFB, MA: USAF Electronic Systems Center, 18 August 2001), Esc.fa.cmb@hanscom.af.mil. POC Major S. Lausman, scott.lausman@hanscom.af.mil.

14 W. H. Switzer PhD, *Distributed Training and Distributed Simulations: Imperatives for Success in Military Operations Other than War* (Washington, D.C.: AB Technologies, Inc.), undated. wswitzer@msosa.dmso.mil.

15 *National Military Command Center Concept of Operations*, Draft (22 November 1999).

16 Gordon Adams, "Inside View – Aftermath of Prague. New Strategy Hinges on U.S. Trade Reform," *Defense News*, 16 December 2002, 17.

17 *National Military Command Center Technical Architecture Description*, (Hanscom AFB, MA: USAF Electronic Systems Center, 21 August 2000).

18 *The Joint Theater Level Simulation*, presented by Dr. R. J. Roland and demonstrated by Mr. R. Kalinyak, R&A Systems Engineer.

19 See http://www.rolands.com/jtls.html.

20 See http://www.jfcom.mil.

21 See Appendix A for a list of International JTLS Users.

22 Appendix A is the list of International JTLS Users.

23 http://www.pacom.mil.

24 http://www.nato.int.

25 http://www.centcom.mil.

26 Mr. Brian Gregg, JTLS PM.

27 David F. Taylor, et al, *NC3A Support for Theatre Missile Defence Operations in NATO Exercise CANNON CLOUD 2002 (CC02)*, (The Hague, Netherlands: NATO Consultation, Command and Control Agency), David.Taylor@nc3a.nato.int.

28 "Pentagon Plans Shift In Training as Part of Military Transformation," *Defense News*, 3-9 December 2001.

29 Allen and Ratzenberger, "Outputs Should Not Equal Inputs."

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MATHEMATICAL MODEL OF FUZZY CONTROL SYSTEM FOR AUTONOMOUS GUIDED VEHICLE IN 3D SPACE

George GEORGIEV and Valentine PENEV

Introduction

At present, the control loops of moving platforms are designed on the base of fuzzy control theory. Especially path searching in a 2D changing environment has received considerable attention as a part of the general problem of robot motion planning. A particularly interesting problem in this context is path planning with respect to a moving object. The design of such intelligent guided vehicles needs capabilities for environment recognition and motion planning.[1, 2, 3] Nowadays, fuzzy control is a promising technique for intelligent system design.[4, 5, 6] The most important feature of this method is that it eliminates the difference between goals and constraints and makes it possible to relate them in the decision-making process.[7] This paper presents a fuzzy control method for autonomous guided vehicle, which tracks an object in 3D space.

Problem Statement

The problem involves finding the best possible time (optimal) registration path of the autonomous guided vehicle from the initial state to the goal. The goal is presented as a moving object, which the guided vehicle has to reach. It changes its coordinates during the decision-making process. The autonomous guided vehicle is modeled as a point, which movement is described by the following system of recurrent equations:

$$x_{k+1} = x_k + v.\cos\Psi_k.\sin\gamma_k.\Delta t \tag{1}$$

$$y_{k+1} = y_k + v.\sin\Psi_k.\sin\gamma_k.\Delta t \tag{2}$$

$$p_{k+1} = p_k + v_h.\Delta t \tag{3}$$

$$h_{k+1} = h_k + v_v.\Delta t \tag{4}$$

$$\Psi_{k+1} = \Psi_k + \Delta\Psi \tag{5}$$

$$\gamma_{k+1} = \gamma_k + \Delta\gamma \tag{6}$$

The states of the system are x_k, y_k, p_k, h_k,Ψ_k and γ_k. The meaning of the notations is as follows:

- x_k, y_k, h_k – coordinates of the model;
- $v_h = v.\sin\gamma_k$ – horizontal velocity;
- $v_v = v.\cos\gamma_k$ – vertical velocity;
- $v = \sqrt{v_h^2 + v_v^2}$ – total velocity;
- $p_k = \sqrt{x_k^2 + y_k^2}$ – total horizontal path;
- Ψ_k – azimuth-path angle;
- γ_k – flight-path angle;

The problem of control of the guided vehicle in 3D space is solved in horizontal and vertical planes. The first, second and the fifth equations are used in the horizontal plane. The azimuth-path angle Ψ_k and the horizontal velocity v_h control the vehicle. In the vertical plane the flight-path angle γ_k and the velocity v control it. In this case equations 3, 4, and 6 are used. The dynamic nature of the system can be modeled by constraining the angle of the velocity vector in the 3D space by its velocity v. The constraints are given in horizontal and vertical planes as follows:

In horizontal plane

$$\Psi = \begin{cases} \Psi_{max}, & \Psi \geq \Psi_{max} \\ \Psi, & -\Psi_{max} < \Psi < \Psi_{max} \\ -\Psi_{max}, & \Psi \leq -\Psi_{max} \end{cases}$$

In vertical plane

$$\gamma = \begin{cases} \gamma_{max}, & \gamma \geq \gamma_{max} \\ \gamma, & -\gamma_{max} < \gamma < \gamma_{max} \\ -\gamma_{max}, & \gamma \leq -\gamma_{max} \end{cases}$$

where:

$$\Psi_{max} = -55°.\frac{v_h}{10};\quad 55°.\frac{v_h}{10},\qquad \gamma_{max} = -30°.\frac{v_v}{10};\quad 30°.\frac{v_v}{10}.$$

The problem is solved using dynamic programming in a fuzzy environment.[8, 9] The objective of the proposed algorithm is to demonstrate a fuzzy method for determination of the trajectory of the dynamic object, which is modeled as movement of a point in the 3D space. The following assumptions are made in the decision-making process:

- sets of alternatives: $X = \{x, y\}$, $P = \{p, h\}$;
- at each time t the control azimuth-path angle Ψ_t is subjected to a fuzzy constraint C_t^{Ψ}, which is a fuzzy set in U characterized by a membership function in horizontal plane $\mu_t^{\Psi}(\Psi_t) = f(\Psi_t)$;
- at each time t the control flight-path γ_t is subjected to a fuzzy constraint C_t^{γ}, which is a fuzzy set in U characterized by a membership function in vertical plane $\mu_t^{\gamma}(\Psi_t) = f(\gamma_t)$;
- the goal is a fuzzy set G^N in V, which is characterized by two membership functions in horizontal and vertical planes. The fuzzy goal might be presented as two functions, which have maximums at the end points. Their combined influence may be respectively expressed in words as: "x, y, h *should be in the vicinity of* x_g, y_g, h_g." Their membership functions are given as follows:

$$\mu_G^h(x, y) = e^{-k_x(x_g - x)^2 - k_y(y_g - y)^2}, \qquad \mu_G^v(h) = e^{-k_p(p_g - p)^2 - k_h(h_g - h)^2}.$$

Description of the Fuzzy Control

The problem of finding the optimal registration path of the model is a multi-stage decision process. The original multi-stage (N-stage) decision process is replaced with N one-stage processes. Dynamic programming is based on the principle of optimality. In the beginning the algorithm uses the reverse problem of dynamic programming. The model is moved from the goal to the initial state. The optimal movement trajectory is calculated in an off-line mode. The last step of the decision process is N for the reverse problem of dynamic programming. It is obtained when the model has attained the initial state. Then, the algorithm uses the direct problem of dynamic programming in an on-line mode.

Problem: The autonomous guided vehicle has to attain given goal, which is moving in given direction. The initial state x_0, y_0, h_0 and the coordinates x_g, y_g, h_g of the goal are assumed to be given. The termination time of the process is N. The decision-making process has the following goal:

G: (x, y, h) should be in the vicinity of (x_g, y_g, h_g).

It has to find the best possible time registration path of the model from the initial state to the goal.

In the horizontal plane the initial and final conditions are defined as follows:

$$\mu_G^h(x_0, y_0) = \alpha \,; \qquad \mu_G^h(x_N, y_N) = 1 \,;$$

The final condition for the control signal Ψ_k is included implicitly. It has to determine the sequence:

$$\mu_G^h(x_{N-1}, y_{N-1}); \qquad \mu_{N-1}^{\Psi}(\Psi_{N-1});$$
$$\mu_G^h(x_{N-2}, y_{N-2}); \qquad \mu_{N-2}^{\Psi}(\Psi_{N-2});$$
$$\ldots\ldots\ldots\ldots\ldots\ldots \qquad \ldots\ldots\ldots\ldots$$
$$\mu_G^h(x_0, y_0); \qquad \mu_0^{\Psi}(\Psi_0);$$

which optimizes the criteria $\mu_G^h(x_k, y_k), \qquad k = 0,1,2,...,N-1$.

In the vertical plane the initial and final conditions are defined as follows:

$$\mu_G^v(p_0, h_0) = \beta \,; \qquad \mu_G^v(p_N, h_N) = 1 \,;$$

The final condition for the control signal γ_k is included implicitly. It has to determine the sequence:

$$\mu_G^v(p_{N-1}, h_{N-1}); \qquad \mu_{N-1}^{\gamma}(\gamma_{N-1});$$
$$\mu_G^v(p_{N-2}, h_{N-2}); \qquad \mu_{N-1}^{\gamma}(\gamma_{N-2});$$
$$\ldots\ldots\ldots\ldots \qquad \ldots\ldots\ldots\ldots$$
$$\mu_G^v(p_0, h_0); \qquad \mu_0^{\gamma}(\gamma_0);.$$

which optimizes the criteria $\mu_G^v(p_k, h_k)$, $k = 0,1,2,...,N-1$.

More explicitly, in terms of membership functions, the decision in the horizontal and vertical planes can be expressed as:

$$\mu_D^h(\Psi_0,...,\Psi_{N-1}) = \mu_0^\Psi(\Psi_0) \wedge \mu_1^\Psi(\Psi_1)...\mu_{N-1}^\Psi(\Psi_{N-1}) \wedge \mu_{G^N}^h(x_N, y_N);$$

$$\mu_D^v(\gamma_0,...,\gamma_{N-1}) = \mu_0^\gamma(\gamma_0) \wedge \mu_1^\gamma(\gamma_1)...\mu_{N-1}^\gamma(\gamma_{N-1}) \wedge \mu_{G^N}^v(p_N, h_N),$$

where:

- in the horizontal plane x_N, y_N can be represented as a function of x_0, y_0 and $\Psi_0,....\Psi_{N-1}$ through the iteration of equations 1 and 2;
- in the vertical plane p_N, h_N can be represented as a function of h_0 and $\gamma_0,....\gamma_{N-1}$ through the iteration of equations 3 and 4.

As is usually the case in multi-stage processes, it is convenient to express the solution in the form:

$$\Psi_t = \pi_t^h(x_t, y_t);$$

$$\gamma_t = \pi_t^v(p_t, h_t), \qquad t = 0,1,2,...,N-1,$$

where:

π_t^h and π_t^v are policy functions in the horizontal and vertical planes respectively. Then dynamic programming is applied to find the maximizing decisions $\Psi_0^M,....\Psi_{N-1}^M$ and $\gamma_0^M,....\gamma_{N-1}^M$.

The following simplified expressions of equations 1, 2, 3, and 4 are used:

$$\left.\begin{array}{l} x_{N-k+1} = f(x_{N-k}, \Psi_{N-k}) \\ y_{N-k+1} = f(y_{N-k}, \Psi_{N-k}) \end{array}\right\} \Rightarrow f(x_{N-k}, y_{N-k}, \Psi_{N-k}) \qquad (7)$$

$$\left.\begin{array}{l} h_{N-k+1} = f(h_{N-k}, \gamma_{N-k}) \\ p_{N-k+1} = f(p_{N-k}, \gamma_{N-k}) \end{array}\right\} \Rightarrow f(p_{N-k}, h_{N-k}, \gamma_{N-k}) \tag{8}$$

More specifically, using a definition of the solution in a fuzzy environment [10] and equation (7), the solution in the horizontal plane can be written as:

$$\begin{aligned} \mu_D^h(\Psi_0^M, \ldots \Psi_{N-1}^M) = Max_{\Psi_0}, \ldots Max_{\Psi_{N-2}}, Max_{\Psi_{N-1}}(\mu_0^{\Psi}(\Psi_0) \wedge \ldots \mu_{N-2}^{\Psi}(\Psi_{N-2}) \\ \wedge\, \mu_{N-1}^{\Psi}(\Psi_{N-1}) \wedge \mu_{G^N}^h(f(x_{N-1}, y_{N-1}, \Psi_{N-1}))) \end{aligned} \tag{9}$$

In the same manner, using the approach of Bellman and Zadeh [11] and equation (8), the solution in the vertical plane can be written as:

$$\begin{aligned} \mu_D^v(\gamma_0^M, \ldots \gamma_{N-1}^M) = Max_{\gamma_0}, \ldots Max_{\gamma_{N-2}}, Max_{\gamma_{N-1}}(\mu_0^{\gamma}(\gamma_0) \wedge \ldots \mu_{N-2}^{\gamma}(\gamma_{N-2}) \\ \wedge\, \mu_{N-1}^{\gamma}(\gamma_{N-1}) \wedge \mu_{G^N}^v(f(p_{,N-1}, h_{N-1}, \gamma_{N-1}))) \end{aligned} \tag{10}$$

After some transformations expressions 9 and 10 can be rewritten in the following form:

$$\mu_{G^{N-1}}^h(x_{N-1}, y_{N-1}) = Max_{\Psi_{N-1}}(\mu_{N-1}^{\Psi}(\Psi_{N-1}) \wedge \mu_{G^N}^h(f(x_{N-1}, y_{N-1}, \Psi_{N-1}))) \tag{11}$$

$$\mu_{G^{N-1}}^v(p_{N-1}, h_{N-1}) = Max_{\gamma_{N-1}}(\mu_{N-1}^{\gamma}(\gamma_{N-1}) \wedge \mu_{G^N}^v(f(p_{N-1}, h_{N-1}, \gamma_{N-1}))) \tag{12}$$

Equations 11 and 12 may be regarded as the membership functions of a fuzzy goal at time $t = N-1$, which is induced by the given goal G^N at time $t = N$.

Repeating this backward iteration, which is a simple instance of dynamic programming, the following recurrence equations are obtained:

$$\mu_{G^{N-k}}^h(x_{N-k}, y_{N-k}) = Max_{\Psi_{N-k}}(\mu_{N-k}^{\Psi}(\Psi_{N-k}) \wedge \mu_{G^{N-k+1}}^h(x_{N-k+1}, y_{N-k+1})) \tag{13}$$

$$\mu_{G^{N-k}}^v(p_{N-k}, h_{N-k}) = Max_{\gamma_{N-k}}(\mu_{N-k}^{\gamma}(\gamma_{N-k}) \wedge \mu_{G^{N-k+1}}^v(p_{N-k+1}, h_{N-k+1})) \tag{14}$$

In equations (13) and (14) unknowns are the membership functions of the control values $\mu_t^{\Psi}(\Psi_t)$ and $\mu_t^{\gamma}(\gamma_t)$. The membership functions of the goal are calculated as follows:

$$\mu^h_{G^{N-k}}\left(x_{N-k}, y_{N-k}\right) = e^{-k_x\left(x_g - x_{N-k}\right)^2 - k_y\left(y_g - y_{N-k}\right)^2} = A_{N-k} \tag{15}$$

$$\mu^v_{G^{N-k}}\left(p_{N-k}, h_{N-k}\right) = e^{-k_p\left(p_g - p_{N-k}\right)^2 - k_h\left(h_g - h_{N-k}\right)^2} = B_{N-k} \tag{16}$$

where A_{N-k} and B_{N-k} are the calculated values of the membership function at moment $N-k$.

To determine the control signals Ψ_{N-k} and γ_{N-k} at $N-k$, one has to represent the system equations 1, 2, 3, and 4 as follows:

$$x_{N-k} = x_{N-k+1} - v.\cos(\Psi_{N-k}).\sin(\gamma_{N-k}).\Delta t \tag{17}$$

$$y_{N-k} = y_{N-k+1} - v.\sin(\Psi_{N-k}).\sin(\gamma_{N-k}).\Delta t \tag{18}$$

$$p_{N-k} = p_{N-k+1} - v.\sin(\gamma_{N-k}).\Delta t \tag{19}$$

$$h_{N-k} = h_{N-k+1} - v.\cos(\gamma_{N-k}).\Delta t \tag{20}$$

The procedure for finding the control angles $\Psi_0^M, ..., \Psi_{N-1}^M$ and $\gamma_0^M, ..., \gamma_{N-1}^M$ is presented below:

a. The goal coordinates are initialized $x_{N-k} = x_g$, $y_{N-k} = y_g$, $p_{N-k} = \sqrt{x_g^2 + y_g^2}$, $h_{N-k} = h_g$, initials values for Ψ_{N-k}, γ_{N-k} and $k = N$ are also given;

b. $\Psi_{N-k} = 0$;

c. $\mu^h_{G^{N-k}}(x_{N-k}, y_{N-k})$ is calculated using equation (13);

d. Equation (15) is computed, where x_{N-k} and y_{N-k} are replaced with expressions 17 and 18;

e. $\Psi_{N-k} = \Psi_{N-k} + \Delta\Psi$ and points *c, d, e* are repeated until the maximum of Ψ_{N-k}^M is found;

f. $\gamma_{N-k} = 0$;

g. $\mu^{v}_{G^{N-k}}(p_{N-k}, h_{N-k})$ is calculated using expression 14, where x_{N-k} and y_{N-k} are the values attained at the maximum $\Psi_{N-k} = \Psi^{M}_{N-k}$;

h. Equation 16 is computed, where p_{N-k} and h_{N-k} are replaced with expressions 19 and 20 respectively;

i. $\gamma_{N-k} = \gamma_{N-k} + \Delta\gamma$ and points *g, h, i* are repeated while the maximum of γ^{M}_{N-k} is found;

j. If $(x_g \neq x_0 \; or \; y_g \neq y_0 \; or \; h_g \neq h_0)$ then

x_{N-k}, y_{N-k}, p_{N-k} and h_{N-k} are calculated using expressions 17, 18, 19, and 20;

the horizontal velocity $v_h = \sqrt{v^2 - \left(\frac{h_{N-k} - h_{N-k+1}}{\Delta t}\right)^2}$ is computed;

$k = k - 1$;

go to point b;

else

end of procedure;

In the process of searching for the maximizing decision the two control angles are altered from 0 to 2π for each of the one-stage decision process. The increments of the control angles ΔΨ and Δγ are calculated by the following expressions:

$\Delta\Psi = \frac{2.\pi}{hwin}$, where *hwin* is the width of the matching window in the horizontal plane,

and

$\Delta\gamma = \frac{2.\pi}{vwin}$, where *vwin* is the width of the matching window in the vertical plane, respectively.

Simulation

In order to explore the validity of the proposed fuzzy control for autonomous guided vehicle simulations have been carried out. The following initial conditions have been given: v=6.0, Δt=1.0, k_x=0.00001, k_y=0.00001, k_h=0.0001, k_p=0.00001, hwnd=720, vwnd=720, x_g=500, y_g=320, h_g=200, x_0=10, y_0=180, h_0=50. The process starts when k reaches 120. The simulation program is written in MATLAB. The moving goal is described by the following linear movement equations:

$x_0=x_0+2$; $y_0=y_0+4$; $h_0=h_0+2$; p_0=sqrt((x_0.^2)+(y_0.^2));

Figure 1 shows the simulation results in 3D space. Figure 2 shows the horizontal and vertical velocity in the process of decision-making.

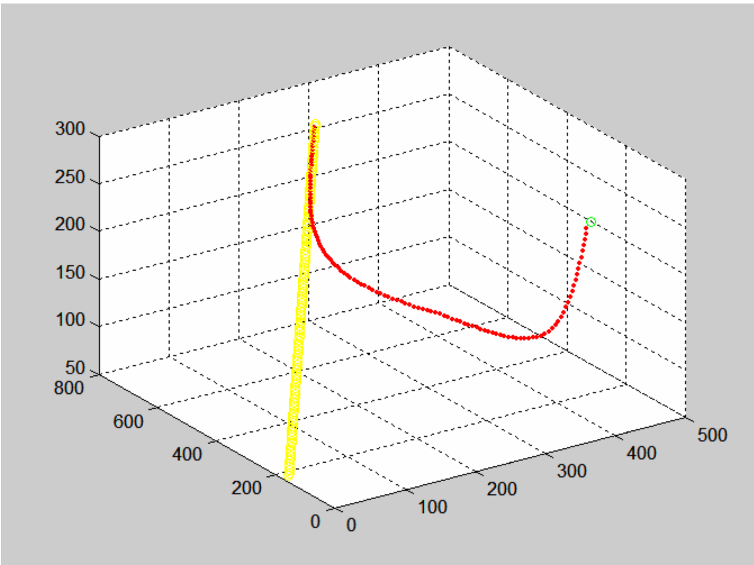

Figure 1: Moving trajectories of the goal and the vehicle in 3D space

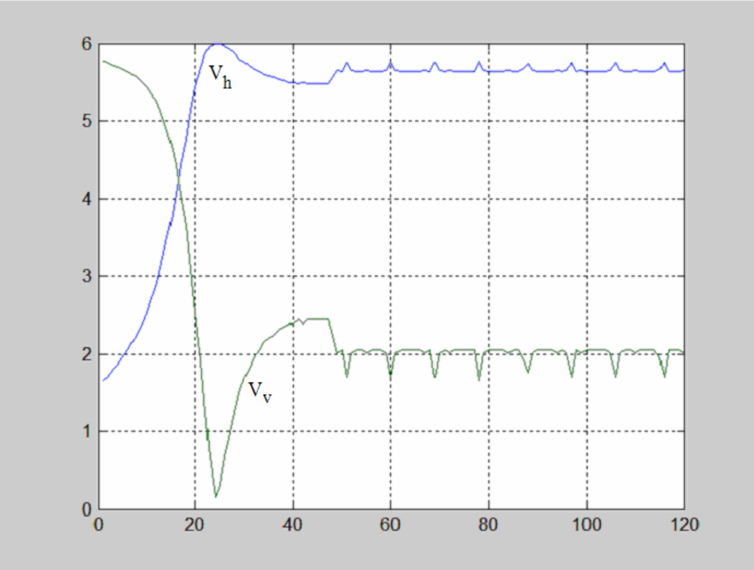

Figure 2: Horizontal and vetical velocity.

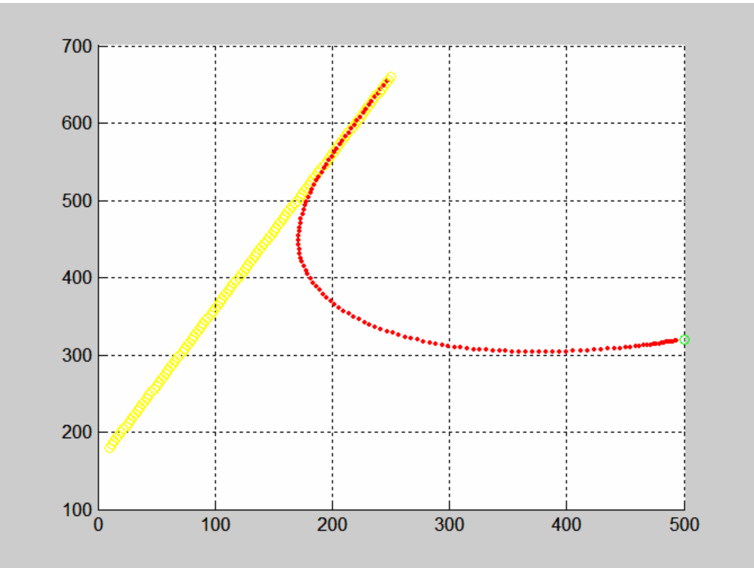

Figure 3: Moving trajectories in horizontal plane.

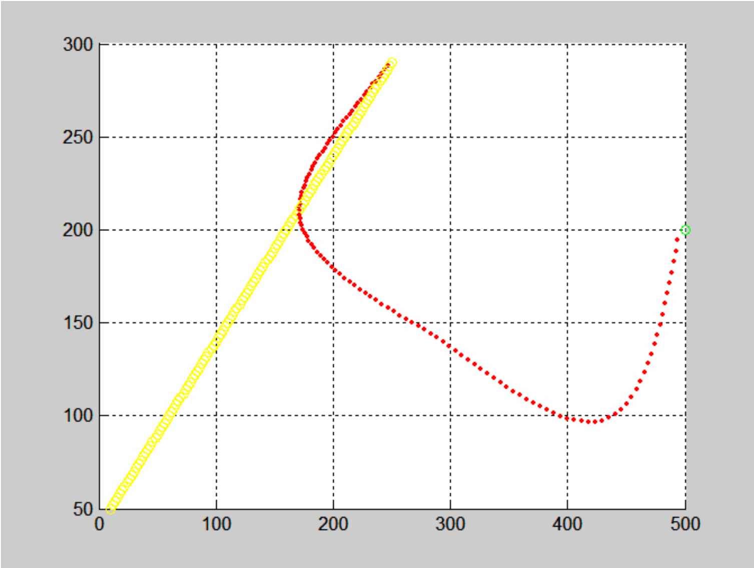

Figure 4: Moving trajectories in vertical plane.

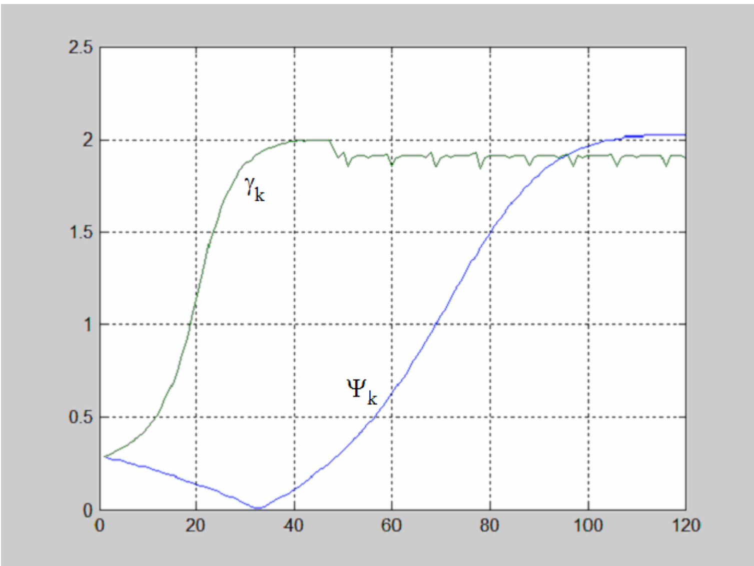

Figure 5: Control angles in horizontal and vertical planes.

Figure 3 and Figure 4 show the simulation results in horizontal and vertical planes. The control angles are shown in Figure 5. It is observed that the guided vehicle can reach the moving object successfully.

Conclusion

A fuzzy control approach has been presented for model movement along the optimal path. The optimal registration path is computed for an autonomous guided vehicle in 3D space. A system of functional equations can be solved using dynamic programming and appropriate membership functions for fuzzy environment. In this context, the proposed approach can be used for other similar applications. Computer simulations have validated the validity of the proposed method for control applications. Experiments of the guided vehicle are simulated in a simple fuzzy environment. In addition, techniques to plan a path in an expanded fuzzy environment, including both stationary and moving obstacles, are under study.

Notes:

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7 Richard E. Bellman and Lotfi A. Zadeh, "Decision Making in a Fuzzy Environment," *Managment Science* Ser. B 17, 4 (1970): 141-164.

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9 Hiroaki Sakoe and Seibi Chiba, "A Dynamic Programming Approach to Continuous Speech Recognition" (paper 20 presented at the *International Congress on Acoustics*, Budapest, Hungary, 1971), C-13.

10 Bellman and Zadeh, "Decision Making in a Fuzzy Environment."

11 Bellman and Zadeh, "Decision Making in a Fuzzy Environment."

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GAME THEORETICAL MODELING FOR PLANNING AND DECISION MAKING

Juliana KARAKANEVA

Military operations are a consistent set of strategic, operational, and tactical actions. Each military conflict is an interaction of hostile parties, which can perform different actions to achieve their goals. In many cases the military conflict consists of offensive actions of one side and defensive actions of the other side. Recently, asymmetric conflicts create many challenges due to their untraditional methods and actions. In all cases the objective of the defense is to minimize the losses caused by the enemy and the objective of the attack is to maximize these losses.

Contemporary strategy and doctrine are based on joint and coalition operations. Operational war-games typically consist of multi-echelon participants as main forces, enemy, control staff, and a number of neutral, friendly and coalition teams. Recently, the Operations Other Than War – peacemaking, peacekeeping, humanitarian relief operations – are of special interest. The asymmetric environment they represent can be modeled in a natural manner using game theory. However, they pose many challenges to the applied game theory in terms of analysis and prediction.

The central part of the model of planning and decision-making is based on the above-mentioned ideas from game theory. Game theory has been chosen due to the fact that it addresses one of the central elements of the process, namely the analysis of alternative courses of action. Planners from each side of the conflict have a separate (and generally different) payoff matrix, representing each planner's perception of the possible courses of action open to him and his opponent, and the consequences of the interaction between them.

The essence of the deliberate planning model[1] is the analysis by the planner of this payoff matrix and the selection of a single course of action that is, in some sense, the 'best' one to take given the perceived options open to the enemy. Selection of a course of action is the command decision and it is the key output of the deliberate planning process model.

Applying modeling software, for example the LINGO-language,[2] gives the opportunity to generate many experiments and to obtain different results. This is very useful in gaining experience through simulation based on historical data. This paper presents practical and fast application of the game theoretic approaches, applied to contemporary asymmetric conflicts.

Game-Theoretical Models

Game theory models provide appropriate mathematical models of real conflict situations.[3] Game theory enables modeling of the most important elements of the planning and decision-making processes – analysis of alternative courses of action, the behavior of the sides, and payoffs and losses. These techniques assist in the optimal allocation of forces and equipment, as well as in making key decisions in operational planning.

Particularly interesting is the game theoretical model of the offensive action. Model development is usually based on different approaches; it depends on the assumed constraints and initial conditions, and it leads to finite or infinite antagonistic game, general positioning game or coalition/non-coalition game, respectively.

Finite Antagonistic Game

A real conflict can be modeled by *finite antagonistic game* if the following conditions are satisfied:

1.1 The conflict is determined by antagonistic interaction of two parties, each of which disposes only finite number of possible actions.

1.2 The parties undertake the actions separately, i.e. each of them does not have information about the operation of the other party. The result of these actions is estimated by a real number that determines the usefulness of the situation for one of the parties.

1.3 Each party evaluates for itself and for the opponent the usefulness of any possible situation, which can develop as a result of their interaction.

1.4 The actions of the parties do not posses formal features. Thus the parties' actions can be treated as abstract homogeneous sets.

If conditions (1.1-1.4) are fulfilled for a given conflict, defining one of the parties by player *I* and the other by player *II*, we can describe the conflict by the following antagonistic game[4]

$$\Gamma = \langle X, Y, H \rangle, \qquad (1)$$

where X is the set of pure strategies of player I, $X = \{X_1, X_2 \dots X_m\}$;

Y is the set of pure strategies of player II, $Y = \{Y_1, Y_2 \dots Y_n\}$;

H is the function of usefulness (payoff) of player I, which is determined for all pairs of possible actions of the players.

Real conflicts that satisfy conditions (1.1-1.4) can then be modeled as finite antagonistic game and represented by the following matrix:

$$H = \left\| h_{ij} \right\|, \qquad h_{ij} = H(i,j), \qquad 1 \le i \le m\,,\ 1 \le j \le n; \tag{2}$$

In order to find a stable optimal strategy it is necessary to solve the following equations:

$$E_1(X, y_j) = \sum_{i=1}^{n} h_{ij} x_i = const; (j = 1,\dots m); \tag{3}$$

$$E_2(x_i, Y) = \sum_{j=1}^{m} h_{ij} y_j = const; (i = 1,\dots n);$$

$$\sum_{i=1}^{n} x_i = 1; \tag{4}$$

$$\sum_{j=1}^{m} y_j = 1;$$

Thus, the game payoff is:

$$E(X,Y) = \sum_{j=1}^{m} \sum_{i=1}^{n} h_{ij} x_i y_j\ . \tag{5}$$

Strategies $X^* \in X$ and $Y^* \in Y$ are optimal mixed strategies for players I and II, if the following expression is true:

$E(X, Y^*) \le E(X^*, Y^*) \le E(X^*, Y)$ - expressed as a Cartesian product of the (X, Y) pair.

The solution then is of the following form:

$$\begin{aligned} &\left\| X^*, Y^*, \nu \right\| \\ &\nu = E(X^*, Y^*) \end{aligned} \tag{6}$$

where ν is the game cost.

Let us presume the following real situation. Side *A* plans an attack against side *B* during time *T*, $T = n*t$. The attack begins at moment *i* and goes on at moments $i+1, i+2, \ldots, n$. Simultaneously, side *B* plans to deploy equipment for electronic warfare (EW) and the beginning of this counteraction is the *j*-th time unit and it continues at $j+1, j+2, \ldots, n$.

We presume that if the EW equipment of side *B*, deployed before the attack of side *A*, is disclosed by the intelligence of side *A;* therefore, this equipment becomes ineffective. On the other hand, when the attack of side *A* begins before the deployment of the EW equipment, side A's weapons' effectiveness decreases due to this deployment. Thus, the assumption is that the time of the attack and the time of the EW deployment are determined and the attack's intensity is constant.

Let the expected value (EV) of the number of destroyed ships of side *B* is $EV = c$. The assumption is that side *B* does not counterattack side *A*. It is also presumed that if the attack of side A happens simultaneously with the EW usage of side B then $EV = c/2$ during the whole time interval *T*. If $i < j$ and side *B* does not counterattack during the time $(j-i)$, after that EW will decrease the attack effectiveness to zero.

The EV of the number of destroyed ships at time *T* is $EV = c\,(j-i)$. If $i > j$, i.e. side *A* attacks after the EW-deployment, then the EW effectiveness is close to zero and $EV = c\,(n-I+1)$. If the actions of both sides happen at the same time ($i=j$), then $EV = c\,(n-i+1)/2$. Side *A* begins the attack at the *i*-th time moment and tries to maximize the number of destroyed ships during the time interval *T*. Side *B* counteracts through their EW equipment at time *j* and tries to minimize the losses.

The described conflict situation is interpreted as offensive action in view of the fact that side *B* could in principle use a military unit, weapons, equipment or maneuvers that can decrease the adversary's effectiveness.

The relevant mathematical model for this situation is a finite antagonistic game $\Gamma = \langle x, y, H \rangle$, where $x = 1, 2, \ldots, n$ is the set of pure strategies of side *A* (player *I*) and $y = 1, 2, \ldots, n$ is the set of pure strategies of side *B* (player *II*) and the payoff function of player *I* is *H*.

Therefore, according to the above:

$$H = \begin{cases} c^*(j-i) & \text{for } i<j; \\ c^*(n-i+1)/2 & \text{for } i=j; \\ c^*(n-i+1) & \text{for } i>j \end{cases} \qquad (7)$$

The related game matrix is the following:

$$H = \begin{pmatrix} n/2 & 1 & 2 \ldots & n-2 & n-1 \\ n-1 & (n-1)/2 & 1 \ldots & n-3 & n-2 \\ \ldots\ldots\ldots & \ldots\ldots\ldots & \ldots\ldots\ldots & \ldots\ldots\ldots & \\ 2 & 2 & 2 \ldots & 1 & 1 \\ 1 & 1 & 1 \ldots & 1 & 1/2 \end{pmatrix} \qquad (8)$$

The solution (X^*, Y^*, v) satisfies the equations:[5]

$$\begin{aligned} & H(X, j) = v, \quad j = 2, 3, 4, \ldots, k+1; \\ & \xi_1 + \sum_{1}^{K+1} \xi_i = 1; \\ & H(i, Y) = v, \quad i = 1, 3, 4, \ldots, k+1; \\ & \sum_{2}^{K+1} \eta_i = 1; \end{aligned} \qquad (9)$$

When $n=6$ the matrix H and the software model look like:

$$H = \begin{pmatrix} 6/2 & 1 & 2 & 3 & 4 & 5 \\ 5 & 5/2 & 1 & 2 & 3 & 4 \\ 4 & 4 & 4/2 & 1 & 2 & 3 \\ 3 & 3 & 3 & 3/2 & 1 & 2 \\ 2 & 2 & 2 & 2 & 2/2 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1/2 \end{pmatrix}$$

```
MODEL:
MAX= P;
        A1+A2+A3+A4+A5+A6  = 1;
-P + 3*A1+  5*A2+ 4*A3+  3*A4+ 2*A5+  1*A6 >= 0;
-P + 1*A1+2.5*A2+ 4*A3+  3*A4+ 2*A5+  1*A6 >= 0;
-P + 2*A1+  1*A2+ 2*A3+  3*A4+ 2*A5+  1*A6 >= 0;
-P + 3*A1+  2*A2+ 1*A3+1.5*A4+ 2*A5+  1*A6 >= 0;
-P + 4*A1+  3*A2+ 2*A3+  1*A4+ 1*A5+  1*A6 >= 0;
-P + 5*A1+  4*A2+ 3*A3+  2*A4+ 1*A5+0.5*A6 >= 0;
END
P 2.181818
A1       0.5454545      A4      0.1818182
A2       0.0000000      A5      0.0000000
A3       0.2727273      A6      0.0000000
```

```
MODEL:
MIN = P;
B1+B2+B3+B4+B5+B6  = 1;
-P + 3*B1+  1*B2+ 2*B3+  3*B4+ 4*B5+  5*B6 <= 0;
-P + 5*B1+2.5*B2+ 1*B3+  2*B4+ 3*B5+  4*B6 <= 0;
-P + 4*B1+  4*B2+ 2*B3+  1*B4+ 2*B5+  3*B6 <= 0;
-P + 3*B1+  3*B2+ 3*B3+1.5*B4+ 1*B5+  2*B6 <= 0;
-P + 2*B1+  2*B2+ 2*B3+  2*B4+ 1*B5+  1*B6 <= 0;
-P + 1*B1+  1*B2+ 1*B3+  1*B4+ 1*B5+0.5*B6 <= 0;
END
P        2.181818
B1       0.0000000              B4       0.5454545
B2       0.3636364              B5       0.0000000
B3       0.9090909E-01          B6       0.0000000
```

The task is solved by the LINGO-solver and the solution is:

$X^* = (0.54, 0, 0.27, 0.18, 0, 0)$, $Y^* = (0, 0.36, 0, 0.54, 0, 0)$, $v = 2.18$.

We can provide the following interpretation. The relevant strategies are: side *A* attacks with a probability 0.54 at the first time unit and with probability 0.27 at the third time units, respectively. Side *B* deploys the EW equipment with a probability 0.36 at the second time unit.

Infinite Antagonistic Game

A real conflict situation can be modeled by *infinite antagonistic game* in case of the following conditions:

2.1 The conflict is determined by antagonistic interaction of two parties where at least one of the parties can initiate infinite number of probable actions.

2.2 The parties initiate the actions in isolation, i.e. they have no information about the operation of the other party. The result of these actions is assessed by a real number, which determines the usefulness of the situation for each of the parties.

2.3 Each party knows the usefulness of any possible situation both for itself and the opponent, which can develop as a result of their interaction.

2.4 The actions of the parties do not posses formal features. Thus, they can be treated as elements of abstract homogeneous sets, which could be distinguished according to the payoff of the game situation.

If the conflict corresponds to (2.1-2.4), defining one of the parties by player *I* and the other by player *II*, we can describe it by the infinite antagonistic game $\Gamma = <X, Y, H>$, where *X* is the set of pure strategies of player *I, Y* is the set of pure strategies of player *II, H* is the function of usefulness of player *I*, which is determined for all pairs of possible actions of the players.

Continuous game theoretical model that is analogous to the offensive action is the following game. We denote as *t* the beginning of side *A*'s attack against the aircraft-carrier unit of side *B* and as *r* – the moment of side *B*'s actions, namely EW, and $0 \le t, r \le T$. Note that $x = t/T$ and $y = r/T$. Then the pure strategy of *A* will be $x \in [0,1]$ and the pure strategy of *B* will be $y \in [0,1]$. The chosen strategies define the game situation (x, y) and the party *A* has the payoff $H(x, y)$. The set of (x, y) situations defines the area $[0, 1]$x$[0, 1]$ and the payoff function of player *A* in this area is presented as the following function:

$$H(x,y) = \begin{cases} c*(y-x) & \text{if } x<y; \\ c*(1-x)/2 & \text{if } x=y; \\ c*(1-x) & \text{if } x>y. \end{cases} \quad (9)$$

We presume that the other conditions are the same as those of the finite antagonistic game. If $c = 1$ and if we apply some transformations on matrix (7) the result is the following matrix:

$$\left\| H\left(\frac{i-1}{n}, \frac{j-1}{n}\right) \right\|, \qquad 1 \leq i, j \leq n \quad (10)$$

where the function H is defined as shown in equation (9).

Thus, the matrix game (7) approximates the infinite game (9), i.e. the conflicts which we model are distinguished only by the nature of the time – in the first case the time is a discrete quantity while in the second case time is a continuous quantity.

The solution of the game described by matrix (10)[6] is $v = 1/e;$ the optimal strategy of player *II* on a segment [$0, 1\text{-}1/e$] is defined by the density $1/(1\text{-}y)$; the corresponding optimal strategy of player *I* is the cumulative distribution function defined by the density $1/(e(1\text{-}x))^2$ on a segment ($0, 1\text{-}1/e$).

General Positioning Game

In principle, real conflicts develop in time and space. Thus, conditions 1.1-1.3 are valid and, moreover, the participants at each phase of the conflict can gather additional information about the situation or, on the contrary, can lose it. The result of their operations can be assessed by a real number, which determines the degree of usefulness of the usual situation for one of the parties. That kind of conflict is modeled by a multi-stage (positioning) game.

Characteristic feature of the application of the positioning games is the construction of a positioning structure of the game and normalization with the subsequent solution in the mixed strategies or strategies of behavior. This feature frequently hampers the application of the game-theoretical methods; to overcome the combinatorial complexity other mathematical means are needed. However, if the number of alternatives is not very large, i.e. the game tree is practically visible, the game, being rather adequate model of dynamics of conflict, allows obtaining nontrivial analysis of the accepted solutions.

It happens in a military conflict one of the sides to have no information about the effectiveness of the other side's weapons. In this case we can consider two aspects of the payoff function: we have a hypothesis of the function or the game theoretical model is developed including the unknown information as a parameter of the strategy. The question is whether this method allows constructing an adequate model of the conflict. One of the approaches leads to the special class positioning antagonistic games with two players. Let we presume the following situation. The players *I* and *II* are opponents with antagonistic interests and can implement finite number of possible actions. The payoff function of player *I* is the set of matrices $H = \{H^1, H^2, \ldots H^r\}$. Presume that the first step is a random event and $k \in K = (1,2 \ldots m)$. The number k is only known by player *I*. Player *I* also knows the matrix $H^k = \left\| h_{ij}{}^k \right\|$, and chooses one number i, $(i=1,2, \ldots m)$. Player *II* knows the set $K = (1, 2, \ldots, r)$ and the distribution P_k, $(k \in K)$ and chooses the number j, $(j=1,2 \ldots n)$. Having this information player *I* can change his strategy to increase his payoff.

Variations in the choice of players' strategies are based on the available information. Thus, the game is a positioning game with incomplete information – the first step is a random event, player *I* makes the second step and player *II* makes the third (see Figure 1).

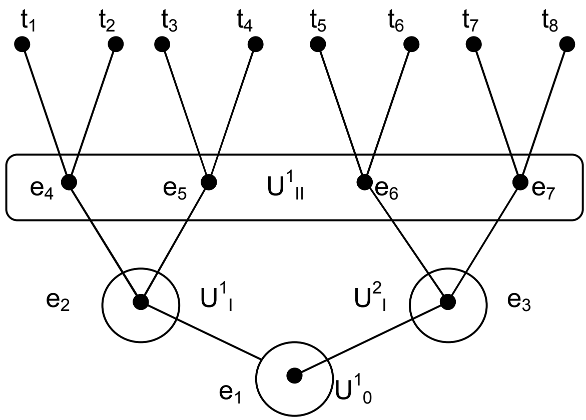

Figure 1: General Positioning Game

The strategy of player I is a function on the family of information sets:

$U_I = \{U^1{}_I, U^2{}_I, \ldots U^r{}_I\}$, with values in the interval $(1,m)$. I.e. the player's strategy is a set

$(i_1, i_2, \ldots i_r)$, where $i_k \in [1,m]$, $k = 1,2,\ldots r$ and we can denote the pure strategy as $X(i_1 \ldots i_r)$ and

$Card(X) = m^r$.

The second player does not have information about the first and the second action and he only chooses the number j – thus, his strategy is:

$$y_j = (\underbrace{0, \ldots, 0}_{j-1}, 1, 0, \ldots, 0);\ j = 1,2,\ldots n;\quad Card(Y) = n.$$

The optimal strategy for player *I* is defined as:

$X^* = \{\xi^*(x_{i1\ldots ir})\}$, where $\xi^*(x_{i1\ldots ir})$ is the probability of application of the pure strategy $x_{i1\ldots ir}$.

The optimal strategy for player *II* will be:

$Y^* = \{\eta^*(y_j)\}$, where $\eta^*(y_j)$ is the probability of application of the pure strategy y_j.

To illustrate a similar task we presume the single throw finite antagonistic game. An antisubmarine aircraft can use two different tools, 1 and 2, to detect the target. The submarine itself can choose a depth A_1 or A_2 according to the available information. We assume as an effectiveness criterion the probability not to discover the submarine.

Let in the case of condition of type *1* the payoff matrix of player *I* is $H^1 = \left\| h^1{}_{ij} \right\|$, where $h^1{}_{ij}$ is the probability not to discover the submarine in condition *1*, *i*–th depth and *j*–th tool.

Let in the case of condition of type *2* the payoff matrix of player *I* is $H^2 = \left\| h^2{}_{ij} \right\|$, where $h^2{}_{ij}$ is the probability not to discover the submarine in condition *2*, *i*–th depth and *j*–th tool.

Player *II* has incomplete information about the situation. Then the payoff matrix is $H^k = \left\| h^k{}_{ij} \right\|$, where $h^k{}_{ij}$ is the probability not to discover the submarine in condition of type *k*, *i*–th depth and *j*–th tool. We suppose that $P_1 = 0.3$ and $P_2 = 0.6$ and the payoff matrices are the following.

$$H^1 = \begin{bmatrix} 0.3 & 0.5 \\ 0.2 & 0.3 \end{bmatrix} \qquad H^2 = \begin{bmatrix} 0.3 & 0.4 \\ 0.6 & 0.2 \end{bmatrix}$$

Let we represent this situation by a positioning game and then construct the payoff table *H* as follows:

H	Y_1	y_2
x_{11}	0.9/3	1.3/3
x_{12}	1.5/3	0.9/3
x_{21}	0.8/3	1.1/3
x_{22}	1.4/3	0.7/3

```
MODEL:                                              PG    1.14
MAX = PG;                                           B1    0.6000
B1+B2+B3+B4=1;                                      B2    0.4000
- PG + 0.9*B1+1.5*B2+0.8*B3+1.4*B4 >= 0;            B3    0.0000
- PG + 1.3*B1+0.9*B2+1.1*B3+0.7*B4 >= 0;            B4    0.0000
END
```

```
MODEL:
MIN = LP;
B1+B2=1;
-LP + 0.9*B1+1.3*B2<= 0;
-LP + 1.5*B1+0.9*B2<= 0;                            LP    1.14
-LP + 0.8*B1+1.1*B2<= 0;                            B1    0.4000
-LP + 1.4*B1+0.7*B2<= 0;                            B2    0.6000
END
```

The problem is then solved by the LINGO-solver and the solution is:

$\xi^*(x_{11}) = 0.6;$ $\xi^*(x_{12}) = 0.4;$ $\xi^*(x_{21}) = 0;$ $\xi^*(x_{22}) = 0;$
$\eta^*(y_1) = 0.4;$ $\eta^*(y_2) = 0.6;$ $v = 0.38.$

The strategy of player *I* is defined as $f^* = ((1,0), (0.6, 0.4)).$

The optimal strategies of the players are:

$\underline{X}^*(1) = (1, 0);$ $\underline{X}^*(2) = (0.6, 0.4);$ $Y^* = (0.4, 0.6).$

The interpretation is the following. In condition of type 1 the best solution is to submerge the submarine at depth A_1. In condition of type 2 the solution is as follows – depth A_1 with probability 0.6 and depth A_2 with probability – 0.4.

Thus, in case of incomplete information it is useful to try to find the optimal solution constructing an appropriate positioning game.

Non-Coalition Game

A real conflict situation can be modeled as a *non-coalition game* if the following conditions are met:

4.1 The conflict is determined by non-antagonistic interaction of parties.
4.2 The parties are not permitted to create coalitions.
4.3 The result of their actions is assessed by a real number that determines the usefulness of the situation for each of the parties.
4.4 Each party knows the usefulness of any possible situation both for itself and the opponent.

If a conflict falls in the category described by (4.1-4.4), we can represent it as a non-coalition game of the following form:

$\Gamma = < I, \{x_i\}, i \in I, \{H_i\}, i \in I >,$

where *I* is the set of players, $\{x_i\}$ is the set of pure strategies of player *i*, $\{H_i\}$ is the payoff function of player *i*, in Cartesian product $x = \Pi_{i \in I} x_i$..

Non-coalition games model real conflict situations when two forces are antagonistic opponents and the benefit of one side is equal to the loss of the other. The theoretical form just presented models the following situation.

An aircraft-carrier unit denoted *A* plans an attack against the aircraft-carrier unit *B* at time *T*, $T = s*t$. The attack begins at time moment *i* and continues at moments $i+1, i+2, ..., s$. Simultaneously, *B* plans an attacks at moment $j, j+1, j+2, ..., s$. At the same time, units *A* and *B* deploy radio-electronic countermeasures. We presume, that units *A* and *B* have equal combat capability and that the most important characteristic is the expected value of the number of destroyed enemy ships, namely:

C (in case of an attack without counteraction);
$c/2$ (in case of an attack with counteraction);
0 (in case of counteraction through EW).

So, if $i<j$, i.e. side *A* attacks at time interval $(j-i)$ without a counteraction and after that the effectiveness of *A*'s actions becomes zero due to the deployment of enemy's EW. If we accept that *B* begins the attack after the deployment of the EW equipment of side *A* and its effectiveness is close to zero, then the EV of the number of destroyed ships at time *T* is as follows:

$a_{ij} = c*(j-i)$ for *B* and $b_{ij} = c*(s-j+1)$ for *A*.

If $i>j$ then $a_{ij} = c*(s-i+1)$ for *B* and $b_{ij} = c*(i-j)$ for *A*.

If $i=j$ then $a_{ij} = b_{ij} = c*(s-i+1)/2$.

Side *A* begins the attack at the *i*-th time moment and deploys the EW equipment. Then its objective is to maximize the EV of its payoff. Side *B* begins the attack at the *j*-th time moment and counteracts through their EW equipment trying to minimize the losses.

The payoff functions of players *A* and *B*, based on their combat capabilities are as follows:

$$H_A(i,j) = \begin{cases} c*(j-i) & for\ \ i<j; \\ c*(s-i+1)/2 & for\ \ i=j; \\ c*(s-i+1) & for\ \ i>j \end{cases} \tag{11}$$

$$HB(i,j) = \begin{cases} c*(s-j+1) & for\ \ i<j; \\ c*(s-j+1)/2 & for\ \ i=j; \\ c*(i-j) & for\ \ i>j \end{cases} \tag{12}$$

$$HA(i,j) + HB(i,j) = \begin{cases} (s-i+1) & for\ \ i \leq j; \\ (s-j+1) & for\ \ i > j; \end{cases} \tag{13}$$

Thus, according to (13) the players' payoff depends on their strategies. Therefore, the conflict is antagonistic one and is modeled by the antagonistic game $\Gamma = <x, y, H_A, H_B>$, where $x = y = \{1, 2, ..., s\}$ are the sets of pure strategies of the players and H_A, H_B are the payoff functions of the players *A* and *B*.

The corresponding matrices are:

$$A = \begin{pmatrix} s/2 & 1 & 2\ldots & s-2 & s-1 \\ s-1 & (s-1)/2 & 1\ldots & s-3 & s-2 \\ c^* & & \ldots & & \\ 2 & 2 & 2\ldots & 1 & 1 \\ 1 & 1 & 1\ldots & 1 & 1/2 \end{pmatrix}$$

$$B = c^* \begin{pmatrix} s/2 & s-1 & & 2 & 1 \\ 1 & (s-1)/2 & & 2 & 1 \\ \ldots & & & & \\ s-2 & s-3 & \ldots & 1 & 1 \\ s-1 & s-2 & \ldots & 1 & 1/2 \end{pmatrix}$$

The analysis of the bi-matrix game Γ equilibrium state is quite difficult. The task is easier when the players have infinite set of possible strategies. Therefore, let we assume that the time interval *T* is of the form [*0, 1*]. If player *A* begins an attack and deploys EW equipment at moment $x \in [0, 1]$ and player *B* at moment $y \in [0, 1]$, then the players' payoffs are as follows:

$$HA(x,y) = \begin{cases} c^*(y-x) & \text{if } x<y; \\ c^*(1-x)/2 & \text{if } x=y; \\ c^*(1-x) & \text{if } x>y; \end{cases} \qquad (14)$$

$$HB(x,y) = \begin{cases} c^*(1-y) & \text{if } x<y; \\ c^*(1-y)/2 & \text{if } x=y; \\ c^*(x-y) & \text{if } x>y; \end{cases} \qquad (15)$$

where $H_A(x,y) + H_B(x,y) \neq const$

This model is a continuous case analog of the game-theoretical model of the offensive attack – the non-antagonistic infinite game.

Concluding Remarks

There are some particular areas that would benefit from game theory and the other modeling and simulation approaches. The objective often is to assist the planning and the decision-making processes, which are the most important activities in military operations. The perspectives for future development are in the aspects given below.

The analyst needs a suitable tool to automatically enumerate the relevant players, their options, and the estimated payoffs. It is necessary to create and maintain a database, and to combine the expert knowledge. A successful approach is to develop the games from the situation and the historical data. Agent-based modeling could assist these activities with appropriate tools for assessment of the situation, finding of the best alternative, estimation of the payoffs and even planning.

These tools aim at the development of optimal strategies. Similarly, multiplayer game models that reflect effectively the conditions of contemporary conflicts – creating coalitions, international organizations – enlarge the scope of application. Varieties of models correspond to static or dynamic equilibrium. The strategy for improvement is based on the use of expert knowledge of psychological factors. It is important to reuse previous expert assessments of payoffs and previous solutions strategies.

The application of computer-aided software environments (CASE) is a very useful means in the whole process. Modeling languages provide powerful tools to model the conflict situations through the use of game theory. The LINGO language is an automatic tool for optimization and modeling that provides the possibility to solve many discrete and continuous, as well as stochastic tasks. This paper has illustrated the application of the game theoretical models to real situations. Several tasks were solved using the LINGO-software illustrating the usefulness of this commercial-off-the-shelf (COTS) product to military research applications. The strategies are experimented and the solutions are proposed to planners and decision-makers.

Given a game theoretical perspective we begin the process of formulating players, options, and payoffs. Figure 1 illustrates the concept of lifting a hypothetical game from an ABC database[7] of historical events. An ABC database includes selected antecedents to historical events, behaviors or options actually executed by the collected targets, and a valuation of the degree of success or value achieved by the target's action (consequent) for a given set of antecedents and behaviors.

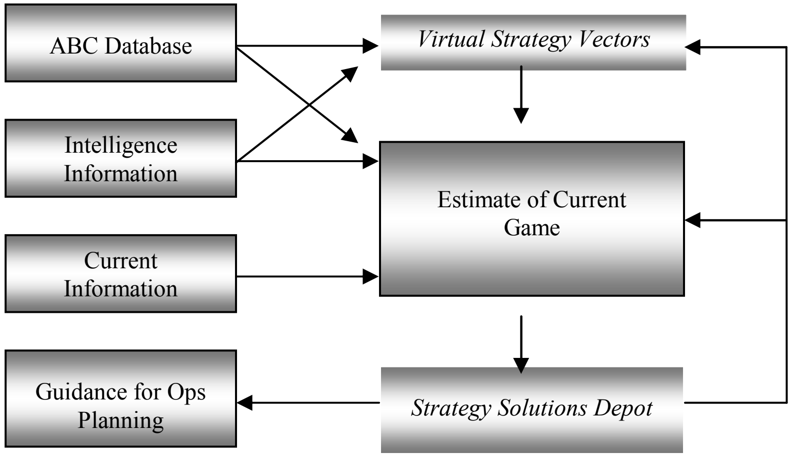

Figure 2: Bootstrapping the Hypothetical Game.

Figure 2 is actually a high-level indication of the process outlined in the research area above. A detailed elaboration is beyond the scope here, but the fundamental notion is that mixed strategy vectors are implicit in the ABC history for each target or player. The process outlined here extracts the implicit strategy vectors and incorporates available intelligence on player ideology, worldview, beliefs, knowledge, capabilities and objectives to generate a plausible set of payoffs. The combination of implicit strategy vectors, plausible payoff matrix and individual player information sets, constitute the initial hypothetical game. Refinement of the initial hypothesis could be directed by reduction of uncertainty in payoff and information estimates and options available to players over time.

In conclusion, using a game theoretic formulation for predictive purposes, we have the problem whether suggested war games representation generates emergent collective behavior that resembles realistic military environment. The assumption of complete information is the greatest impediment to the practical application of classic game theory. An asymmetric information game where players have incomplete information on either payoffs or options or both is much more typical of the real world situation. Preliminary results are encouraging.

Notes:

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[1] Colin R. Mason and James Moffat, "Decision Making Support: Representing the C2 Process in Simulations: Modelling the Human Decision-Maker," in *Proceedings of the 2000 Winter Simulation Conference*, (Orlando, FL, USA, 10-13 December 2000), 940-949.

[2] *LINGO the Modeling Language and Optimizer* (LINDO Systems Inc., 2001).

[3] Drew Fudenberg and Jean Tirole, *Game Theory* (Cambridge, MA: MIT Press, 1993).

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[6] Dubin and Suzdal, *Introduction to Applied Game Theory.*

[7] Gregory M. Whittaker, *Asymmetric Wargaming: Toward a Game Theoretic Perspective* (The MITRE Corporation, October 2000).

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MODELING IN SHAPED CHARGE DESIGN

Hristo HRISTOV

The efficient development of scientific programs dealing with studies of reliability of the body lining of a spacecraft, as well as the quality of the results being obtained, depends to a great extent on the operational parameters of the shaped charges, their killing characteristics in particular, which are used to form jet particles. An integral parameter for assessment of the efficiency of the shaped charge is the length of the shaped jet.

It is known that the characteristics of the shaped jet, and its length in particular, depend on the geometry of the shaped charge. The influence of this factor will be analyzed shortly.[1] The solution of the task is satisfied within the hypothesis of the radial-flat scheme of the hydrodynamic model of Orlenko-Stanukovitch (See Figure 1). In the Cartesian co-ordinate system *z0y* the following equations of the generating line of the surfaces of the basic details of the shaped charge with height H are determined: $y_1 = F(z)$, $y_2 = \Phi(z)$, $y_3 = \varphi(z)$, and $y_4 = f(z)$. They describe the external and internal surface of the body, and the external and internal surface of the lining of the shaped charge, respectively. The following constraints are imposed on the functions just listed -- they are continuous and have continuous first derivatives. Furthermore, the following conditions are always fulfilled:

$$\xi \geq F(z) \geq \Phi(z) \geq \varphi(z) \geq f(z); \qquad H \geq 0;\ y \geq 0. \tag{1}$$

The front of the detonation wave is flat and perpendicular to the polar axis of the shaped charge in its movement into the weight of the charge from left to right. There are no constraints on the permissible boundary deformations of the jet material.

Let us assume that the collapse velocity of the lining *Wo(z)* does not depend on time and it is a function only of the *z* coordinate.[2] *Wo(z)* is related to the launch velocity of the shaped jet $W_1(z)$ in the cross-section that is examined by means of the kinematics relation:[3]

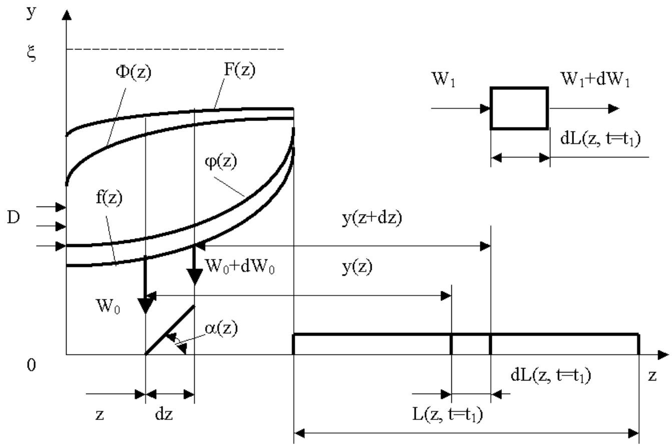

Figure 1: Radial-flat scheme of Orlenko-Staniukovitch for deformation and collapse of the lining of the shaped charge and formation of the jet.

$$W_0(z) = W_1(z).tg\frac{\alpha(z)}{2} = \frac{k_i.D}{2}.\sqrt{\beta(z).[2+\beta(z)]^{-1}} \ ,$$

where:

k_i is coefficient which gives the reading of redistribution of the impulse of the explosion according to the height of the shaped lining;

D is a velocity of detonation of the explosive;

β(z) is an explosive load coefficient;

α(z) is an angle of collapse of the lining.

The complete collapse of the lining is performed for a period of time $t = H/D$. The elementary fraction of the lining with a coordinate *z* and a length *dz* occupies a spatial position which is limited by the coordinates *y(z)* and *y(z+dz)*, and taking into account the geometry of the charge and the kinematics of the elementary fraction of the lining, we obtain:

$$dL = \left\{ \left(\frac{W_0}{tg\frac{\alpha}{2}} \right)' \left[\frac{H-z}{D} + \frac{f(H)}{W_0(H)} - \frac{f}{W_0} \right] + \frac{W_0}{tg\frac{\alpha}{2}} \left[-\frac{1}{D} - \frac{f'W_0 - fW_0'}{W_0^2} \right] \right\} dz \,. \qquad (2)$$

For $tg\frac{\alpha}{2}$ we have the following quadratic equation:[4]

$$Atg^2\frac{\alpha}{2} + 2tg\frac{\alpha}{2} - A = 0 \,.$$

And according to the physics of the process, the solution is the root

$$tg\frac{\alpha}{2} = \frac{-1+\sqrt{1+A^2}}{A} \,,$$

where

$$A = f' - \frac{f\beta'}{\beta(2+\beta)} + \frac{1}{2}\sqrt{\frac{\beta}{2+\beta}} \,.$$

If we integrate (2) from *0* to *H* we shall obtain the complete length of the shaped jet at the moment of completion of its formation:

$$L = \int_0^H \left\{ \frac{A}{\sqrt{1+A^2}-1} \left[\frac{\beta'}{\sqrt{\beta(2+\beta)^3}} \left(B_H - \frac{1}{2}z \right) - f' - \frac{1}{2}\sqrt{\frac{\beta}{2+\beta}} \right] - \right.$$

$$\left. - \frac{A'}{\sqrt{1+A^2}\left(\sqrt{1+A^2}-1\right)} \left[\sqrt{\frac{\beta}{2+\beta}} \left(B_H - \frac{1}{2} \right) - f \right] \right\} dz \,, \qquad (3)$$

where B_H is a known function of the load coefficient at $z=H$:

$$B_H = \frac{H}{2} + f_H \sqrt{\frac{2+\beta_H}{\beta_H}} .$$

Expression (3) is an initial expression that can be used to determine the extremum of the functional:

$$I = \int_0^H \overline{L}\left[z, \zeta(z), \zeta'(z)\right] dz ,$$

where:

$\overline{L}$ is a specified function;

0 and *H* are specified boundaries of integration;

$\zeta = \zeta(z)$ is a variable function of the geometry of the charge (e.g. external or internal surface of the body, the charge or the lining).

The function $\zeta = \zeta(z)$ that is sought, is a solution of the boundary task with boundary values for a conventional Euler-LaGrange differential equation of the type:

$$\overline{L}'_{\zeta} - \overline{L}''_{z\zeta'} - \overline{L}''_{\zeta\zeta'} \frac{d\zeta}{dz} - \overline{L}''_{\zeta'\zeta'} \frac{d^2\zeta}{dz^2} = 0 \quad (4)$$

and specified boundary conditions:

$$\zeta(0) = \zeta_0 ; \quad \zeta(H) = \zeta_H . \quad (5)$$

For real designs with a cylindrical body and a shaped lining with a constant thickness an additional integral condition can be used that provides optimum conditions for formation of the shaped jet[5] where the variable function is the profile of the lining:

$$\int_0^H G(z, f, f') = \int_0^H \left\{ \frac{1}{2} \frac{\beta'}{\sqrt{\beta(2+\beta)^3}} + f'' - \frac{(f'\beta' + f\beta'')(2+\beta)\beta - 2f\beta'^2(1+\beta)}{\beta^2(2+\beta)^2} \right\} dz = K \quad (6)$$

Here, K is a specified parameter. According to some authors[6] values for lining made of steel, aluminum and copper are equal to $K_{St}=0,231;\ K_{Al}=0,268;\ K_{Cu}=0,364$, respectively.

As a result we obtain a task with a conditional integral extremum that is equal to the task of an unconditional extremim of the expression:

$$\int_0^H \overline{L}(z,f,f')dz + \lambda\int_0^H G(z,f,f')dz = \int_0^H (\overline{L}+\lambda G)dz \quad , \tag{7}$$

where λ is an unknown constant multiplier of LaGrange.[7]

The task is reduced to the determination of the solution of the Euler equation for the modified function:

$$\overline{L}^*(z,f,f') = \overline{L}(z,f,f') + \lambda G(z,f,f') =$$

$$= \left[\frac{\beta'}{\sqrt{\beta(2+\beta)^3}}\left(B_H - \frac{1}{2}z\right) - f' - \frac{1}{2}\sqrt{\frac{\beta}{2+\beta}}\right]\frac{K}{\sqrt{1+K^2}-1} +$$

$$+\lambda\left[\frac{1}{2}\frac{\beta'}{\sqrt{\beta(2+\beta)^3}} + f'' - \frac{(f'\beta' + f\beta'')(2+\beta)\beta - 2f\beta'^2(1+\beta)}{\beta^2(2+\beta)^2}\right]. \tag{8}$$

The function $f = f(z)$ that was sought is a solution of the boundary task with two (one) no-move values for a conventional differential equation of Euler-LaGrange:

$$\overline{L}^{*\prime}_{f} - \overline{L}^{*\prime\prime}_{zf'} - \overline{L}^{*\prime\prime}_{ff'}\, f' - \overline{L}^{*\prime\prime}_{f'f'}\, f'' = 0 \tag{9}$$

and specified boundary conditions:

$$f(0)=f_0; \qquad f(H)=f_H. \tag{10}$$

The two integration constants and the LaGrange multiplier are determined by the three conditions -- two boundary and one additional condition.

The solution of the task is a set of straight lines that are parallel to the straight-line profile of the body (a cylinder or a cone) and depend on the specified boundary conditions. Figure 2 illustrates the solutions.

The solutions have a physical meaning. In all solution cases the angle of collapse and the load coefficient along the shaped charge are constants. The angle of collapse is minimum and is formed as a result of the delay of the front of the detonation wave that, in turn, provides the high launching velocity of the jet and its maximum length.

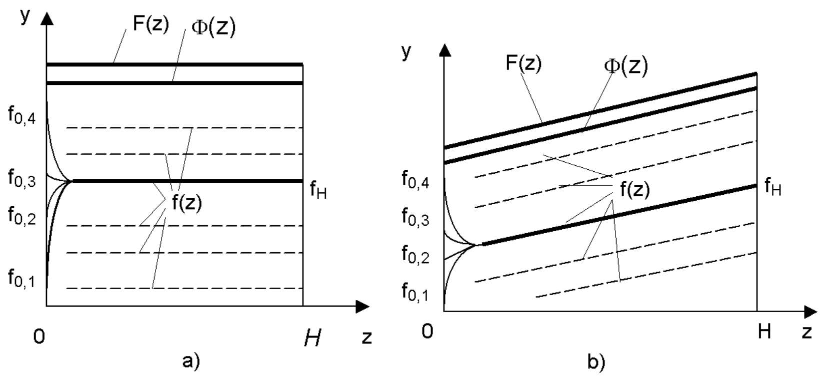

Figure 2: Solutions in case of: a) cylindrical body profile; b) conical body profile.

Notes

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IMoViS: A SYSTEM FOR MOBILE VISUALIZATION OF INTRUSION DETECTION DATA

Andrea SANNA and Claudio FORNARO

Introduction

Intrusion detection applications often produce large amount of data. The visualization of this information is a key task in order to allow the user to effectively detect attacks and intrusions. Information visualization is an important sub-discipline within the field of scientific visualization and focuses on visual mechanisms designed to communicate clearly to the user the structure of information and to *facilitate* the access to large data repositories. Information visualization helps people in dealing with all this information by taking advantage of the visual perception capabilities of the human being. By presenting the information in a more graphically oriented fashion, it is possible for the human brain to take advantage of its perceptual system in the initial information acquiring, rather than immediately relying entirely on the cognitive system. Some of the most important papers in the field are collected in a book.[1] Information visualization algorithms require merging of data visualization methods, computer graphics solutions, and graphical interface design.

A new challenge in information visualization is the use of Personal Digital Assistant (PDA) devices. PDAs were originally designed as personal organizers and their use was limited for a number of reasons, among them small screen size, low computational resources, limited wireless communication bandwidth, reduced interaction capability. But today's PDAs are efficient pocket computers and thus can be effectively used for remote monitoring purposes.

This paper proposes an integrated architecture, which is used by a security manager to remotely monitor large buildings for computer intrusion attempts; the front-end is just a PDA. The system is composed of two different parts:

- Intrusion detection and information collection system;
- Visualization interface.

Information collection is achieved by monitoring the network traffic of the LAN under control. The program used intercepts all the network traffic and scans it for traces of a possible attack.

For the Intrusion Detection part, an architecture based on existing software has been defined. Its purpose is to set some preprocessing steps for the information data, mainly cleaning and reduction, in order to meet the limited computational and communication resources of the mobile devices.

From the visualization point of view, this paper presents a graphical interface designed for PDAs. Data related to the building are organized hierarchically; this allows the user to see a global view, as well as detailed information concerning every machine located in each office/room of the building. Moreover, a tool for designing building maps is proposed. An arbitrary number of machines can be placed in every office and a set of information items, such as IP address, operating system, user name, and office telephone number, is associated with every machine.

The paper is organized as follows. The first section reviews main concepts of intrusion detection and some examples of visualization on PDAs, while the second explains in detail the proposed architecture and shows how intrusions are displayed on a PDA. Finally, the last section presents some remarks concerning performance issues of the proposed framework.

Background

Intrusion Detection Systems

To hinder the attacks performed against computer systems, information and security professionals turn to *Intrusion Detection Systems* (IDSs) to set up an active defense-in-depth strategy. A *firewall* is an essential and important part of network security but it does not have the ability to detect hostile intent. IDSs are classified as Host IDSs and Network IDSs. While the former are installed directly on the machine to be monitored and are intended just for that machine, the latter perform surveillance for the whole network. The most common scheme for a NIDS is composed of at least one sensor that intercepts the network traffic and an analysis engine. Different machines may handle alerting and attack analysis. An analysis engine considers packet protocol flags, source and destination addresses, sequential numbers, and application payload, such as email messages or web requests. Common attack signatures consist of strings to search for in the payload or network packet parameters. In addition, analysis may be applied to the whole TCP connection rather than individual packets or even include correlation of the connection to those occurred earlier or elsewhere on the network. The advantage of a NIDS is the ability to protect an entire network with a single machine, in a transparent way with respect to network hosts, with no impact on the network architecture and performance, detecting not only actual attacks, but also potential ones. Traffic wiretapping (sniffing) is possible because of the way data are transmitted over a LAN. Unencrypted data are split in packets (frames) and each one is directed to a particular NIC, which is identified by an address (a 48-bit number) called the MAC Address. No two NICs are manufactured with the same MAC Address (however, some NICs allow to change it). When a packet travels over the LAN, all the NICs that see it read the embedded destination MAC Address, but only the NIC whose MAC matches the one in the packet reads the whole packet and forwards it to the machine network protocol stack (e.g. TCP/IP) to be processed. On the contrary, NIDS' sensors use a NIC set up in *promiscuous mode*, so that they read all the network traffic, all the packets, independently of the destination MAC Address. The NIDS can, thus, have a big picture of the entire network and is able to recognize attacks conducted to every machine connected to the LAN.

Visualization on PDA Devices

PDAs, and mobile devices in general, have proven to be very effective tools for a large range of disciplines. The interested reader may consult a good survey on remote visualization.[2] This section briefly reviews the main areas where mobile devices (and among them PDAs) are used.

2D, and 3D graphics in particular, can be computed directly on PDAs by using operating system's APIs (for example see the article of Fairuz Shiratuddin and co-workers)[3] or Java Virtual Machines that allow designing graphical applications in Java, or by means of some ad-hoc software. Elite (http://home.rochester.rr.com/ohommes/elite/) is a fast 3D rendering engine for small devices running Java. This engine provides a framework for creation and display of 3D wireframe models. PocketGL (http://pierrel5.free.fr/pocketglb/) for Pocket PC (written in C and C++) allows drawing 3D objects and managing 3D transformations.

On the other hand, realistic visualization of large and complex models is not yet possible due to the computational limitations of PDAs. To overcome this problem, solutions for hardware-accelerated remote rendering have been recently presented.[4,5] These works aim to deploy hardware resources of centralized systems in order to allow the user to visualize and investigate large data set models on PDAs. This kind of application is strictly related to the problem of transmitting video data streams to remote devices.

One of the first applications of PDAs was for tourist and transportation purposes. Mobile devices can guide people through both real and virtual sites (museums, archeological sites, etc). Oppermann and Specht[6] and Vlahakis and colleagues[7] present two examples of virtual guides for museums and archeological sites, respectively. On the other hand, PDAs have been used to visualize maps of Virtual Harlem:[8] maps allow retrieving information about current location, as well as moving to any place in Virtual Harlem. Preim and co-workers present a mobile information system for public transportation:[9] this system helps travelers to find the best public transport to reach a destination and to estimate the time needed to arrive.

Another field of application where the use of mobile technologies seems very promising is telemedicine. Telemedicine scenarios include in-hospital care management, remote teleconsulting, collaborative diagnosis, and emergency situations handling. Different types of information need to be accessed by means of heterogeneous client devices in different communication environments in order to enable high quality continuous sanitary assistance delivery wherever and whenever it is needed. Personal mobile telemedicine systems using wireless communication links have been employed in several applications and have been extensively studied.[10,11,12] Java, XML, and XSL technologies are used by some reserhers to ensure software portability and effective data presentation on heterogeneous access devices.[13]

Education, entertainment, and training are fields where new technologies have always found large application. For instance, students of an elementary school can observe phenomena on a large display size and PDAs are used to aid data collection.[14] Many commercial programs are available for entertainment on mobile devices; a nearly exhaustive list of reviews and articles concerning games for PDAs can be found at http://www.pdarcade.com/.

The Proposed Architecture

This section provides an overview of the proposed architecture. Details concerning components of the whole system are presented in respective subsections.

A complete scheme is shown in Figure 1. Three main components can be identified:

- Snort
- Guardian
- Portable Intrusion Visualization Interface (P.I.V.I)

Snort (http://www.snort.org/) IDS is able to monitor network traffic. It uses a set of rules to identify attacks and intrusions (the terms attack and intrusion in this context refer to a violation of *Snort* rules). *Snort* stores each attack into a database (Snort DB) shared with the second component of the system: *Guardian*.

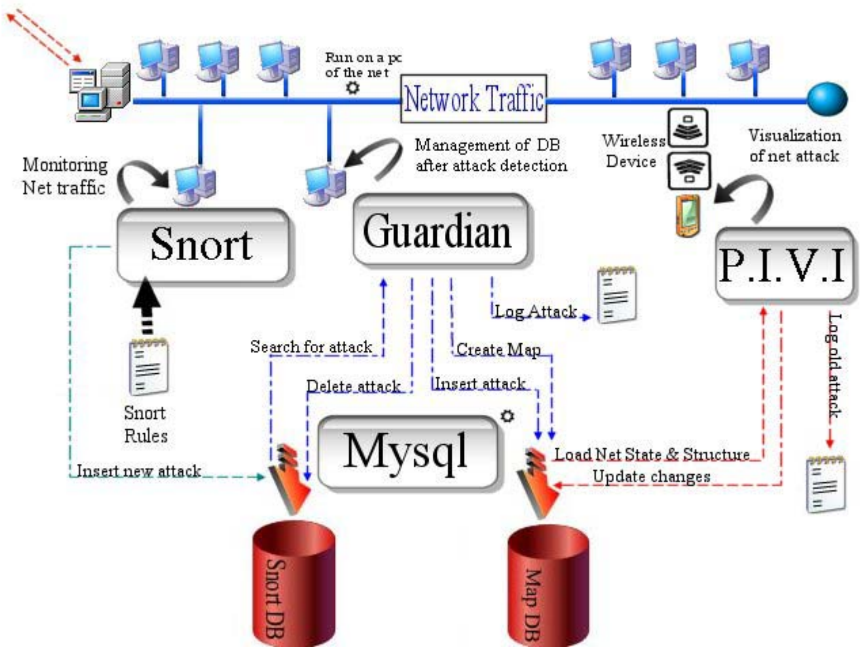

Figure 1: IMoViS Architecture.

Guardian is a program devoted to interface *Snort* to the visualization application and is not necessarily located on the same machine as *Snort*. *Guardian* manages the Snort DB in order to search for and delete attacks and produces a specific database (Map DB) used by the visualization application. *Guardian* can also produce log files useful for saving attack information and details.

P.I.V.I. is the visualization application. It loads a description of the building to be monitored, as well as the network status information from Map DB. The description of the building can be organized at different levels of detail and contains a graphical representation of the site under analysis. It is possible to specify which data have to be monitored, such as IP address, user name, and office telephone number. *P.I.V.I.* allows the user to delete already "processed" attacks from Map DB and to save log files of them.

MySQL (http://www.mysql.com/) has been chosen for database management system. MySQL has good performance in terms of speed and reliability and is open source. JDBC drivers allow the interaction between MySQL and the three system components: *Snort*, *Guardian*, and *P.I.V.I.*

Guardian and *P.I.V.I.* have been developed in Java and need a Java Virtual Machine (JVM) to be executed. Among the different Personal Java Application Environment implementations available for PDAs, the *Insignia Jeode Runtime* (http://www.insignia.com/) has been preferred to other implementations for its high adherence to Sun Microsystems Personal Java 1.2 specifications and for its advanced performance in executing Java byte-code. Jeode Runtime can be used both as a Pocket Internet Explorer plug-in to run Java applets from a Web page and as a stand-alone JVM to run Java applications.

Description of Snort

Snort is a Network Intrusion Detection System well known among the computer security professionals. Free and open source, it is rapidly becoming the tool of choice for Network Intrusion Detection. Unix and Windows versions are available and a huge and active enthousiastic community of users contributes to the development of filters and rules (signatures) suited to discover intrusion attempts (and, of course, makes them free to other users). It is considered one of the most advanced intrusion detection systems, free, but with the quality of a commercial product.[15] *Snort* is based on the sniffing libraries libpcap/winpcap.[16,17] The detection engine uses detection rules written using a simple but powerful language that describes per packet tests and actions: logging, content pattern matching, and attacks and probes detection. *Snort* has real-time alerting capability: alerts are sent to syslog, via SMB messages, or written to a separate "alert" file. A database may also be used to store them. *Snort* is configured using command line switches and Berkeley Packet Filter commands.[18] Third party add-ons may be used to simplify the administration tasks.

Description of Guardian

Guardian has two main purposes:

1. Interfacing *Snort* to *P.I.V.I.*;
2. Providing an effective tool for map design.

Every time a rule violation is detected, *Snort* pushes a record into the database (Snort DB in Figure 1). *Guardian* manages data produced by *Snort* and generates a second database (Map DB in Figure 1) containing a sort of "meta-data" used for the visualization process. Only a subset of the information produced by *Snort* is required by *P.I.V.I.*

Guardian periodically polls Snort DB in order to detect new data insertions. Two cases may occur:

- A new attack or violation is detected;
- A new event is detected.

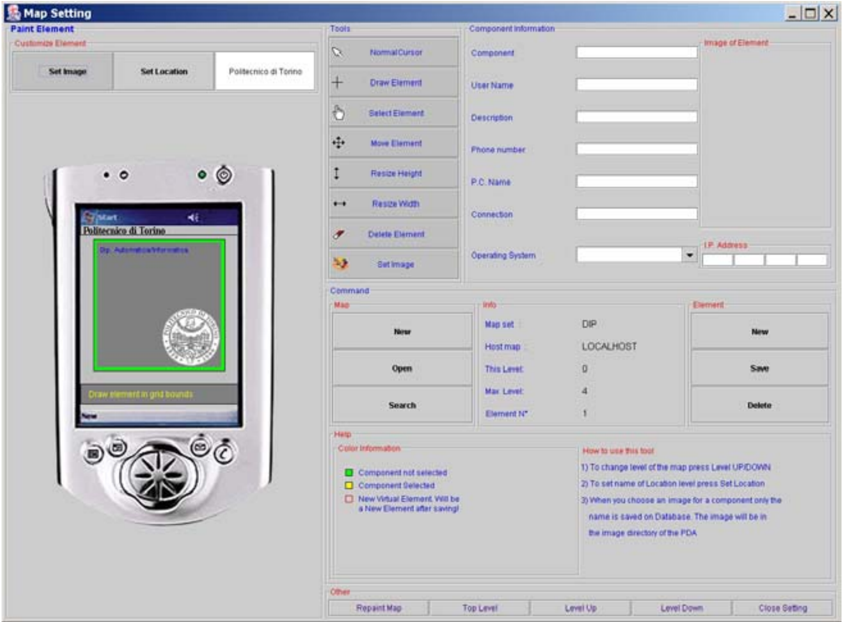

Figure 2: The Interface for Map Design.

The first case causes a data insertion in Map DB in order to generate a new visual event; the second case concerns an already active attack and just the information regarding it is updated in Map DB.

Snort inserts a new record each time a security rule is violated. After an attack has been processed, *Guardian* deletes the corresponding record in Snort DB keeping the database size near constant. The deletion of a set of records would lead to a loss of information; in order to avoid this, the user can configure *Guardian* to save the deleted information into a log file (see Figure 1).

The tool for map design, shown in Figure 2, is entirely written in Java. Three main zones can be identified: painting area (left part), information insertion area (upper-right part), and command area (lower-right part). The painting area allows defining rectangular areas over a grid. Rectangle sizes and spatial coordinates can be intuitively drawn by the mouse. Each rectangle is an *element* that can be selected, moved, resized, and deleted. An image can be placed inside a rectangle and the related information is introduced in the information area.

When a new map is designed, a new database is created using the *New* button of the command area. Existing databases can also be modified and deleted.

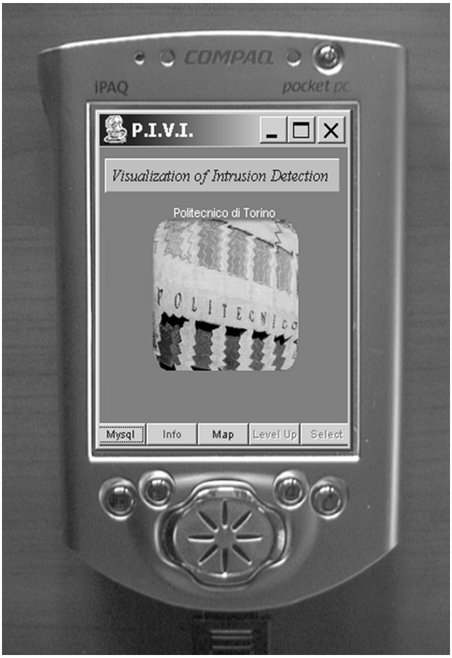

Figure 3: The Introductory Screenshot of the PDA.

The description of the building is organized in different levels. *Level up* and *Level down* buttons allow moving up and down through the levels' hierarchy.

Description of P.I.V.I

This section will provide details of *P.I.V.I.* and, in particular, of the graphical interface. The visualization application has been developed and tested on a Personal Digital Assistant Device Compaq iPaq H3630 equipped with the Microsoft PocketPC operating system. Basic features of this PDA are: 206 MHz Intel StrongArm CPU, 4096 colors TFT LCD display, 240 x 320 pixels (2.26 x 3.02 inches) resolution touch screen, 32 MB RAM and 16 MB Flash ROM. Although the graphical interface has been tailored for PDA devices, *P.I.V.I.* can be used on every device equipped with a Java Virtual Machine (multi-channel interface).

The introductory screenshot of *P.I.V.I.* is shown in Figure 3. The main problem involved in designing graphical interfaces for mobile devices is the display size.[19] In particular, large size images have to be accurately managed.

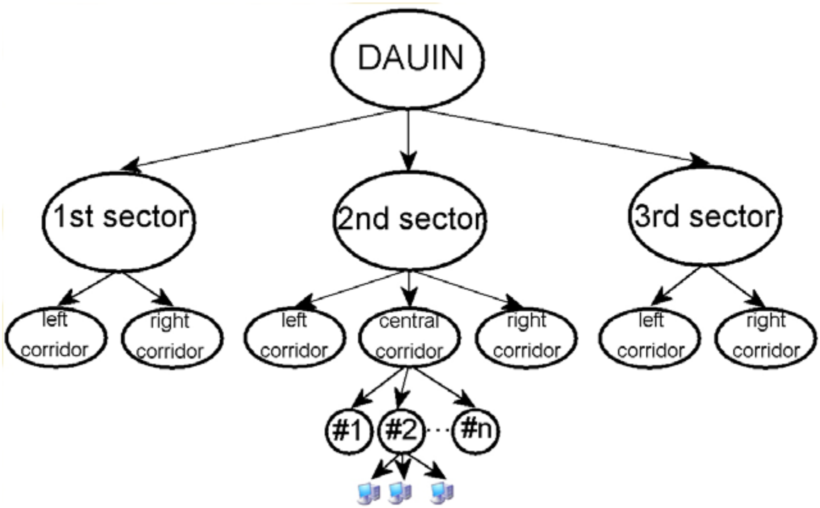

Figure 4: DAUIN's Hierarchical Representation.

Two solutions are possible:

- Displaying an image larger than the display, allowing the user to move and zoom it;
- Representing the information by means of a set of hierarchical images.

The former approach is easier to implement and is recommended when the user must have a global view at maximum level of detail; for instance, a radiograph has to be analyzed in its entirety. In these cases the user has to be able to move the image in order to "browse" it. This operation can require a lot of computational power and turns out to be particularly slow on low-end PDAs.

The latter strategy is appropriate for applications where hierarchical organizations of information may be obtained. The proposed intrusion detection system has been devised to monitor the network traffic within the aurthors' Computer Science Department (DAUIN). The hierarchical representation of the building is shown in Figure 4.

DAUIN is divided in three sectors; offices are organized as two rows (left and right) in the first and in the third sector, while, in the second sector, two corridors divide three rows of offices. Each office can contain arbitrary number (generally from one to four) machines.

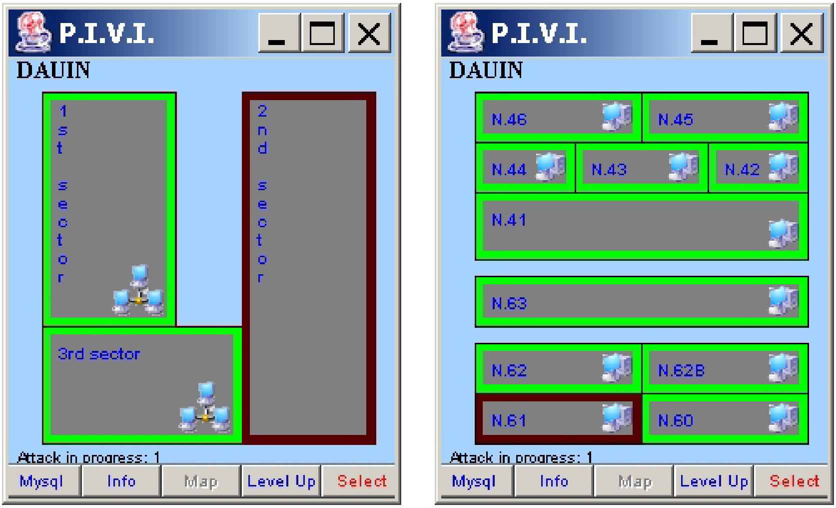

Figure 5: Two Screenshots of an Attack.

The starting panel (see Figure 3) allows the user to configure a set of parameters that are used to connect to the database (Map DB in Figure 1). *P.I.V.I.* loads the map of a building from Map DB and makes queries for new attacks.

The colors used to draw each building contour focus the attention of the user where a new attack has been detected.

An example is shown in Figure 5. The left image shows an attack to a machine placed in the department area labeled “*2nd sector*” (the border of this sector is darker in order to denote an attack). More details may be found by browsing the lower level related to the red part. The lower level is shown in the right image of Figure 5; here the attack involves a machine placed in office N. 61. Selecting this office, it is possible to retrieve all the details of the attack.

Figure 6 (left image) shows all the information about the attack: IP address and operating system of the PC, user name and office telephone number, and date and hour of the attack. The user can get further information by pressing the *Next* button placed at the right lower corner (see Figure 6, right image). The kind of attack (in this case a telnet bad login) is shown together with the IP address and the name of the remote machine performing the intrusion and, when available, the name of the user on the remote machine. A set of pages is automatically generated when the number of attacks affecting a machine grows.

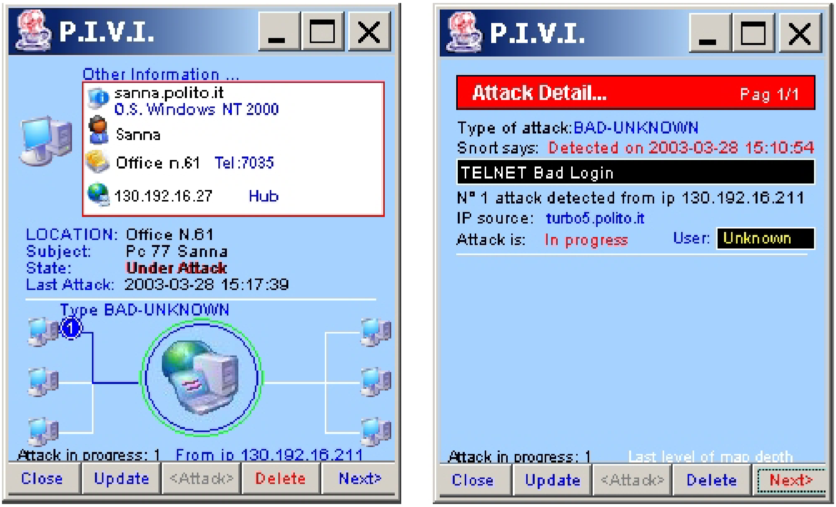

Figure 6: Details of Detected Attack.

An alarm is activated every time a monitored machine is attacked; this alarm is outlined by changing the color of the map from the lowest level of the hierarchy (“office level”) to the highest level (“building level”). The user can deactivate the alarm by selecting a level via the *Select* button (refer to Figure 5) and updating the status of the alarm. In this way, the alarm will be deactivated for the selected level and for all lower levels; for instance, a set of alarms concerning a unique part of the building can be deactivated at the same time. Moreover, the user can delete all the information related to each attack from Map DB; in this case a log file containing the deleted information can be generated.

Performance Issues

In order to test the proposed system the authors have developed a program able to generate “customizable” attacks over a LAN. The number of packets (every packet represents a violation to the *Snort*’s rules) and the delay between packets are changed in order to measure the number of lost packets (a packet is denoted as lost when the corresponding rule violation has not been detected and processed). Two tests have been performed:

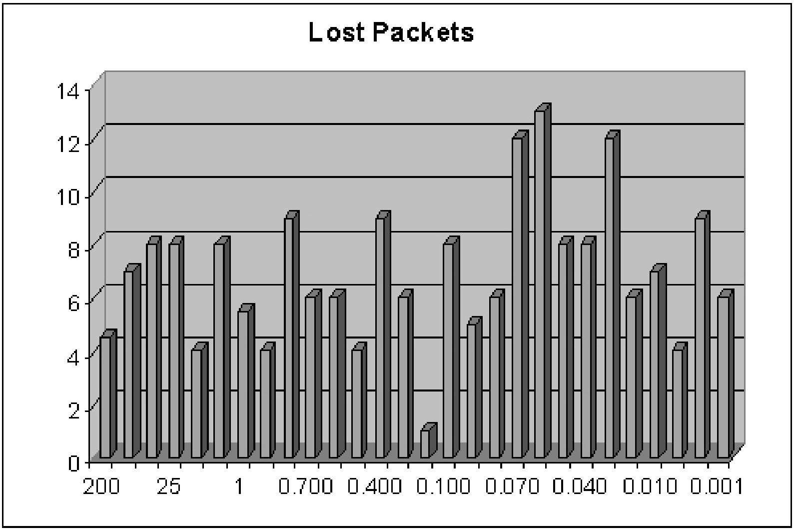

Figure 7: Test 1- lost packets.

1. The system is stressed by transmitting a fixed number of packets (1000) and varying the delay between the packets. This test aims to measure the number of packets correctly received and processed.
2. The system is stressed by transmitting a variable number of packets with a fixed delay (500ms). This test also aims to measure the number of errors in the receiving and processing phases.

The results for the first test are reported in Figure 7. The graphic lists the number of lost packets (on the ordinate) for a delay varying from 200 ms to 0.001 ms. It can be observed that the number of lost packets is almost independent of the delay; moreover, the percentage of error is 1.3% in the worst case.

Results from the second test are reported in Figure 8. The graphic lists the number of lost packets (on the ordinate) for a number of transmitted packets varying from 150 to 6000 ms. It can be observed that the number of lost packets is negligible for a number of transmitted packets less than 1500, while the error is about 10% for 6000 packets transmitted.

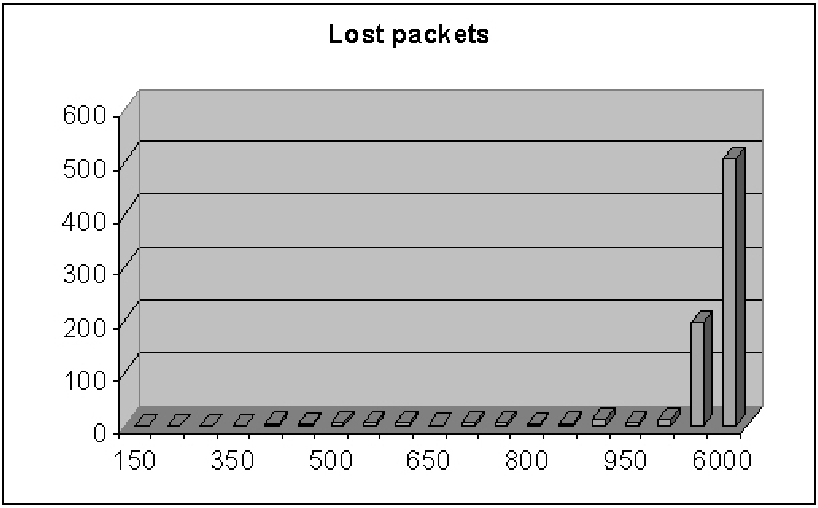

Figure 8: Test 2- lost packets.

Conclusions

Mobile devices, and in particular PDAs, are quickly changing the way information can be retrieved and visualized. Computational power and display size of a PDA are still two factors that limit the application of these new technologies when large data repositories have to be managed. On the other hand, Network Intrusion Detection Systems add a new level of visibility into the nature and characteristics of the network traffic, identifying threats from unauthorized users, back-doors, and hackers.

This paper proposes architecture able to manage and visualize the large amount of data produced by an intrusion detection program. Every time an attack or an intrusion is detected an effective visual event is sent to the user's PDA. An ad-hoc tool allows the user to organize the building to be monitored by a set of different levels of detail. Machines are placed at the leaf level of the hierarchy and for each machine it is possible to specify the user, the IP address, the operating system, etc. This hierarchical spatial data organization allows the user to efficiently and intuitively control large buildings obtaining a global view of the whole system, as well as detailed information concerning any incoming attack.

Acknowledgements

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CONSTRUCTING A PROXY SIGNATURE SCHEME BASED ON EXISTING SECURITY MECHANISMS

Wei-Bin LEE and Tzung-Her CHEN

Introduction

Due to the growth of the Internet, e-commerce is widespread and the security of Internet transactions is a matter that is becoming more and more important and challenging. Fortunately, the digital signature and the digital time stamp are well-defined tools used to address this challenge. Digital signature schemes are widely used in security mechanisms such as integrity, authentication and non-repudiation. They can be used to check the integrity of a message, authenticate the origin, and protect from dishonest repudiation. Digital time stamp schemes are used to ascertain when digital data were created or when data were signed.

However, a conventional digital signature is not suitable for some practical applications. For example, a team leader wants to take a trip to a tourist attraction where there is no computer network to use. Hence, during his vacation, he must delegate to a trusted member of his staff to perform his tasks including signing electronic documents. However, conventional digital signature schemes do not address the proxy function, and it is not reasonable to give the secret signing key to the proxy. To provide a solution, the proxy signature scheme was proposed in 1996.[1,2] The proxy signature allows a designated person, called a proxy signer, to sign a message on behalf of an original signer. Many proxy signature schemes have been proposed. Unfortunately, there are still permanent challenges, such as security and complexity, in the proposed schemes. Mambo, Usuda and Okamoto describe a situation,[3] where it was possible for the original signer to forge a proxy signature on behalf of the proxy signer, a situation called repudiation.[4] Sun and Hsieh argue that Mambo and coworkers' proxy signature scheme has a delegation transfer problem.[5] This means that the proxy signer can transfer the proxy without both the agreement and the consciousness of the original signer. Therefore, another party can generate a "valid" proxy signature on behalf of the original signer. Later, certain nonrepudiable proxy signature schemes [6,7,8] and threshold proxy signature schemes[9,10,11,12] were proposed. The reader may refer to a number of references for details.[13,14,15,16,17,18,19,20,21]

Actually, the strength of a cryptographic scheme cannot really be proved. When a new scheme is proposed, the authors always believe that their scheme is strong, secure, and unbreakable if one does not know the secret key. In fact, all that the authors can do is to demonstrate the scheme's power against some known attacks. However, we often find that there is always a new attack invented for a new scheme; hence, a newly proposed scheme almost always suffers from some inborn weakness, so we must always be careful when applying a new cryptographic scheme. To reduce this concern, a novel proxy signature scheme is proposed that does not invent a new mathematical model, but rather combines well-defined tools and existing mechanisms, such as the digital signature and the time stamp to satisfy the requirements of proxy signature. The scheme can be implemented by conventional digital signature schemes and public key infrastructures without significant modifications. Therefore, unknown security problems introduced by a new mathematical model can be minimized.

This paper is organized as follows. In the section that follows, the authors briefly introduce the Mambo-Usuda-Okamoto scheme and some other well-designed cryptographic tools and mechanisms. Then, a novel proxy signature scheme is proposed. Security analysis and discussions are given after that.

Preliminaries

Review of the Mambo-Usuda-Okamoto Scheme

To understand the concept of the proxy signature scheme, a brief review of the Mambo-Usuda-Okamoto scheme is necessary.[22]

Denote $s \in Z^*_{p-1}$ as a private key of an original signer and $v = g^s \bmod p$ as the corresponding public key, where p is a prime and g is a generator for Z^*_p.

Step 1. Proxy generation

An original signer generates a random number $k \in Z^*_{p-1}$ and computes $K = g^k \bmod p$. Furthermore, he determines $\sigma = s + kK \bmod p\text{-}1$.

Step 2. Proxy delivery

The original signer delivers the proxy (σ, K) to a proxy signer over a secure channel.

Step 3. Proxy verification

The proxy signer checks for congruence as to whether or not $g^{\sigma} = vK^{K} \bmod p$. If the equation holds, the proxy signer accepts it as a valid proxy.

Step 4. Signing by the proxy signer

When the proxy signer signs a message *m* on behalf of the original signer, he uses the σ as an alternative to *s*, and executes the ordinary signing operation. Thus, (*m*, (Signature of the original scheme), *K*) serves as a created proxy signature.

Step 5. Verification of the proxy signature

The verification of the proxy signature is the same as in the ordinary signature scheme except for the extra computation $v\,K^{K} \bmod p$, which is dealt with as a new public value.

There are six main security properties to be satisfied by a proxy signature scheme: unforgeability, secret-key's dependence, verifiability, distinguishability, identifiability and undeniability.[23] These properties are discussed in detail below.

Roles of Certification Authority and Time Stamping Authority

In general, the digital signature operation signs a message using a private key. Subsequently, anyone can verify it using the corresponding public key. However, the challenge of how to ascertain who really owns the public key has arisen. To ascertain the genuine public key, the accepted solution is to make a trusted party, called a Certification Authority (CA), digitally sign data structures. This is known as certification – mapping between public key and identity information. If someone knows CA's public key, he can ascertain that the public key belongs to a particular person.

On the other hand, digital time stamp schemes are used to ascertain when a particular event took place, for example, when digital data were created, a digital message was sent or received, a digital signature was generated or a signature key was revoked/overdue.[24] In order to associate a message with a particular time, a Time Stamping Authority (TS) has been standardized by IETF. Furthermore, it is well known that time stamping plays an important role in digital signature schemes. According to Zhou and Lam, "A typical approach to secure digital signatures as non-repudiation evidence relies on the existence of an on-line trusted time-stamping authority (TS). Each newly generated digital signature has to be time-stamped by a TS so that the trusted time of signature generation can be identified."[25]

The Proposed Proxy Signature Scheme

The following notations are used to represent message and protocols in this paper:

ID_U: identity information of party U.

S_U and V_U: the private key and the corresponding public key of party U.

$sS_A(m)$: digital signature of message m with the private key S_A.

$A \rightarrow B$: X: party A delivers message X to party B.

There are several participants involved in this scenario, including an original signer (for example, a manager), a proxy signer (for example, a secretary), CA, and TS. Each party has a regular key pair, certificated by CA, including TS's (S_{TS}, V_{TS}), the original signer's (S_o, V_o) and the proxy signer's (S_p, V_p). For example, the manager goes on vacation for one week. He creates a temporary proxy-signature key pair (s_p, v_p) based on the same cryptographic assumption. Subsequently, the delegation information, including a proxy-signature key, is delivered to TS for time stamping. After receiving the time-stamped delegation information, the signing and verifying operations of a proxy signature are the same as in existing ordinary digital signature schemes. The detailed steps are given as follows:

Step 1. Proxy generation

The original signer designates a proxy signer and generates a short-term key pair (s_p, v_p) for the proxy signer. The expiry date Td of the delegation should also be defined. Furthermore, the delegation message is determined by creating the signature $D = sS_o(ID_o, ID_p, v_p, Td)$,

Original signer $\rightarrow$ TS: ID_o, ID_p, v_p, Td, D

TS: verifying the validity of D with V_o

TS $\rightarrow$ Original signer: $Tt, sS_{TS}(D, Tt)$, where Tt denotes the timestamp.

The original signer verifies the validity of $sS_{TS}(D, Tt)$.

Step 2. Proxy delivery

The original signer sends $(ID_o, ID_p, (s_p, v_p), Td, D, Tt, sS_{TS}(D, Tt))$ to the proxy signer over a secure channel.

Step 3. Proxy verification

The proxy signer authenticates the proxy signature key s_p with the public key v_p, then checks the validity of D and $sS_{TS}(D, Tt)$, if necessary. Thus the expiry date Td and the delegation relationship between the origin signer and the proxy signer are confirmed. It is worth emphasizing that s_p is a temporary and short-term key.

Step 4. Proxy signature generation

The proxy signer generates the proxy signature of a message *m* with the signature key s_p based on an ordinary digital signature scheme. Thus the signing operation generates (*m*, (Signature of the original scheme)). Finally, (*m*, (Signature of the original scheme), ID_o, ID_p, v_p, Td, D, Tt, $sS_{TS}(D, Tt)$) serves as generated proxy signature.

If necessary, the proxy signer could sign the signature again with his individual private key to prevent a malicious original signer from forging a proxy signature on behalf of the proxy signer.

Step 5. Verification of the proxy signature

The verification of the proxy signature is divided in two phases. The first phase checks whether or not the proxy signature is valid. This is the same as the procedure for the ordinary signature scheme. The second phase checks the validity of the expiry date *Td* and the proxy relationship between the original signer and the proxy signer. This is achieved by checking the validity of the signatures *D* and *sSTS(D, Tt)*.

Security Analysis and Discussion

The proposed proxy signature scheme is straightforward and easy to implement based on the currently existing public-key infrastructure. Due to the fact that the security of the signature is inherent in the original scheme, the delegation process causes the major security concern. Therefore, it is worthwhile to further discuss the role that TS plays in the proposed scheme. It is known that the proxy signature schemes focus on the security issue of the temporary proxy-signature key pairs. In the proxy signature schemes, a proxy-signature key is a short-term key and it is only valid during a specified period. However, CA is responsible to issue and maintain the certification of the regular keys, i.e., the long-term keys, including their creation and revocation. Nevertheless, short-term keys demand minimal key management and protection. It is inappropriate and impractical for a CA to confirm these short-term keys. For the sake of reducing cost, TS, instead of CA, issues the certificate for the proxy key by time-stamping the delegation information and the expiry date. Appending a timestamp by TS is more economical than generating a regular certificate by CA. Discussions related to the security and the advantages of the proposed scheme are given in the following sub-sections.

Discussion of Essential Properties

The paper discusses the following properties that have to be satisfied by a proxy signature scheme:

1. Unforgeablity: It is impossible for anyone to create a valid proxy signature without knowing the private key s_p.
2. Secret-key's dependence: The original signer using his certificated private key signs a proxy signature key. It implies that the proxy signature key is computed from the secret key of the original signer.
3. Verifiability: Anyone can verify the validity of a proxy signature using the corresponding public key, verified by CA.
4. Distinguishability: Anyone can verify the proxy signature by the proxy signing key *vp* which is generated by the original signer with his individual private key V_o. That is to say that a verifier can distinguish a proxy signature from the regular signature signed by the original signer.
5. Identifiability: The verifier can determine the relationship of delegation between an original signer and a proxy signer by verifying the delegation message *D*. Hence, the verifier can determine the corresponding proxy signer from a proxy signature.
6. Undeniability: Due to the fact that the delegation information is signed by the original signer and time stamped by TS, a proxy signer can not deny his behavior.

Other Properties

The proposed scheme is based on the security of existing cryptographic tools and commercial products. Therefore, any attack to forge a valid proxy signature will fail unless an adversary can defeat sophisticated security mechanisms. There are still some properties that cause concern.

1. In the proxy generation phase, the original signer signs the delegation information as the proxy certificate, $sS_o(ID_o, ID_p, v_p, Td)$, which is subsequently appended to the proxy signature. Therefore, the delegation relationship between the original signer and the proxy signer is addressed and proved. Hence, it is impossible for the signer to transfer the proxy without the agreement of the original signer. This property can avoid the delegation transfer problem. Furthermore, the alternative of additionally signing the message with his individual private key can further overcome this problem, unless the proxy signer releases his private key. Meanwhile, the original signer cannot forge a valid proxy signature. That is, the proxy signer cannot claim that the proxy signature in dispute is illegally signed by the original signer, i.e., non-repudiation.
2. Based on well-defined commercial TS and CA mechanisms,[26,27,28] the proposed scheme naturally has fewer security considerations.

3. All necessary mechanisms have already been implemented in the real world, so the proposed scheme can be easily implemented without any problems.
4. The proxy signature key automatically expires when the expiry date arrives. There is no extra cost to maintain or revoke the proxy signature keys. Furthermore, because the proxy signature key is a temporary and short-term key, there are fewer security problems than with regular keys.

Furthermore, in order to prevent a malicious proxy signer from signing even if the expiry date arrives, the proxy signature must be time-stamped by TS. This is a general secure digital signature problem, and therefore is omitted here.

Conclusions

The authors apply the currently existing CA and TS mechanisms in a straightforward way to construct a solution to the problem of the security challenges of newly proposed proxy signature-related schemes. The proposed proxy signature scheme not only satisfies the essential properties mentioned in the Mambo-Usuda-Okamoto's proxy signature scheme but also has the following additional advantages: it provides non-repudiation and prevents delegation transfer. It is obvious that the scheme does not affect the current security infrastructure and, thus, is more practical than the previously proposed schemes.

Notes:

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3 Mambo, Usuda, and Okamoto, "Proxy Signatures for Delegating Signing Operation."

4 Kan Zhang, "Threshold Proxy Signature Schemes" (paper presented at the Information Security Workshop, Japan, September 1997), 191-197.

5 Hung-Min Sun and B.-T. Hsieh, "Remark on Two Nonrepudiable Proxy Signature Schemes," in *Proceedings of the 9th National Conference on Information Security* (Taiwan, 1999), 241-246.

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15 W.-B. Lee and C.-Y. Chang, "Efficient Proxy-Protected Proxy Signature Scheme Based on Discrete Logarithm," in *Proceedings of the 10th National Conference on Information Security*, (Hualien, Taiwan, 2000), 4-7.

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19 Sun, Lee, and Hwang, "Nonrepudiable Threshold Proxy Signatures."

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21 Zhang, "Threshold Proxy Signature Schemes."

22 Mambo, Usuda, and Okamoto, "Proxy Signatures: Delegation of the Power to Sign Messages;" Mambo, Usuda, and Okamoto, "Proxy Signatures for Delegating Signing Operation."

23 Mambo, Usuda, and Okamoto, "Proxy Signatures for Delegating Signing Operation."

24 Jianying Zhou and Kwok-Yan Lam, "Securing Digital Signatures for Non-Repudiation," *Computer Communications* 22, 8 (May 1999): 710-716.

25 Zhou and Lam, "Securing Digital Signatures for Non-Repudiation."

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28 Surety, <http://www.surety.com/> (14 January 2004).

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MODELING AND SIMULATION INTERNET SOURCES

APPLICABLE M&S STANDARDS

Army Standards Repository (ASTARS)

http://www.msrr.army.mil/astars/

The Army Standards Repository (ASTARS) is a user friendly web-based tool that houses all approved Army modeling and simulation (M&S) standards. The system has been online since June 1998. For each approved standard in ASTARS, the user can find a brief description of the standard, to include its utility and limitations, as well as a point of contact. ASTARS allows the user to search by standards category or conduct a general search of all standards, tools, and documents in the repository by title, description, or keywords.

High Level Architecture (HLA)

https://www.dmso.mil/public/transition/hla/

HLA is general-purpose architecture for simulation reuse and interoperability. HLA provides a distributed simulation framework for new simulations. HLA is defined by a set of rules, an interface specification, and an object model template. Initial definition of the HLA was accomplished under the sponsorship of DARPA ADS program. It was transitioned to the DMSO in March 1995 for further development. HLA was approved by the Undersecretary of Defense for Acquisition, Technology and Logistics, USD AT&L, as the standard technical architecture for all U.S. DoD simulations on 10 September 1996. HLA is not a standard but only a methodology for developing standards. There are many different simulation standards being developed using the HLA architecture.

Aggregate Level Simulation Protocol (ALSP)

http://alsp.ie.org/alsp/

http://ms.ie.org/alsp/

Aggregate Level Simulation Protocol (ALSP), both software and a protocol, is used to interoperate simulations. It is used extensively by the United States military to link analytic and training simulations to support training requirements for Corps and above.

ALSP consists of three components: the ALSP Infrastructure Software (AIS) providing distributed runtime simulation support and management; a reusable ALSP Interface consisting of a set of generic data exchange message protocols (i.e., formal rules for information exchange) to enable interaction among objects represented in different simulations; participating simulations adapted for use with ALSP.

SIMULATION SYSTEMS AND SOFTWARE

Joint Simulation System (JSIMS)

http://www.jsims.mil/

The primary purpose of the Joint Simulation System (JSIMS) is to support training and education of ready forces by providing realistic joint training across all phases of military operations for all types of missions. JSIMS will provide for Joint training as well as Service specific training. A distributed, constructive war-gaming simulation, JSIMS is designed to create a single, seamlessly integrated Joint Synthetic Battlespace (JSB) providing a common environmental and operational picture of the battle space. It will interface with command, control, communications, computers, and intelligence (C4I) functions and equipment in the field, thus providing the interface between the JSB and the training audience. The resulting effect is a training environment indistinguishable by the training audience and the real world. JSIMS employs the DoD High Level Architecture (HLA) for Modeling and Simulation.

Joint Conflict and Tactical Simulation (JCATS)

http://www.jwfc.jfcom.mil/about/fact_jcats.htm

The Joint Conflict And Tactical Simulation (JCATS) is a self-contained inherently joint simulation in use for entity-level training in open, urban, and subterranean environments. JCATS represents an interactive, high-resolution conflict simulation that models joint-multi-sided air, ground, sea combat on high/low resolution digitized polygonal terrain. Uses range from the joint task force level down to tactical and operations other than war in open/urban/subterranean environments using aggregates and individual systems. Most unique features include the replicating of small group tactics in urban terrain to include enhanced multi-floor buildings with doors, windows, interior walls, day-night operations under differing visibility and artificial lighting to include an underground environment. Other features include human characteristics– secondary suppression, fatigue, fratricide, health, etc. and its capability to mount/dismount entities and the use of linear and area sensors for rear-area security operation. JCATS was developed by Lawrence Livermore National Laboratory (LLNL) and is managed by the director for joint force training through the Joint Warfighting Center. Applications include training and exercises; analysis and experimentation; mission planning and rehearsals.

Warfighter's Simulation (WARSIM 2000)

http://www-leav.army.mil/nsc/warsim/index.htm

WARSIM 2000 is a computer based simulation with associated hardware and is the Army's next generation command and control training environment. In conjunction with JSIMS, it will support the training of unit headquarters and command posts from battalion through theater-level in joint and combined scenarios. Additionally, it will provide command post training events in educational institutions. It will be designed to allow units worldwide to train in their command posts using organic C4I equipment, with a minimum of overhead. This simulation system will meet emerging distributed simulation standards and protocols, thus providing a comprehensive joint environment capable of linking its simulation-based constructive entities with virtual (simulator-based) and instrumented vehicles.

Tactical Simulation (TACSIM)

http://www-leav.army.mil/nsc/famsim/tacsim/index.htm /

TACSIM is a part of Models A Branch of Models Division, Constructive Directorate, U.S. National Simulation Center. The Tactical Simulation system is designed to provide training to intelligence staffs, collection managers, and analysts in a simulated war situation. TACSIM accomplishes this mission by simulating and or stimulating the entire spectrum of intelligence operations. TACSIM can support training from large-scale joint exercises to training on specific intelligence section tasks. Because of the realistic manner in which TACSIM portrays the Intelligence Battlefield Operating System (IBOS), TACSIM is also a tool for testing Intelligence Electronic Warfare (IEW) equipment. The TACSIM system is composed of several parts: a main simulator; peripheral devices that support computer generated analysis, after action reports, and national collection systems; and, the Communications Support Processor (CSP).

Corps Battle Simulation (CBS)

http://www-leav.army.mil/nsc/famsim/cbs/index.htm

The Corps Battle Simulation is a part of Models A Branch of Models Division, Constructive Directorate, U.S. National Simulation Center. CBS is a geographically and functionally distributed air/land warfare simulation. CBS serves as an exercise driver to support training of commanders and staff officers at the Joint, Corps, and Army Division levels. CBS provides training stimuli for all ground forces staff elements from Brigade to Corps including combat, combat support, combat service support, and fixed and rotary wing air operations. All Battle Operating Systems are represented: Maneuver, Command & Control, Fire Support, Air Defense, Combat Service Support, Mobility / Countermobility / Survivability, Intelligence, as well as fixed and rotary wing air operations, NBC operations including Smoke and Chemical Recon and Decon, Special Operations, Civil Affairs and PsyOp.

CBS is written in SIMSCRIPT II.5. Network communications, workstation, and graphics software are written in C programming language. There are two expert systems utilized in CBS and are written in Ruleworks.

Joint Modeling and Simulation System (JMASS)

http://www.redstone.army.mil/amrdec/jmass/

JMASS is a Joint program to develop engineering level related simulation tools. JMASS is a simulation support environment, which is a collection of well-defined, well-documented interface standards to which a model should be built. It also includes a toolkit, which allows modelers to build representations of real world systems, configure those models, assemble them into simulations, execute those simulations, and process the results. JMASS is HLA compliant.

Air Force Electronic Warfare Evaluation Simulator (AFEWES)

http://afewes.edwards.af.mil/

AFEWES is a secure, Government-owned, Hardware-In-The-Loop (HITL) test laboratory, located at Air Force Plant 4 in Fort Worth, Texas. Managed by the Air Force Flight Test Center’s (AFFTC) 412th Test Wing at Edwards AFB, CA, AFEWES develops and operates validated, high-fidelity Radio Frequency (RF) and Infrared (IR) threat simulators which evaluate the effectiveness of U.S. DoD and

Allied Electronic Combat systems in a controlled, ground-based laboratory environment. Simulated engagements are conducted at actual frequentcies/ wavelengths, in real-time, incorporate hostile operator-in-the-loop effects, and produce vector miss distance and other end-game data products. AFEWES provides many unique test capabilities not available at other types of T&E facilities.

Air Warfare Simulation (AWSIM)

http://afmsrr.afams.af.mil/index.cfm?RID=SMN_AF_1000000

AWSIM is the official U.S. Air Force theater-level war-gaming model. The purpose of AWSIM is to provide a training capability for the air warfare environment. In fulfilling this purpose, AWSIM represents the air component of commander-level battle staff training for Air Force conducted exercises, and the air portion of joint training exercises. AWSIM is an interactive and prescriptive, computer-driven, time-stepped simulation of a theater air warfare environment. AWSIM is latitude and longitude based and simulates day and night operations and limited weather conditions over a smooth earth (no terrain). It supports a two-sided scenario where opposing sides define, structure and controls their forces.

Modeled features include aircraft, air bases, surface-to-air missiles, short-range air defense systems, ships and radar sites. AWSIM results include success of individual aircraft missions, munitions consumption, and the systematic playing out of a scenario based on kill algorithms that determine the outcome of many separate aircraft interactions.

Business Simulation Packages

http://www.towson.edu/absel/Packages/packages.html

The web site provides links to the web pages of the following simulation games:

- AIRLINE: A Business Simulation
- Beefeater Restaurants Microworld
- Professional Services Microworld
- Alacrity Team Simulation Exercise
- Micro Business Publications
- The Business Policy Game - An International Strategy Simulation
- Business-Sims.Com
- BusSim: An Integrated Business Instruction System
- Capstone: The Business and Financial Strategy Simulation

- CEO: A Business Simulation for Policy and Strategic Management
- Simulated Collective Bargaining
- COMPETE: A Dynamic Marketing Simulation
- The Global Business Game
- Corporation: A Global Business Simulation
- DEAL: An Entrepreneurship Gaming Simulation
- Entrepreneur: A Business Simulation in Retailing
- GEO: An International-Business Gaming Simulation
- The Human Resources Management Simulation
- INFOGAME: Game for Research and Education in Information Systems
- INTOPIA: International Operations Simulation/Mark 2000
- MAGEUR: A General Business Game
- MANAGEMENT 500: A Business Simulation for Production and Operations Management
- The Management Accounting Simulation
- Manager: A Simulation Game
- Marketer: A Simulation Game
- Marketplace: a web-based business simulation game with several levels of difficulty.
- Smart Sims Includes many different simulations including MikesBikes-Advanced: An Advanced Business Simulation, MikesBikes-Advanced: Accounting Edition, MikesBikes-Intro: A general Business Simulation and music2go: A Marketing Simulation.
- The Multinational Management Game
- Threshold Competitor: A Management Simulation.

MAGNUS, A Simulated Environment for Decision Making

http://magnus.comp.nus.edu.sg/

MAGNUS, which stands for MAnagement Game, National University of Singapore, is designed to provide students an opportunity to learn and practice the art and science of corporate planning and managerial decision-making. It is also used for students in information systems to practice building and testing decision support systems. The system runs on a PC network with an Administration System and a graphical player interface running under Windows. The system is continually undergoing development, which includes multilingual and internet support. A demo version is free for download.

M&S SELECTED PUBLICATIONS

Volume 9: Modeling and Simulation, of Technology for the United States Navy and Marine Corps, 2000-2035: Becoming a 21st Century Force

http://books.nap.edu/html/tech_21st/msindex.htm

Published by National Academy of Sciences. Provides extensive discussion of almost every aspect of DoD Modeling and Simulation.

Downloadable Articles from SIMULATION and TRANSACTIONS Special Issues

http://www.scs.org/pubs/special/specinfo.html

SIMULATION Articles from the Special Issue on High Level Architecture

SIMULATION Articles from the Special Issue on Parallel and Distributed Simulation

TRANSACTIONS Articles from the Special Issue on Parallel and Distributed Simulation

Articles from Military Magazines

http://www.magweb.com/sample/readsamp.htm

The web site contains sample articles from more than sixty military history and war-gaming magazines.

AIR FORCE INSTRUCTION (AFI) 14-206, Modeling and Simulation

http://www.e-publishing.af.mil/pubfiles/af/14/afi14-206/afi14-206.pdf

This instruction implements AFPD 14-2, Intelligence Collection, Production, and Application. This instruction guides intelligence modeling and simulation activities. It also includes intelligence support to modeling and simulation activities in weapon systems acquisition, research and development, test and evaluation, education and training, military operations, and national level policy making.

Conceptual Models of the Mission Space (CMMS)

http://www.dtic.mil/ndia/livefire/sheehan.pdf

This is the place where one can download Conceptual Models of the Mission Space (CMMS): Communicating Warfighter Requirements to Systems Engineers

Simulations and the Future of Learning

http://www.amazon.com/exec/obidos/ASIN/0787969621/inseadcalt/103-5864299-1778267

An Innovative (and Perhaps Revolutionary) Approach to e-Learning. Written by Clark Aldrich.

Simulations and the Future of Learning offers trainers and educators the information and perspective they need to understand, design, build, and deploy computer simulations for this generation.

Digital Game-Based Learning

http://www.amazon.com/exec/obidos/ASIN/0071363440/inseadcalt/103-5864299-1778267

The book is written by Marc Prensky.

A strategic and tactical guide to the newest trend in e-learning - combining content with video games and computer games to more successfully engage the under-40 “Games Generations.” The book fully explores the concept of Digital Game-Based Learning, including such topics as How Learners Have Changed, Why Digital Game-Based Learning Is Effective, Simulations and Games, How Much It Costs, and How To Convince Management. With over 50 case studies and examples, it graphically illustrates how and why Digital Game-Based Learning is working for learners of all ages in all industries, functions and subjects.

M&S RESOURCE REPOSITORIES, REFERENCES AND WEB LINK SITES

RESOURCE REPOSITORIES

DMSO Modeling and Simulation Resource Repository (MSRR)

http://www.msrr.dmso.mil/

The Modeling & Simulation Resource Repository, comprised of seven nodes, is a DoD-wide system of M&S databases that allows a user to discover, access, and obtain M&S resources that support military operations, training, and acquisition. MSRR is sponsored by DMSO, and operated by the Modeling and Simulation Information Analysis Center (MSIAC). Providers include the DMSO system, Army, Navy, Air Force, Missile Defense Agency, DIA, C4ISR Decision Support Center Information System & MSRR.

The MSRR is actually a collection of web sites for searching and navigating to M&S information and M&S related resources located on a wide variety of organizational web servers.

Air Force Modeling and Simulation Resource Repository

http://afmsrr.afams.af.mil/

The goal of the Air Force Modeling and Simulation Resource Repository is to provide a single source for information about and access to U.S. DoD models, simulations, data sources, algorithms, and other M&S resources in order to facilitate reuse and avoid duplication.

Navy Test and Evaluation Repository for Models and Simulations (NTERMS)

http://nterms.mugu.navy.mil/

An on-line searchable catalog containing M&S operational information.

Army Modeling & Simulation Resource Repository

http://www.msrr.army.mil/

The Army MSRR is part of the U.S. DoD-wide Modeling & Simulation Resource Repository (MSRR). The MSRR promotes interoperability, reuse, and commonality through information sharing and communication throughout the M&S community.

Users can locate, access, and obtain M&S resources that support Training, Exercises, & Military Operations (TEMO); Advanced Concepts and Requirements (ACR); and Research, Development, and Acquisition (RDA).

Ballistic Missile Defense Modeling & Simulation Resource Repository

http://bmdssc.jntf.osd.mil/MSRR/Default.shtm

Modeling & Simulation Resource Repository of the Ballistic Missile Defense Organization Simulation Support Center.

Classified Modeling and Simulation Resource Repository (CMSRR)

http://www.fas.org/irp/program/disseminate/cmsrr.htm

The Classified DIA MSRR is required to support the Department of Defense (DoD) Modeling & Simulation Community with Intelligence resources. The DIA is responsible for providing DoD Intelligence community support to DoD users of models and simulations. DIA is the DoD Modeling & Simulation Executive Agent (MSEA) for Intelligence and the Joint Simulation System (JSIMS) Executive Agent (EA). To meet the goals and objectives of the M&S community, DIA is responsible for the development of an initial capability of the classified Intelligence Node of the DoD CMSRR (DIA CMSRR).

M&S Resources

http://home.ubalt.edu/ntsbarsh/ref/RefSim.htm

Resources covering recent advances in discrete event systems simulation, including a classification of optimization techniques and unification of sensitivity estimators.

Simulation/Gaming Exchange (SGX)

http://sg.comp.nus.edu.sg/

SGX (Simulation/Gaming Exchange) is the Internet Clearinghouse for Simulation/ Gaming Resources (including a specialized search engine for simulation/gaming).

REFERENCES

Mallory's Modeling and Simulation Acronyms and Web Sites

http://www.afams.af.mil/doclib/doclib.cfm?AFAMS_FID_2330

This is the web link to a file from the Air Force Agency for Modeling and Simulation that contains M&S acronyms and web sites. It is a very comprehensive list that includes every aspect of simulations and exercises. The information is subdivided into the following categories:

- U.S. DoD Modeling and Simulation Center Links
- M&S Related Organizations
- M&S Related Associations, Newsletters, Conferences and Courses
- DoD Academies, Universities, Colleges and Schools
- M&S References and Resource Repositories
- Exercises Wargames and Experiments
- M&S Related Policies and Standards
- Simulation Systems and Software
- M&S Web Link Sites on the Internet
- M&S Acronym and Glossary Web Sites on the Internet.

Online Glossary of Modeling and Simulation (M&S) Terms

https://www.dmso.mil/public/resources/glossary/

From MSIAC, official glossary of modeling and simulation terminology, abbreviations, and acronyms for use throughout the U.S. Department of Defense.

Automated Joint Threat Systems Handbook (AJTSH)

http://afmsrr.afams.af.mil/index.cfm?RID=DTS_AF_1000141

The AJTSH is a classified database available to U.S. DoD and contractors that provide information on available threat simulators, foreign materiel, threat M&S, targets, and the ranges and facilities in which they are located.

Discrete Event Systems Simulation

http://home.ubalt.edu/ntsbarsh/simulation/sim.htm

This site surveys concepts and techniques for system modeling and simulation using digital computers including computer simulation languages such as Simscript II.5 and

GPSS; variance reduction techniques; input/output analysis; sensitivity and optimization of systems simulation and application of computer simulation to various practical scenarios.

Simulation & Games for Education

http://www.insead.fr/Encyclopedia/Education/Advances/games.html

Business simulation games, education games, etc.

Database with Literature on Gaming and Simulation

http://www.kun.nl/methoden/refbase/

This is a database with more than one thousand references of literature on gaming and simulation. It is a database that has grown during the last couple of years. The list, stored as a Filemaker 4 file, allows for sorting, searching and selecting.

ISAGA mailing list

http://groups.yahoo.com/subscribe/isaga

A mailing list on simulation, games and related methodologies.

M&S WEB LINK SITES

M&S Website (Link) Directory

http://www.msiac.dmso.mil/msosa-net/link_directory.asp

This is the web site of the MSIAC's list of useful web sites for sources of M&S operational information and support to assist M&S activities.

Air War College Gateway to Wargames, Simulations, and Exercises

http://www.au.af.mil/au/awc/awcgate/awc-sims.htm

Contains numerous links to sites pertaining to wargames, simulations, and exercises.

SimCentral Modeling and Simulation Portal

http://www.simcentral.com/

The modeling and simulation information network.

Modeling and Simulation Resources

http://home.hiwaay.net/~georgech/Common/modsim.htm

A collection of resources for modeling and simulation.

Defense Modeling and Simulation Sources on the Internet

http://www.dtic.mil/dtiwl/toc_ms.q.html

A collection of defense related modeling and simulation resources.

WAR GAMING RESOURCES AND EXERCISES

Swedish Defence Wargaming Centre (SDWC)

http://www.fksc.mil.se/?lang=eng

The Swedish Defence Wargaming Centre (SDWC) is an independent organization within the Swedish Armed Forces, which together with the Joint Forces Staff is included in the Joint Forces Command. The center supports tests and staff exercises with simulated courses of events in all phases of an armed conflict. In addition, SDWC takes part in the development of computer simulated planning methodology as well as directing experimental exercises within the frames for control of development requirements for C2 systems.

War Gaming Department, U.S. Naval War College

http://www.nwc.navy.mil/wgd/

The War Gaming Department is a component of the Center for Naval Warfare Studies. At the Naval War College, various gaming techniques are used to support a gaming schedule of approximately 50 games a year. These events support internal College needs and externally generated requests, which can come from various sources, including Defense and Navy departments, operational commands, and civilian agencies. War games are used to study a wide range of issues from space to anti-submarine warfare, from unconventional warfare to global war, from advanced technology to political-military relationships. Gaming participants can range from junior officers to four-star flag-rank officers and civilian equivalents.

College of Aerospace Doctrine, Research and Education, Home of AF Wargaming Institute

http://www.cadre.au.af.mil/

Home of "Connection" annual war game conference – military and civilian wargamers/ designers.

Wargame Developments Network

http://www.users.dircon.co.uk/~warden/index.htm

War game Developments (WD) is a group of like-minded war gamers that are dedicated to developing war games. It is a non-commercial organization, and its aims are to provide a forum for the exchange of new ideas and concepts and to develop both new and existing methods of recreating military conflicts.

The Complete Wargames Handbook

http://www.hyw.com/Books/WargamesHandbook/Contents.htm

Written by James Dunnigan, 1992/1997, a classic overview that includes designing war games, history of war games, and uses of war games.

Year 2000 introduction, wargame development in the 1990's may be found at:

http://www.hyw.com/Books/WargamesHandbook/Introduc.htm

Wargaming Resources

http://www.au.af.mil/au/aul/bibs/wargame/wgtoc.htm

Listings by Air University Library, Maxwell AFB, AL; compiled by Stephen B. Chun, bibliographer. The resources are broken into many areas of interest:

- Game Theory
- Lanchester Theory & Equations
- Wargaming
- Bibliographies
- History
- Board Games & Famous Battles
- Politico-Military Gaming
- Models and Modeling

- Artificial Intelligence
- Scenarios
- Warrior Preparation Center

War Gaming - Thinking for the Future

http://www.airpower.au.af.mil/airchronicles/apj/3sum90.html

An article written by Lt Col David B. Lee, USAF, published in Airpower Journal.

EXERCISES

DefenseLINK list of Military Exercises and Deployments

http://www.defenselink.mil/other_info/deployments.html

US European Command (EUCOM) list of current and planned exercises

http://www.eucom.mil/Directorates/ECPA/index.htm?http://www.eucom.mil/

/Directorates/ECPA/Exercises/main.htm&2

DEFENSE RESOURCE MANAGEMENT SIMULATION IN BULGARIAN MINISTRY OF DEFENSE

Bisserka BOUDINOVA

A simulation on defense resource management was held in the period 8-12 December 2003 at "G.S. Rakovsky" Defense and Staff College, Sofia, Bulgaria. The Bulgarian Ministry of Defense (MOD) organized the event in collaboration with the Institute for Defense Analyses (IDA).

The cooperation between the Bulgarian MOD and IDA dates back to the year 2000, when MOD launched a new defense resource management system based on a programming approach. Cooperation activities included one week working visits of American experts every month in 2000-2003. The same format is planned for 2004 to consider specific phases of resource planning and programming. The visits are focused on the development of the Integrated Defense Resource Management System (IDRMS), on the elaboration of its main documents, and on the harmonization of IDRMS with the principles of planning in NATO. Efforts have been directed to training of personnel, discussions with senior leaders on crucial issues in planning and programming, implementation of lessons learned, as well as on the ongoing Strategic Defense Review and especially on the creation of tools for precise costing of defense programs. As a result the Integrated Defense Resource Management System has improved considerably. At present, the system is in operation and four cycles of programming, leading to budget formulation, have been conducted. Future improvements are envisioned based on the accumulated practical experience.

Purpose of Computer Simulation

The importance and the results of the organized interactive computer simulation could be sought in the following directions: training of personnel and fostering of better understanding of the programming approach in defense resource management and promotion of the implementation of the Integrated Defense Resource Management System among the planning community in the Ministry of Defense.

The simulation was devoted to training of personnel involved at different management levels in the planning, programming and budgeting process. Representatives from the Defense and Staff College, the General Staff and the Ministry of Defense, the programming offices of the Services and representatives from the program teams of every major defense program participated in the simulation.

Computer simulation is of great importance for having well-educated experts in defense resource management. Some of the civil and military experts have only practical experience and need to learn more from theory; some are newcomers to the field and have to be trained in defense planning starting from the very beginning. The years of implementation of the new defense resource management system teach us that the education of personnel is a permanent activity. Furthermore, the education and training of senior leadership and other administrative staff, which influences decision-making, and units' staff, is a crucial factor for the proper functioning of the planning system and for gaining all the benefits from its implementation.

In addition, the simulation contributed to the strengthening of IDRMS as system for effective and efficient allocation of resources and for transparent decision-making in MOD and the Armed forces. It demonstrated the promise of IDRMS as a means for systematic, financially realistic, output-oriented planning and programming based on national defense policies. It further proved how essential it is to develop annual budgets and measure performance against the established objectives.

Objectives of Computer Simulation

The DRM Simulation is designed to improve host country defense resource management staff's understanding of a western-style defense resource management system that includes four interrelated phases: planning, programming, budgeting, and implementation of approved programs and budgets. At the same time it should explore interdependence of the processes, participants and products used in typical cycle of planning, programming, and budgeting of resources. The simulation uses a series of process-oriented, interactive workshops to familiarize participants with a broad range of the activities, roles and responsibilities, and analytical challenges encountered in such a management system. It is highly desirable that the attendees represent a cross-section of Ministry of Defense offices, General Staff, and Services staffs, and program manager offices.

The interactive workshops emphasize important interrelationships and management concepts and are designed to give participants practical experience in:

- Developing and using key policy and analytic documents that are needed in a typical planning, programming, budgeting, and implementation cycle.
- Drafting selected work products (defense planning guidance, program proposals, program review issues, program decisions) that are generated within a defense resource management system and are consistent with senior leadership objectives within fiscal constraints.
- Assessing typical resource management issues and challenges encountered by senior civilian and military leaders and their supporting staffs during a cycle.
- Working collaboratively with representatives of multiple functional interests to develop solutions to resource allocation problems within a framework of national security policies.
- Presenting complex resource management issues for senior leader decision.

Approach

The simulation uses a dataset that describes a notional, medium-sized, military in a country with democratic rule and a market-based economy (Republic X). The workshops that comprise the core of the simulation involve a series of situations in this notional country. In addition to improving the people's standard of living, the new Government has decided to reduce and restructure the nation's Armed Forces to meet projected fiscal realities and a dramatically reduced military threat.

The workshops expose participants to a series of situations and tasks that typically take place in such an environment. They also enable participants to experience several different roles including the supporting staffs of the Minister of Defense, the Vice Minister of Defense for Resource Management, the Chief of Defense, key leaders of joint staff resource management offices, the commanders of major force elements, and major program managers. While simulating these roles, participants analyze complex situations, draft and debate key work products, and present the results of their work to senior decision makers who are played by the simulation facilitators. The facilitators form Resource board as an authorized decision-making body.

The simulation employs a simple force structure and macro-level planning factors that enable participants to explore the relative merits of alternative long-term resource allocation strategies and guidance. The data describe a military that needs to balance its readiness, force structure and modernization goals with the fiscal resources available. Simple force structure and associated cost factors are provided in an easy to use spreadsheet format that permits participants to calculate costs of current and potential alternative future forces and programs over a six-year program period.

The simulation has an introductory seminar and a workshop to explain the excel-based cost spreadsheet tool, eight process-oriented interactive workshops, and a concluding summary discussion period.

Workshop participants work in teams of approximately 8-9 persons and report the results of their efforts in a short briefing at the end of a workshop. Each workshop consists of a short introductory briefing, an interactive workshop and briefing to decision makers, and a short, structured concluding group discussion that focuses on important principles.

The objectives of the introductory seminar are to inform participants of the purpose and design of the simulation and to highlight the key features of the country scenario and the management system employed in the simulation.

The workshop's simulated activities include the following:

- Linking national policy and long-term planning to resource management in a fiscally constrained environment;
- Developing appropriate mid-term programming guidance and supporting administrative instructions;
- Translating guidance into realistic and affordable multi-year programs;
- Program review process;
- Developing program alternatives for consideration of executive management;
- Accommodating unanticipated changes in budget guidance;
- Resolving program-budget implementation issues at periodic reviews.

Let describe briefly the simulation activities and what concrete objective of every activity is. Exploring *linkage between national policy and planning to resource management* highlights the key features of the planning phase and the documents that are typically developed during this phase. It demonstrates the importance of developing realistic long-term plans and how long-term plans can provide key insights that influence development of the Minister's Defense Guidance.

Participants are given excerpts from several long-term plans (force structure, acquisition, facilities, and personnel management) to evaluate for consistency with the new government's defense reform objectives. They also are asked to determine how the plans should influence development of the upcoming Defense Guidance as well as to evaluate what aspects of the plans make them useful sources for developing an integrated resource strategy.

Developing Ministerial Guidance highlights the primary purpose and key features of policy guidance from the Minister and the importance of establishing an underlying resource allocation strategy that influences development of the Guidance. This activity will stress on the importance of establishing realistic and quantitative Guidance objectives that can be linked to national objectives and used to measure progress of defense programs.

Participants evaluate several proposed additions to the latest draft Guidance in terms of their consistency with the Government's defense objectives and fiscal limitations. They also evaluate the level of detail that should be included in the Defense Guidance and the situation that is simulated in the workshop.

Program Preparation Instructions highlight the primary purpose of instructions for program managers and the considerations that should influence the scope and level of detail the document contains. The Program Preparation Instructions should comprise the format of program objective memorandum and the "display" of program that will be presented and submitted to senior managers at different levels of programming structure. Participation in this activity provides practical experience in estimation of appropriate level of detail for this document and what are the major factors that typically affect the requested scope of information presented.

Participants evaluate the level of detail that should be submitted by program managers, given the Minister's Guidance and the situation that is simulated in the workshop.

Program development demonstrates that clear consistent priorities and fiscally realistic programming guidance are essential for developing fiscally constrained program proposals. It proves the crucial importance and value of having in place a cost-analytic capability during the program development process. Participation in this activity provides practical experience that enables participants to translate Guidance objectives and priorities into an integrated multiyear program that addresses force structure, readiness and operations, sustainability, and investments. Program development reinforces the importance of having reliable cost information during the planning and programming phases and trained staff to make cost analyses.

Participants develop recommended programs for the Land Forces, Naval Forces and Air Forces using materials from previous workshops and the cost factor spreadsheet tool supplied. In addition to presenting the rationale for their recommended program, participants are asked to assess compliance with the Guidance, to indicate where fiscal constraints will necessitate missing or postponing Guidance objectives, and to develop a list of prioritized, unfunded requirements (modernization projects or investment projects).

Program review process means to assess proposed programs that should be aligned with Programming Guidance of Minister of Defense. It highlights important factors supporting staffs should consider in assessing program manager developed multiyear program proposals. Participation in this activity provides practical experience in analyzing program managers' program recommendations, particularly in terms of their compliance with guidance, fiscal feasibility, internal consistency, and consistency with other programs. It is necessary to compare major program proposals and ensure cross-program linkages have been appropriately addressed.

Using the proposed programs developed in the previous event, plus summaries of the recommended programs of other defense activities, participants are asked to identify areas where the proposed programs fail to meet Guidance objectives at every level of hierarchical programming structure. The participants should analyze areas in which the programs may not be balanced when compare subordinated programs within major program or find that cross-program linkages may be inconsistent. They also are asked to identify and estimate alternatives using the cost spreadsheet and to prepare a presentation of potential program issues accompanied by analysis and alternatives for senior decision-maker consideration.

Developing and presenting program alternatives describe the role and typical concerns of senior decision-makers during the program review process as well as some important factors should be considered. Participation in this activity provides practical experience in developing appropriate program alternatives (to include funding increases and offsetting funding decreases) for senior leader consideration. The rule to follow in developing program alternatives is to build alternatives on the different ways of achieving program objectives, using various combinations of material, human, financial and time resources, but within given financial quotas for every program.

Participants develop and present briefings on major issues selected by senior leaders. Briefings presented describe the importance of the issue, address the major pros and cons of available alternatives, and identify the staff's preferred alternative and rationale for selecting the alternative.

Budget development and review process allow discussing the primary purpose and objectives of the budget development process and how it should relate to programming decisions. This activity highlights some important factors that should be considered in developing appropriate budget preparation guidance and assessing proposed budgets. Participation in this activity provides practical experience in linking programming and budgeting phases and accommodating unanticipated changes in budget guidance using focus on program goals and priorities. In budgeting phase the participants should understand the leading role of programs approved at the end of Program review process (in the final programming decisions made) and that budgets always serve to programs.

Participants are given a proposed budget revision that has been developed to comply with a last minute reduction in defense funding guidance for the coming budget year. Participants assess the proposal and develop an appropriate counter proposal.

Program-budget implementation and report identify the primary purpose and objectives of the implementation and status-reporting phase of activity and how it should influence the planning, programming and budgeting phases. This activity highlights some important factors that should be considered in developing appropriate program-budget implementation plans and status-reporting system. It points out that for having real and productive planning process there should be in place system for assessing periodic performance and issuing reports (for example, every three months and after the end of the fiscal year). These reports could help to meet program-budget implementation challenges and shortcomings and undertake corrective actions to ensure achievement of established priorities and objectives.

Participants are given a program-budget implementation report that contains several problems, e.g., program cost growth, acquisition slips that free near-term funds, training shortfalls, draw down delays and some unexpected cost growth. Participants must identify these problems, assess their severity and causes, and develop recommendations for senior leader decision.

Implications

While exercising how to develop the planning, programming, budgeting and execution processes in Republic X, the participants could draw a parallel line between this imaginary country and certain host country. Hence, the key factors for success in Republic X could be considered and applied for improving of defense resource management in host country.

Examining these factors in detail, we may observe situations and shortcomings that have been experienced and tackled by the Bulgarian MOD in recent years. We may further identify potential improvements in terms of requirements, responsibilities and commitments of different organizations in order to exploit the benefits of advanced defense resource management.

Key factors for success in planning phase are addressed in two directions:

- At the level of the Government: Clear statements of Government policy in basic documents (National Security Strategy, National Military Strategy), strategies that account for limited resources, a stable, multi-annual financial forecast from the Government, and clear statements of priorities.

- Within the Ministry of Defense: Clear assignment of responsibilities for planning and a collaborative, transparent process, integrated long-range planning that accounts for financial limits, and annually issued Defense Guidance with clear statements of objectives, priorities, and financial limits.

The key factors for success in programming phase are:

- Sustained engagement by senior leaders and their commitment to use the system.
- Clear division of responsibilities between program managers, General Staff, and Ministry of Defense offices.
- Technical staff capable of preparing and assessing options for meeting program objectives set out in Defense Guidance. Staff should be able to analyze best combinations of capability and costs, be able to plan the proper integration of force structure, readiness, and modernization to achieve a balance that complies with policy priorities and makes sense from a military perspective.
- Above all, success requires everyone (staff experts, senior leaders) to accept the discipline of living within financial limits, and not to propose or make ad hoc decisions.

The key factors for success in the budgeting phase are:

- Key here is an understanding that the budget is derived from the program.
- Planners must be able to cope with unanticipated last-minute changes during budget preparation and implementation.
- But, after the program is adopted, the budgeting phase should not be the source of new substantive decisions unless absolutely necessary.
- A key technical requirement is the ability to portray the cost of the approved program within the national budget structure. This is the starting point each year for translating the first year of the multi-annual program into a budget request.

The key factors for success in performance monitoring phase are:

- Program managers and budget holders must report periodically on progress and problems, especially if the programming structure differs from set of budget holders.
- A formal analysis of performance reports must be made collaboratively by General Staff and Ministry of Defense resource offices.
- Significant problems must be presented to the senior leadership council (Defense Resource Board).

- Problems must stay on the agenda of senior leaders until corrected

The key factors for overall success of the implementation of new resource management system:

- All aspects of resource management should be transparent and collaborative.
- Resource management offices must have specialist staffs of adequate size.
- Staff experts, and supervisors, need adequate training.
- Senior leaders must know and understand their roles in the system.
- It is critical to adhere to the overall annual calendar for resource management, in order not to eliminate time for program review, which is one of the most important steps.
- Defense resource management reform will not succeed until resource offices have a capability for cost analysis and proper normative base for costing (methodology for calculating defense expenditures and agreed set of cost factors).

Conclusion

IDA experts conducted similar simulations on Defense Resource Management in several countries. They organized first test of the simulation in Romania during the first week of July 2003 at the Regional Center for Defense Resource Management in Brašov. The test was successful, and Romania adapted the simulation for use both in the Ministry of Defense and separately within the Romanian Air Force. The same simulation was conducted in Croatia during the last week of September 2003, and in Albania during the last week of October 2003. The results from all simulations have been exceptionally productive and promoted good governance practices. The interest of planning and programming experts and their willingness to study were considerable. The simulation may be used by every host country as a tool for further education of staff and future resource managers. In Bulgaria, for example, it already provided the basis for developing a regular course in the Defense and Staff College for training students in planning, programming, and budgeting.

This paper begins by defining CGF systems and grouping CGF simulation applications into three broad types. Calls in the CGF research literature for automated learning by CGF systems are surveyed. Categories of learning-modified behavior for CGF systems are defined based on what behaviors have been learned. Arguments are given, organized by application and behavior category, explaining how learning could increase and/or reduce the utility of the CGF system for the application. Real and notional examples are provided. Finally, specific applications where learning by CGF systems might be useful are identified.

Command, Control, Communications and Intelligence (C3I) and Modelling and Simulation (M&S) Interoperability (RTO-MP-MSG-022)

This is the last report of the NATO RTO Modelling and Simulation Group (NMSG). It can be found on the web site of the NATO Research and Technology Organization – http://www.rta.nato.int – if one restricts the search to the NMSG panel.

To support operational support and training, the two high priority areas of military applications of M&S within the Alliance, interoperability of legacy and future Command, Control, Communications and Intelligence (C3I) and Modelling & Simulation (M&S) applications is required. This is the main subject of the report. The reader may refer to the paper by Andreas Talk in this volume of *Information & Security* for a rather comprehensive treatment of the issue. Dr. Talk is a major contributor to the report.

The report is based on papers presented at the NATO RTO Modelling and Simulation Group (NMSG) Conference (MSG-022) "Command, Control, Communications and Intelligence and Modelling & Simulation Interoperability" that was held in Antalya, Turkey, from 9 to 10 October 2003. All sessions of the conference were unclassified. The conference audience of 128 persons included experts from NATO countries, Partners-for-Peace (PfP) nations, as well as Invited Nations. The conference focused on:

- Lessons learned from past experience in linking C3I and M&S,
- Current Joint use of C3I and M&S in Computer Assisted Exercises (CAX),
- Interoperability and data standards,
- Future projects.

The report contains two keynote speeches, one capstone document, and 19 papers covering NATO efforts as well as efforts of the nations. Furthermore, the results of organizations dealing with the issues of C3I and M&S interoperability are presented as well, in particular the work of Simulation Interoperability Standards Organization

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(SISO) and the European Co-Operation for the Long-term in Defence (EUCLID). State-of-the-art solutions are presented, future Research & Development domains are defined, and an overview of the contribution capability of the participating nations and organizations is given.

Other technical reports of the NATO Modelling and Simulation Group, also available free of charge, are listed below:

- NATO-PFP/Industry/National Modelling and Simulation Partnerships (RTO-MP-094)
- M&S Support from PATHFINDER Programmes to Bi-SC Staff Training and Exercises Capabilities (RTO-TR-065)
- Recommendations on the Establishment of a NATO Simulation Resource Library (RTO-TR-051)
- Feasibility Study on Modelling & Simulation Technology in Support of Simulation Based Acquisition (RTO-TR-064)
- Future Modelling and Simulation Challenges (RTO-MP-073)
- NATO HLA Certification (RTO-TR-050)
- The Second NATO Modelling and Simulation Conference (RTO-MP-071)

A Visual Tool to Simplify the Building of Distributed Simulations using HLA

Shawn Parr

Keywords: Distributed Simulations, High Level Architecture, HLA, Calytrix, SIMplicity, Integrated Development Environment, Model Driven Architecture.

Abstract: The High Level Architecture (HLA) is intended to promote the reuse and interoperability of distributed simulations. Unfortunately using HLA also adds a significant amount of overhead and complexity to the development process. This paper looks at the issues associated with HLA and introduces Calytrix SIMplicity, an Integrated Development Environment (IDE), based on the OMG's Model Driven Architecture that simplifies the process of developing distributed simulations.

Common Data Administration, Data Management, and Data Alignment as a Necessary Requirement for Coupling C4ISR Systems and M&S Systems

Andreas Tolk

Keywords: Interoperability, Metadata Modeling, Data Modeling, Object Modeling

Abstract: Within the application domain of military simulation systems, training and exercises as well as support to real operations require the coupling of the simulation system delivering the needed functionality with the Command, Control, Computing, Communications, Intelligence, Surveillance, and Reconnaissance (C4ISR) system providing the necessary data. The solution to this challenge is to build appropriate interfaces. Although in long term a more integrated approach will be necessary, in short and mid term, gateways and interfaces are likely to remain the standard. However, in order to succeed with the respective efforts, at least on the data level of interoperability, a common solution is necessary. Subsequently, in achieving interoperability issues like a common architecture, a common set of algorithms, and a common view of the world in the form of ontology, including dynamic aspects, can be addressed as well. First of all, however, in order to make a meaningful integration possible, the common data issue has to be dealt with. The methods used to achieve this are not only applicable to the coupling of Modeling and Simulation (M&S) and C4ISR systems, they are necessary in preparing the coupling/integration of different C4ISR systems as well, e.g., to prepare a common operation with new partners and allies. Therefore, it is a general approach to interoperability. The paper outlines some of the work done in this field on international level and draws some conclusions for future work.

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A Small Step toward Interoperability

Ronald J. Roland

Keywords: Joint Theater Level Simulation, JTLS; simulation environment for crisis management; interoperability; combined, joint and coalition training; National Military Command Center (NMCC) initiative;

Abstract: The paper addresses the critical issues that have been resolved toward meeting the NMCC requirements of providing a common simulation software environment for both crisis management coordination at the intra and international levels and a potential candidate that can be used for combined, joint and coalition training of combat and security forces. A common architecture for the NMCC concept and support the guidelines of North Atlantic Treaty Organization (NATO) M&S have been proposed. Information and guidelines have be provided concerning future enhancements programmed for JTLS and how each user can help guide continued upgrades and revisions. The proliferation of M&S related tools, use of the term M&S (and its image, S&M), technology developers and claims of value have been discussed. Caveat emptor has been defined to mean that simulation users should be technologically competent and use expert judgment in their selection and acceptance of simulation technology.

Mathematical Model of Fuzzy Control System for Autonomous Guided Vehicle in 3D Space

George Georgiev and Valentine Penev

Keywords: Fuzzy control, Maximizing decision, Dynamic programming, Policy function, Autonomous guided vehicles.

Abstract: In previous papers, the authors have described a theoretical approach to the development of mathematical meta-models, which aim to capture the emergent behaviour of intelligent agent-based constructive simulation models of military conflict. These intelligent agents capture the process of C4ISR (Command, Control, Communications, Computers, Intelligence Surveillance and Reconnaissance) in such agent-based simulation models. In this paper, the authors present both historical evidence and evidence from experiments using cellular automata models that support hypotheses derived from their theory.

Game Theoretical Modeling for Planning and Decision Making

Juliana Karakaneva

Keywords: Game Theory, Planning, Decision-Making, Optimization, LINGO-language

Abstract: The objective of this paper is to focus the reader's attention on the game theoretical methods applied to modeling of real conflict situations. Game theory is a well known and established approach and there are many researchers working in this field. Recently, the importance of these techniques has increased in order to address the necessity to plan and make timely decisions in conditions of incomplete information and in asymmetric environments. In many cases it is impossible to apply mathematical methods due to the difficulties in finding adequate solutions. Modern software for optimization, such as the LINGO-solver, is a powerful tool to obtain credible models and solutions.

Modeling in Shaped Charge Design

Hristo Hristov

Keywords: shaped charge, design, variational problem, jet length maximization

Abstract: The possibility of using variational calculus is substantiated by optimization of shaped charges for high-velocities forming of compact, discrete or dispersed jets. Each characteristic function of the shaped charge geometry can be considered a variational parameter in the Orlenko hydrodynamic model. Respectively, the author formulates the problem for determination of an unconditional extremum, as well as a subproblem for determination of a conditional extremum when an integrated condition is added.

IMoViS: A System for Mobile Visualization of Intrusion Detection Data

Andrea Sanna and Claudio Fornaro

Keywords: intrusion detection, information visualization, mobile devices, PDA

Abstract: Mobile devices, such as PDAs, allow a sort of ubiquitous access to the Internet. This can be of great value to all disciplines where information has to be conveyed to the user in "real time" independently of his/her physical location. Intrusion detection applications can take advantage of the use of mobile devices by allowing a constant monitoring of the state of a computer system.

This paper proposes an integrated framework to visualize intrusion detection data on PDAs. The Snort ID system is used to detect attacks and intrusions and to store the collected information into a database. The information is processed by software called Guardian that produces the actual data to be fed to the visualization application. The proposed architecture is tailored for monitoring large buildings by organizing spatial data information in a hierarchical way. The user can discover and manage attacks/intrusions at the top level of the hierarchy (the entire building), as well as at the leaf level (the single machine placed into a room), where detailed information about the attack can be obtained.

Constructing a Proxy Signature Scheme Based on Existing Security Mechanisms

Wei-Bin Lee and Tzung-Her Chen

Keywords: digital signature, proxy signature, certification authority, time stamp authority

Abstract: A proxy signature allows a designated person, called a proxy signer, to sign a message on behalf of an original signer. Many proxy signature-related schemes have been proposed due to the fact that this type of scheme is very important. However, these new schemes always face security challenges. To minimize security challenges, the objective of the authors of this paper is to construct a proxy signature scheme that combines existing security mechanisms, rather than attempting to invent a new scheme. They believe that the proposed proxy signature scheme not only satisfies the essential properties mentioned in Mambo-Usuda-Okamoto's proxy signature scheme but also has additional advantages, such as non-repudiation and prevention of delegation transfer. Furthermore, the fewer security challenges and easy implementation are direct benefits obtained from using the existing mechanisms.