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INTERFACING COMMAND AND CONTROL INFORMATION SYSTEMS AND SIMULATION ENVIRONMENTS: TECHNICAL APPROACH, OPERATIONAL PAYOFF AND PROCEDURAL CHALLENGES

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ABSTRACT

This paper describes a modular approach for the interfacing of simulation environments and command and control systems. It focuses on the type of interface that is required during the execution of a military exercise. Experiments have been conducted with prototypes that represent subordinate decision making. They tend to show that the same exercise effectiveness can be achieved while reducing the amount of support personnel considerably. A further reduction in personnel can be achieved by modelling of the formal reporting process. A prototype capability has been built and tested in which a report generation mechanism combines all relevant structural and content data stored in a single repository to produce valid reports. This approach has proven successful in the laboratory and must now be tested in the field.

A spin-off result is the availability of data to support the monitoring and the analysis of the exercise. It is also necessary to highlight the security and performance implications of implementing such a tight interfacing between an operational command and control system and an exercise driver.

1 INTRODUCTION

Traditionally, automated exercising environments have taken two approaches to provide a Command and Control Information System (CCIS) interface. Either a CCIS-like capability was implemented and provided to the exercising staffs or a manual swivel-chair interface procedure relying on so-called Response Cells was used to simulate the relevant flows of information.

Since a few years, the concept of exercising military staffs has shown a shift from exercising the people and their procedures to exercising the entire CCIS. In this context, we adopt a broad definition of the CCIS as being the people, procedures, communications, hardware and software. It is interesting to note that this trend applies both nationally and internationally. As this new requirement causes both previously described approaches to become ineffective or too costly, the need for a cost-effective interface between CCIS and simulation environment is great.

The Supreme Headquarters Allied Powers Europe (SHAPE) has expressed this need in the Military Operational Requirement (MOR) for Computer Assisted eXercises (CAX). SHAPE Technical Centre Project XC which is charged with the amplification of the MOR into a suitable capability, has investigated this problem more closely. Prototypes have been developed and tested.

We will start by discussing the nature of the information flow that must be supported by the interface to the CCIS. We will introduce the concept of Exercise Information Systems (EIS) and limit the scope of this paper to the aspect of interfacing EIS and CCIS during exercise conduct.We will describe the technical approach that we have selected and discuss some of the experiments that we have carried out. We will then illustrate the expected benefits of using this interface and highlight some interesting spin-off results. Finally we will discuss the procedural issues and related technical problems that must be overcome to utilise this capability in an operational environment.

2 THE EXERCISE INFORMATION SYSTEM AND THE CCIS

In order to define the nature of the interface between the Exercise Information System and the CCIS, we must specify the functionality of the EIS. The three major processes that the EIS must perform are:

1. Exercise preparation

2. Exercise conduct
3. Exercise analysis

For each of the processes an interface must be established between EIS and CCIS. For exercise preparation, the EIS should be able to draw relevant scenario data e.g., status of forces from the CCIS. It should also be able to instrument the CCIS e.g., set routing tables, geography, status of forces, analysis collection specification, to participate in the exercise in a meaningful manner. During exercise conduct, the EIS must be capable of encapsulating the CCIS from an information flow perspective. For exercise analysis, the EIS should be able to combine data collected by the EIS and the CCIS during the exercise. From this brief description, it is clear that this concept of tight interfacing between EIS and CCIS will undoubtedly have an impact on the CCIS itself. Although, this aspect is of great interest and relevance, it would expand the scope of this paper too much if we were to address it here in greater detail. We will therefore focus the following discussions on the interface that must be established between EIS and CCIS during the conduct of the exercise.

3 INTERFACING EIS AND CCIS DURING EXERCISE CONDUCT

The information that flows between EIS and CCIS during the conduct of an exercise can be separated into two distinct categories:

1. the information flow to and from exercising staffs which consists of reports, orders, queries and responses;
2. the information flow between exercising directing staff and CCIS elements which is necessary for the coordination of activities and which is used to monitor the progress of the exercise.

As the second flow is closely related to the area of exercise analysis, we will not address this issue in this paper. The first most active and critical flow from the exercising staff point of view can itself be split into a reporting and an ordering information flow.

4 FROM THE CCIS TO THE EIS

The ordering information flow runs between the lowest level of exercising staff and the EIS. Orders represent decisions that are made at a given level of complexity. The EIS simulates activities at another level of complexity. Therefore the role of the ordering interface between CCIS and EIS is to transform the decisions that are contained in the order into actions that can be simulated. This process, which we term *order translation*, corresponds to a decision making process and has traditionally been carried out by Response Cells with little or no automated support. As decision making processes have been studied extensively in the military field and formal process steps and criteria have been identified, refer to military staff college handbooks for examples, these processes can be automated to such an extent that intelligent decision automata perform adequately in an exercise setting, see Coppieters (1990) for a number of examples. The benefit of developing such capabilities lies in their re-use with multiple simulations and in the reduction in response cell personnel.

The key element to re-using decision automata is to design them to mirror the human decision making process while keeping in mind the reductions in complexity that are likely to exist in simulation models. In the context of our work, we have developed a number of interactive decision automata in the areas of air, land and naval planning. They have been developed using commercially available artificial intelligence tools in combination with powerful graphical user interface development environments as described in Driessche (1994). A number of these automata have been tested in laboratory experiments. In the case of an offensive air mission planner, it has shown that the same level of effectiveness can be achieved by a single aided response cell operator as a completely manual response cell consisting of four operators, (Coppieters 1992). During these experiments, both response cells used the same information flow. It was interesting to note that in addition to this efficiency improvement, the aided response cell was capable of achieving an increase in effectiveness. The limited amount of time required by the aided response cell to plan and enter its orders in the simulation, allowed the aided cell to wait for additional information about current operations before committing its available resources to new missions.

Re-use of decision automata is possible because they interoperate with a data repository that is independent of the simulation model. Data is drawn and written to this repository. A particular interface handles all simulation-specific processing. This approach allows the usage of the EIS at various levels of decision making. An example is the usage that was made of our testbed EIS environment by another STC project which deals with air command and control systems. The objective of the experiment that conducted in June 94 was to test command and control system prototypes that had been developed in the area of air mission planning. The previously tested aided response cell level corresponded to the level of decision making of the prototypes. After initialising the prototypes with our scenario data, the decisions taken by planners using the command and control system prototypes were output in a standard order format which was parsed and stored in our repository. The simulation-specific interface ensured that the orders are entered into the simulation. The results of the simulated actions were returned to the CCIS prototypes through the report generation process that we will discuss later.

Therefore we can conclude that modelling decision making explicitly in the simulation environment can allow us to apply it with various implementations of activity simulation. It will allow us to save support personnel cost and may improve the actual performance of the response cell function. A word of caution is in order concerning the difference in assumptions between the model of the world as represented in the decision automata and in the simulation. For interoperability between these elements to work, the differences between these basic assumptions cannot be too great without running the risk of effectiveness degradation. Let us then consider the process that triggers the decision making loop namely, the reporting flow.

5 FROM THE EIS TO THE CCIS

As in any organisation, information is exchanged between organisational elements in a structured and in an unstructured manner. In the EIS, we consider that the current state of technology mandates that the simulation of unstructured information flow should be left to personnel in the response cell function. Structured information, on the other hand, can be simulated to a large extent through a fully automated process. The military organisation has defined a reporting approach which is based on the aggregation of information. For each level of command, the type and level of detail of information is specified as well as the expected frequency of reporting. Therefore the nature of the simulated reporting flow must vary according to the lowest level of command level that is being exercised.

Our approach has been to develop a data model that can describe the structure of reports, the contents of reports, and the mapping between structure and contents. The report generation process combines these three type of data to generate a valid formal report. Hence the report generation process itself has no embedded knowledge about the product that it is generating. Changing a report structure is therefore limited to changing values in a data base.

The basic elements of reports are fields, field groups, and sets of field groups. Fields can be mandatory, optional or conditional, and appear in a certain sequence in a field group. Field groups are mandatory, optional or conditional, and appear in a certain sequence in a report or in a set of field groups. Sets of field groups are mandatory or optional and appear in a certain sequence in a report structure.

The conditional element causes problems when the report is generated sequentially. Indeed references to previously generated fields and their values must be used to determine a conditional field's correct value. Rather than include the condition in our data model and complicate the report generation process, we have elected to describe conditions through different reports structures i.e. a field group with a conditional field is entered as two distinct field groups and the mapping of data ensures the correct handling.

In certain cases, field groups and sets of field groups need to be repeated e.g., the status of unit is described as a field group and every unit must be described in the report. We have resolved this aspect by associating a field group or set of groups with a specific data table and attribute. The report generation process ensures that for each distinct value of the attribute in the data table, the associated field group or set is created e.g., in the unit_status table, the unit_id attribute.

The greatest effort lies in modelling the actual content of the reports that can be generated. For each report type data structures must be defined that store the respective data. We have chosen to build data structures that reflect the structure of the reports in order to simplify the modelling process and the mapping of data on structures.

In order to gain empirical knowledge about this approach we have implemented a testbed using the Joint Theater Level Simulation (JTLS) as the simulation. JTLS was selected because it is representative of the types of simulations used to exercise NATO headquarters. A set of representative reports were selected to start our testing according to the following categorisation of report types, the discriminating factor being the event that triggers the generation of a report:

1. periodic reports: typical situation, intelligence, summary and assessment reports. They are generated every x number of hours. The number of reports generated during the exercise can be predicted exactly.
2. single event reports: a report will be generated once for a given simulation entity e.g., 1 mission report will be written for 1 air mission. The number of reports generated during the exercise will be the same as the number of occurrences of the simulation entity e.g., if during the exercise approx. 5000 air missions will be flown then approx. 5000 mission reports will be generated.
3. multiple event reports: a report is generated multiple times for a simulation entity according to

several criteria e.g., a land intelligence report is generated by the same own unit about an opposing forces unit every time that unit has a significant change in posture on combat effectiveness. This number of reports is difficult to predict as it depends on the dynamics of the situation.

A JTLS-specific interface was built that passes data provided by the simulation to the data base which we refer to as the Operational Environment Simulation (OES) data base. The structure of the selected set of reports is described in the OES data base. Tables have been created that can store the actual report data and the mapping of structure to content has been defined. The report generation process was implemented. Together with the report-related tables of the OES data base, we refer to this capability as the Situation Translation Module (STM). Tests were conducted with the testbed in December 92 and May 93 which showed the approach to be effective. The main concern was in the area of efficiency. The problem has both a semantic and a technical dimension.

From a semantic point of view, the most unforeseeable flow of reports is constituted by multiple event reports. It is important to establish carefully which thresholds actually cause a report to be generated again e.g., what constitutes a significant change in combat effectiveness which will prompt a new intelligence report. These considerations are report-type specific and are also related to the level of detail of the simulation. Therefore, we would recommend resolving these issues at the interface level between simulation and OES data base.

From a technical point of view, our first implementation used a single flow of data. As several processes must communicate and consume data from each other in a sequential manner, delays may occur. Accessing the same data tables may also cause delays i.e. the interface is writing data while the report generator needs to read data from the tables. Increasing the buffer size of processes and parallelizing processes has proven effective in reducing delays to the simulation model itself. Indeed the report generation can be specialized to specific report types by applying a filter mechanism. Currently, we are considering testing this capability in a real exercise with a limited set of reports. If successful, we will propose to NATO to fund the expansion of the capability to cover the complete range of reports required for exercising.

A limitation of our current and foreseeable testbed capabilities is the need for simulations to be changed to meet the data reporting requirement. We would like to investigate ways in which simulations can be considered as pools of data which can be accessed using a standardized language similar to the data base world and SQL. We have conducted some exploratory work in this area, (Missiaen and Bertrandias 1994), which has shown promising results but as yet does not seem applicable to large simulations from an efficiency and expert availability point of view.

6 USING THE ORDER AND REPORT DATA FOR OTHER PURPOSES

As described in both previous sections, all data flowing between EIS and CCIS is stored in the OES data base. The combination of data formed by the orders that are given to and by the reports that generated by the simulation environment, creates a potentially very rich basis for exercise monitoring and analysis. The capability exists to monitor decisions as they are made which allows exercise directing staff to assess the course that the exercise is taking and if necessary intervene unobtrusively.

Even more powerful is the analysis capability. Indeed all orders and reports are time-stamped and therefore a comprehensive history of the exercise can be created. This data can be used to analyze problems with the simulation environment e.g., sensitivity of simulation to particular action in certain circumstances. The course of the exercise can be explained and lessons can be learned for subsequent events. We have only shown this potential by implementing some simple spreadsheet tools and history visualisation capabilities.

7 PROCEDURAL INTERFACE ISSUES

Interfacing an EIS and a CCIS implies that a physical connection exists between these information systems. This raises the issue of security. We can assume that data and communications security can be enforced in both information systems. Therefore it would appear that from this perspective, they can be joined together without any problems. The impact that the exercise information flow may have on the operation of the CCIS however is less clear. Therefore it will be necessary to assess the performance requirements that interfacing in such a tight manner will add to the existing need.

Finally, we should bear in mind that an ever improving simulation capability which becomes increasingly realistic may be an effective tool for deception. Although, the likelihood remains low at this time, we should consider this aspect of interfacing early on in the design of an effective solution.

8 CONCLUSIONS AND WAY AHEAD

Underlying the work that we have conducted is the requirement that this approach should be applicable to other simulation models or groups of simulations. We believe that we have met this requirement since the only pre-requisite for simulations is to be able to generate the necessary data. Furthermore, we consider this process to be the responsibility of the exercising organisation because the form of the information is managed and updated by NATO. It would therefore appear logical that we should also manage the exercise data requirement specification. In addition to this consideration, the interface constitutes a controllable layer from a security perspective. Providing a sound and acceptable solution to the security question is essential for the successful implementation of an interface between Exercise Information System and Command and Control Information System.

In order to validate our approach further, we intend to pursue the utilisation of this capability as a field prototype. We are also considering incorporating it in our efforts which involve multiple national models operating together as a distributed multi-national defence simulation, (Coppieters 1995).

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