Enhancing Operational Effectiveness through the Integration of Planning and Simulation Technology

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Abstract

This paper discusses recent results and proposed work in enhancing operational effectiveness through the integration of planning and simulation technology, especially during the joint contingency planning process. The paper presents a preliminary architecture that provides a loose coupling between existing planning and simulation architectures via a query and data manager. Novel plan and simulation query languages are described and a number of research issues identified, in the context of a joint logistics planning scenario. Initial functionality of the query and data manager is briefly introduced and the next steps for the project discussed.

1. Project Vision & Objectives

Recent research on generic plan description languages in the UK and US has led to their incorporation within advanced prototypes for various military and civilian planning tasks. Within the UK Defence Evaluation and Research Agency (DERA), a constraint-based object-oriented plan description language has been developed and applied to joint operations planning tasks[1]. However, none of these languages can adequately represent and propagate measures of effectiveness and uncertainty throughout the plan in a consistent manner, especially *during* the plan development process. Thus, fundamental research is required to integrate measures of effectiveness and uncertainty within generic plan description languages in a principled manner.

To support this aim, the following objectives are being addressed within this project[2]:

- to explore the integration of existing planning languages with simulation models to permit planning queries to be answered by configurations of specific simulations;
- to demonstrate the benefits of such an integration on relevant military operations planning scenarios derived from the DERA Joint Planning Aids (JPA) project [Desimone *et al*., 1998];
- to make recommendations on improvements to planning languages and representation languages for simulation models and uncertainty measures to facilitate their integration.

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[1] This work was reported at the 1998 Command & Control Research & Technology Symposium (CCRTS), US Naval Postgraduate School, Monterey [Desimone *et al*., 1998].

[2] This work is being carried out as part of Technology Group 10 (Computing, Information and Signal Processing) of the UK Ministry of Defence Corporate Research Programme.

A more comprehensive plan description language that expresses measures of effectiveness and uncertainty would provide value-added support to a range of planning and decision aids currently being explored for future operational UK/US C3I systems. Such a language would provide direct links between decisions made during the planning/command process and relevant simulation models that characterise and justify the military effectiveness of these decisions. Thus, planners and commanders would be able to explore the effectiveness of each decision, rather than *just* for the operations plan (OPLAN) as a whole.

Such a language would also provide an audit trail for the generation and validation of OPLANs and operations orders (OPORDERs), thus facilitating mission rehearsal and after action review. Furthermore, it would provide a solid foundation for exploring the business process and the changing roles and functions of organisations, such as the UK Permanent Joint Headquarters (PJHQ), and the US military commands, in the context of changing threats and doctrine.

2. Preliminary Architecture for Integrating Planning and Simulation Systems

This project started in April 1998 and will continue until March 2001. This paper discusses early results in developing a preliminary architecture that will provide a loose coupling between planning and simulation system architectures. This loose coupling will permit planning queries to be mapped into specific simulation queries, requests made for clarifications of the query and results from the simulations fed back directly to the planning system that issued the query. Figures 1 and 2 highlight the role of the planning and simulation query and data manager (QDM) that will provide the linkages between these two architectures. The loose-coupling provided by the QDM is seen as the first step in defining a more tightly-coupled architecture that would permit greater interleaving of planning and simulation functionality.

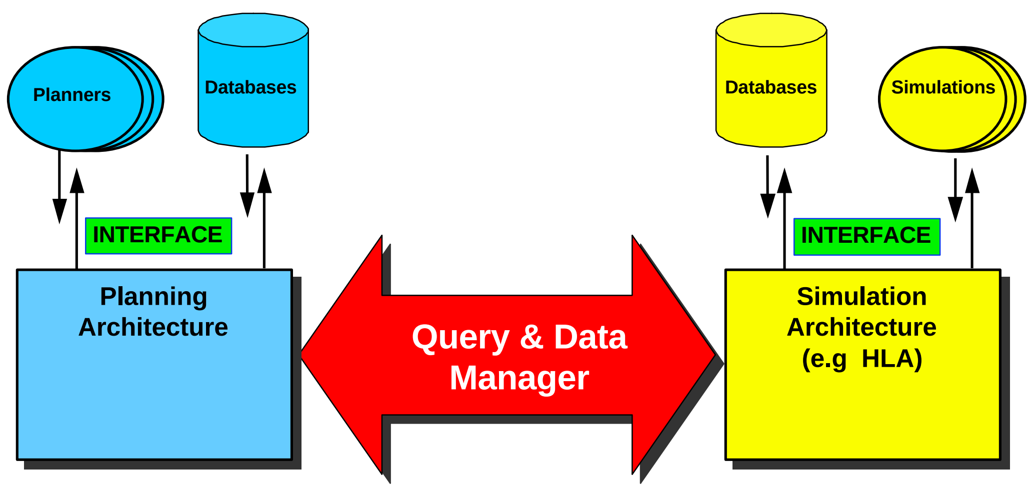

Figure 1. Preliminary architecture for loosely-coupled integration of planning and simulation systems

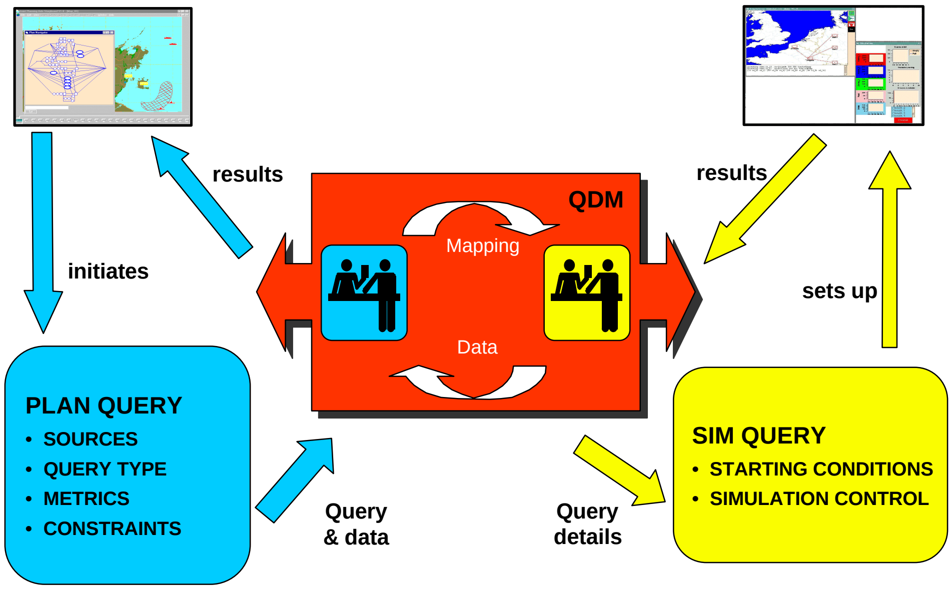

Figure 2. Dataflow between plan and simulation query languages via QDM.

Figure 2 shows the linking of existing plan description languages with simulation models via *novel* planning and simulation query languages[3]. In particular, it highlights the flow of queries and data between planning and simulation systems via the query and data manager (QDM). The planner initiates a query, expressed in a plan query language. This plan query is mapped into a specific simulation query, denoted by a simulation query language. The simulation query provides the set-up for a number of simulation runs, the results of which are fed back through the QDM to the planner that initiated the query.

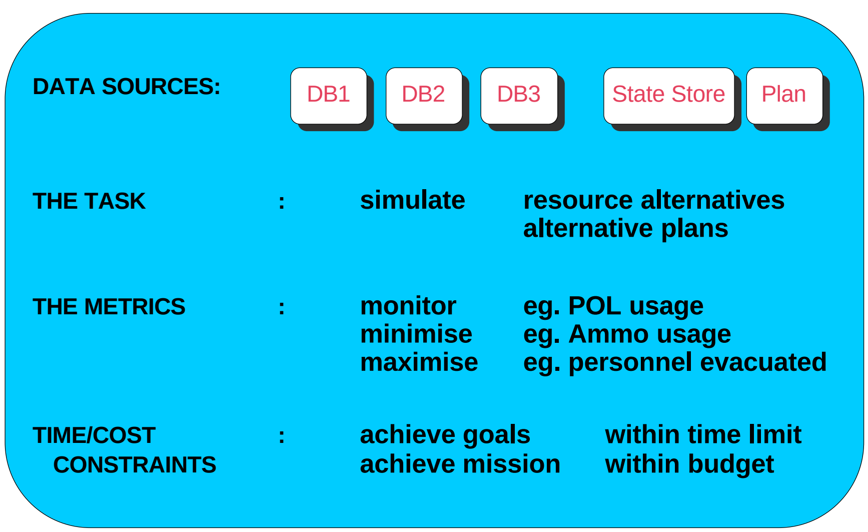

Figure 3. Format of the plan query

[3] Related work on simulation query language was also reported at 1998 CCRTS [Wiederhold *et al.*, 1998].

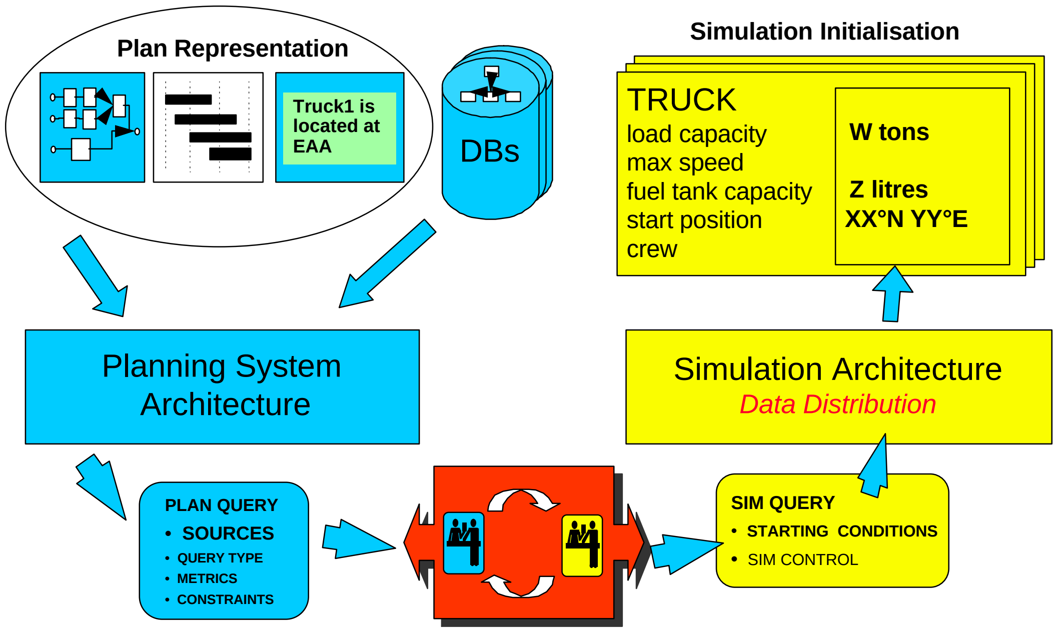

Figure 4. Dataflow between planning and simulation architectures through QDM

The plan query (see Figure 3) contains all the information necessary for the QDM and the simulation architecture to prepare, run and return results from simulations. There are four types of information referred to in the query:

- *data sources* - comprising the sources of information used by the planning system
- *task details* - specifying the parts of the plan to be simulated
- *metrics* - giving the planner control over the use of resources within the simulation
- *time/cost constraints* - specifying deadlines and constraints on answering the plan query.

The plan query is converted by the QDM into a simulation query, which has two parts: starting conditions and simulation control commands. The starting conditions include instructions on how to populate the initialisation files for the simulations required. The control commands instruct the architecture on how best to simulate the required action whilst taking account of the metrics and constraints imposed by the planner.

The QDM also functions to translate data generated by the planning system into formats appropriate to the chosen simulators. This data includes the structured sequence of goals and actions generated in the planning process to date; information about the constraints on the scheduling of those elements within the plan; and a time-indexed description of the state of the world which gives the plan its context. Figure 4 shows the flow of data through the QDM.

When the simulations have run their course, the QDM re-formats their results according to the metrics given in the plan query and returns them to the planner, as shown in figure 5. In addition to the simulation results, an audit trail of the initial plan query and the corresponding simulation query is recorded, together with any modifications that were required to answer the initial query.

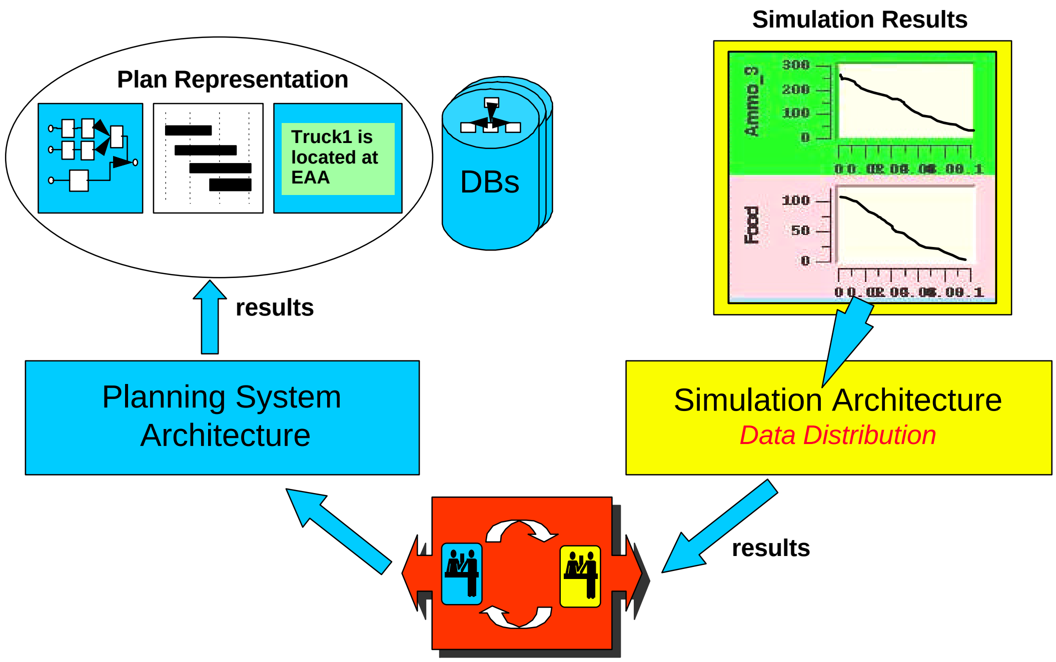

Figure 5. Simulation results fed back through QDM

Further details concerning the format of these query languages and the structure of the proposed QDM are given in a more complete technical report [Desimone *et al.*, 1999].

3. Research issues concerning the integration of planning and simulation systems

A number of research issues concerning the integration of planning and simulations systems have been identified. The full list of 16 research issues are as follows:

1. How much of the plan needs to be passed to the simulator? ✪✪
2. How would an inability to simulate part of the plan be handled? ✪
3. Unplanned goals may be part of the plan - how will simulators cope? ✪✪
4. How can meta-data on simulations be represented? ✪✪
5. Can the meta-data be enough to automatically select simulations? ✪✪✪
6. How much of the plan should be simulated? ✪✪
7. How much guidance should be given on scheduling specific actions? ✪✪
8. How is location mapped between the plan and the simulation? ✪
9. How can abstract classes be mapped onto specific simulation entities? ✪
10. How to achieve minimise and maximise metrics? ✪✪
11. How much control of trade-off should be automated? ✪✪✪
12. How to take account of assumptions made by simulator? ✪✪✪
13. What is recorded for decision auditing? ✪
14. How much control should planner and simulator have? ✪✪
15. How should system handle distributed and parallel simulations? ✪✪
16. How to interleave simulations within planning process? ✪✪✪

These issues are not all mutually exclusive. Some are broad issues that overlap other more specific ones. They have been labelled and colour-coded. One star (green) denotes the research issue is within the scope of the project and good progress in resolving the issue should be expected. Two stars (blue) denotes the issue is more complex and that limited progress in resolving it within the project should be expected. Three stars (red) signifies that the issue is very complex and that it cannot be comprehensively addressed within this project.

These research issues have been related to a logistics planning scenario derived from the JPA project, that highlights not only their complexity and importance within the preliminary architecture, but also the practical benefit derived from answering plan queries through simulation results. The scenario involves the movement of evacuees from two different evacuee assembly areas (EAAs) to an evacuation point (EP). A plan has been developed setting up the EAAs with relevant logistics supplies, but the specific choice of trucks to perform the movement to the EP has not been made. Three alternatives have been identified and guidance is required from simulations of these three truck movements (see figure 6). In parallel with the evacuee movement, there is also a planned movement of combat forces from a forward mounting base (FMB) to a forward operating base (FOB). The FMB is close to the EP and the FOB is close to EAA2. The low fidelity plan does not currently reflect any potential conflicts, due to traffic congestion, that will be picked up by higher fidelity simulations.

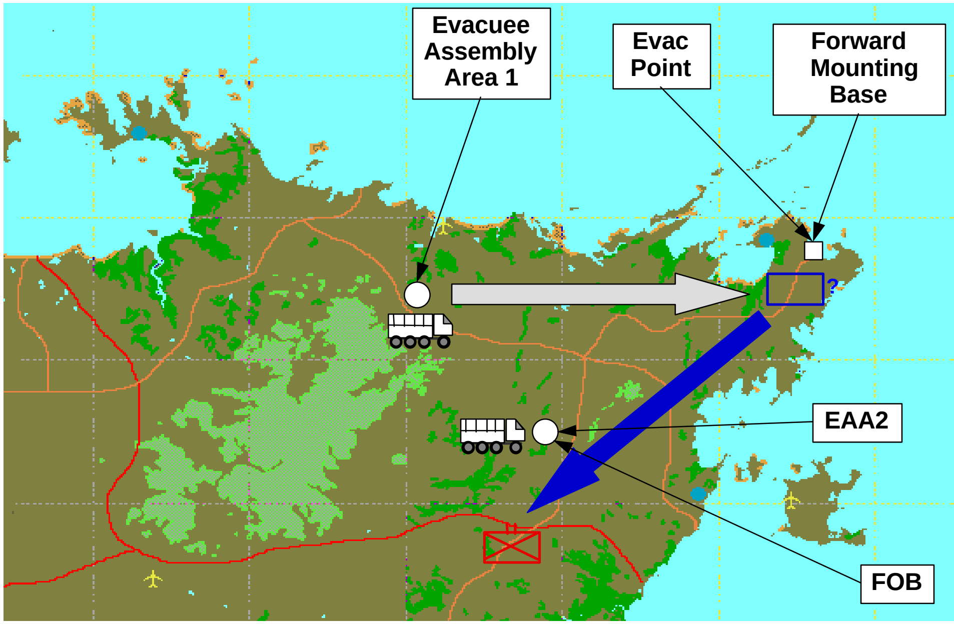

Figure 6: Joint logistics planning scenario for the worked example

The description of these research issues, in the context of the above logistics scenario, will be given at the presentation of this paper at CCRTS99, together with a discussion of the priorities for further research and the way forward. Detailed descriptions of these issues and discussion of the research priorities are contained within the full technical report [Desimone *et al.*, 1999].

4. Planning and Simulation Query and Data Manager (QDM)

The planning and simulation query and data manager (QDM) has not been implemented yet and elements of the functionality are still being designed. The main functionality of the QDM will *eventually* be provided by artificial intelligence (AI) planning technology currently being developed for experimentation within the JPA project. This technology will support the composition of complex simulation queries from initial plan queries and then enact or run the queries on relevant simulators. In the meantime, the initial QDM will be implemented with a mechanism for matching appropriate pre-scripted simulation queries, previously validated, with the input plan queries and then enacting the queries.

Figure 7 shows the architectural diagram for a versatile QDM implementation. The plan query manager takes the input plan query, parses it, feeds it to the simulation script matcher/retriever, where it is matched with a set of pre-scripted simulation queries from a database. The appropriate simulation query is retrieved and passed onto the simulation query enactor, which runs relevant parts of the simulation query/script on appropriate simulators for that specific part of the query.

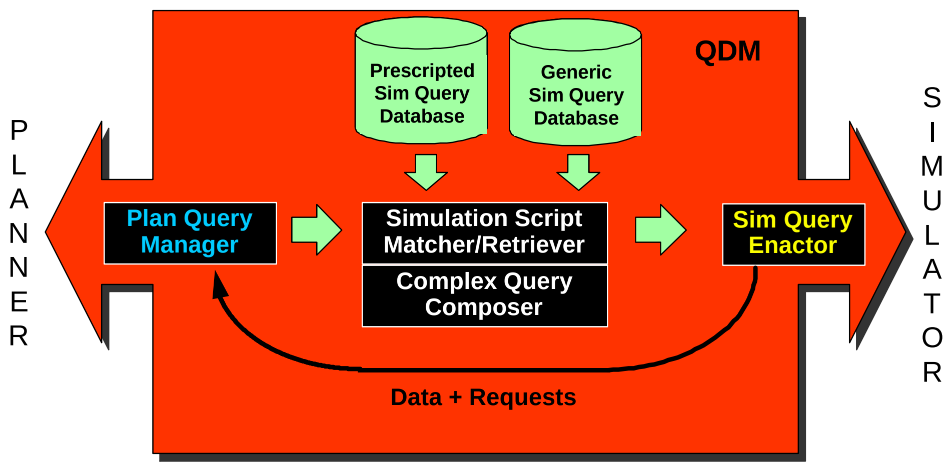

Figure 7: Versatile QDM architecture

As planning queries become more complex it is *not* possible to have exactly the right pre-scripted simulation query available in the database. One way of dealing with this situation is to select the *closest-fit* simulation query and tailor it to meet the requirements of the current plan query, very much in line with the case-based planning paradigm. Alternatively, the appropriate simulation query could be generated by composing smaller, generic simulation query fragments together to suit the specific needs of the complex plan query. This approach follows the generative planning paradigm which is being actively explored within the JPA project.

5. Next steps

The preliminary architecture is currently under development and the planning and simulation query languages are being specified and implemented. A series of experiments will be undertaken to demonstrate the practical benefits to military planners of supporting the evaluation of planning choices through access to simulation models *during* the planning process. These experiments will address the research issues highlighted in this paper, although by no means is it practical for all the research issues to be addressed. The results of this project will be exploited in other projects, including JPA, and could influence the requirements and specifications for future operational UK joint command systems.

References

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