

VIRTUAL ENVIRONMENTS IN INTELLIGENT MILITARY OPERATIONS PROBLEM SOLVING



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ABSTRACT

In the last two decades computers have become more and more common in supporting a commander's decision taking. The increasing volume, diversity and complexity of the available data however pushes the limitation of comprehension and absorption of human decision takers. This coupled to the need of rapid response leads to human decision makers shifting from cognitive decision making to more and more instinctive decision making. It is stated that VPE's can buy us the time to shift back to a cognition. Furthermore they can enhance command and control by supporting human qualitative reasoning. Virtual environments still have to grow in maturity to be able to create VPE's both in terms of hardware requirements and available metaphors in the VE. Research from both the VE- and AI communities should focus on the latter.

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*The time has come, the walrus said,
To talk of many things,
Of sailing ships and sealing wax,
Of cabbages and kings,...*

(Lewis Carroll)

INTRODUCTION

Integrating, analysing and acting upon data has always been a vital aspect at all levels of intelligence handling, battle management

and military command and control. In the last two decades computers have become more and more common in supporting a commander's decision taking by taking user and sensor input to fuse information, simulate and calculate battle outcomes and plan troop deployment & logistics.

The increasing volume, diversity and complexity of the available data, partially due to the application of the information technology mentioned above, pushes the limitation of comprehension and absorption of human decision takers. It becomes more and more difficult for the human senses to translate all the complex data into meaningful images of events. Some data actually may be lost because of human limitations (Smith 1993).

Even the most modern systems, supporting the military commander, currently available or in development (e.g. EUCLID 6.1) are heavily depending on doctrine and expert routine. The applicability of these systems therefore is largely dependent of the flexibility and adjustability of the captured knowledge in the system via user interaction. It is stated that Virtual Environments are the way to go to boost the performance of these systems by direct high-level user interaction with the planning process.

The time has come, the walrus said

The time has come to capitalise upon advances made in Artificial Intelligence (AI) techniques and Virtual Environment (VE) technology. Research programmes which are aiming on the acceleration of the availability of mature capabilities arising from these advances for future command, control, communication and Intelligence (C³I) systems, have to be initiated. As a start the research community has to investigate how the efficiency and effectiveness of systems which try to intelligently support military operations planning can benefit from the use of virtual planning environments (VPE's).

HUMAN INFORMATION PROCESSING IN COMMAND AND CONTROL

It is clear that one does not want to let technological developments to direct the research and development in the area of command and control instead of operational requirements.

Therefore one has to have a clear view of how humans act when performing tasks in a Command & Control environment. The usual cyclic model (figure 1) is to general for this purpose.

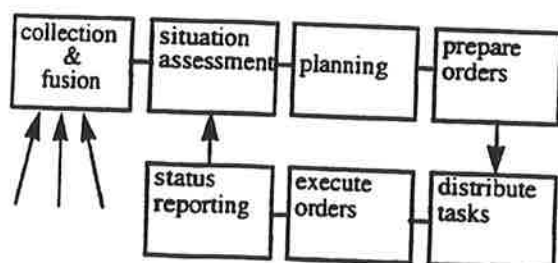


figure 1: Command and Control paradigm.

To talk of many things

The factor: available time on the other hand, may provide a way. The availability of time to create a plan or to take decisions has

important consequences for the nature of the decision making processes. When little time is available, one tends to emphasize on the recognition of tactical patterns and the execution of pre-learned actions. When time is more available the accent shifts to a cognitive analysis of the information and the generation and evaluation of alternative plans. The latter is typical for the higher levels of command and control.

Advances in communications, information technology (IT) and computing power facilitate significant in the scope for improving the overall effectiveness of command and control. On the other hand however one can conclude that these developments in communications and IT have also resulted in a tremendous increase in volume, diversity and complexity of the information. This coupled to the need for a rapid response coordinated across a number of military functions, makes the exploitation of advances in for instance artificial intelligence and the human computer interface a high priority for the European defence. Ignoring the information abundance as one of the major obstacles in human decision making will result in a command and control process that is more and more instinctive and less cognitive.

Because of the complexity and inherently subjective nature of command and control, human analysts and commanders necessarily have to interact closely with the systems that support them. AI-technology plays an important role in assisting the assessment of situations and the evaluation of possible courses of action of own forces. Decision support of an intelligent system interacting with a commander will largely be based however on the doctrine that is put into the system, the human-computer interface and the commanders judgements. It is realistic to assume that doctrine can't express every situation development according to a certain course of action in full detail. In other words the system has to fill in

the gaps in terms of uncertainty and incompleteness of information in interaction with the commander.

INTEGRATING BATTLE MANAGEMENT AND VIRTUAL ENVIRONMENTS

Virtual Environment technology and Battle Management are a natural combination. The battle management system deals with a virtual world (to reason about the real world) in need of senses to explore it. Virtual environment technology on the other hand provides the sense in search of a world to explore. The two have to be merged to discover managing opportunities that humans previously were not capable of creating (Smith 1993).

Of sailing ships and sealing wax

With virtual environment interfaces, computers generate total images of terrain, buildings, phenomena and even life forms that inhabit the world. Because this information is in electronic bits, it can be manipulated in every imaginable way. Virtual Environments are revolutionary in that the user can enter the world being created and explore it with the senses of sight, sound and touch.

The human mind can process visual data easier and faster than for instance text information. Commanders are looking for trends and familiar patterns that reveal opponent actions and intentions. Visual data have a type of 'fingerprint' that the human mind clearly retains, just as pictures are more easily remembered than text.

Initially one could think of the virtual reality interface that supports the commander who is making the decisions on how to wage war. Commanders will be able to fly over the battlefield viewing their sensors' perception of enemy units and formations. They also will be able to see what forces look like from the enemy's point of view. By looking from their side and positions, they may better understand the enemy's immediate intentions. Using the vir-

tual reality capabilities commanders may be able to expose holes in the intelligence collection. For instance, when it may look that no enemy units are in a certain area, it could become clear that a lack of sensor capabilities exists.

Recapitulating the above, VE's can buy the human decision maker the time needed to shift back from instinctive reaction to cognitive process in which the creation and evaluation of alternatives is possible. Instinct does not have to be ignored but can very well take place in such a process.

Besides extracting and deducing information from the world, virtual environments can also be used to extract decisions from the commander in terms of filling up the gaps in the knowledge of the domain and forcing decisions in the under lying (planning) application.

Of cabbages?

In order to live up to the requirements that military command and control is going to put on the use of virtual environments, VE has still to grow in maturity. Some important factors to be considered are:

- Trade-off between reaction time and the quality of graphics (resolution, colour, number of moving objects, etc).
- Usability of virtual environment hardware (helmet mounted displays, data gloves etc.) in terms of weight, degrees of freedom, mobility etc.
- The ability of the environment to dynamically adapt to developing situations by independently using sensor information or information coming from the user and other applications.
- The ability of the environment to capture the decisions the commander takes in the environment.

The first two points are clearly beyond the scope of current research and have to be solved by the VE-industry. The latter two are

more interesting. It is expected that at least for the static information (terrain, buildings etc.) VE-technology can gain a lot of current geographic information system (GIS) research (Essens et al. 1992), in which 3D-visualisation bird's eye view, line-of-sight calculations etc. are hot topics.

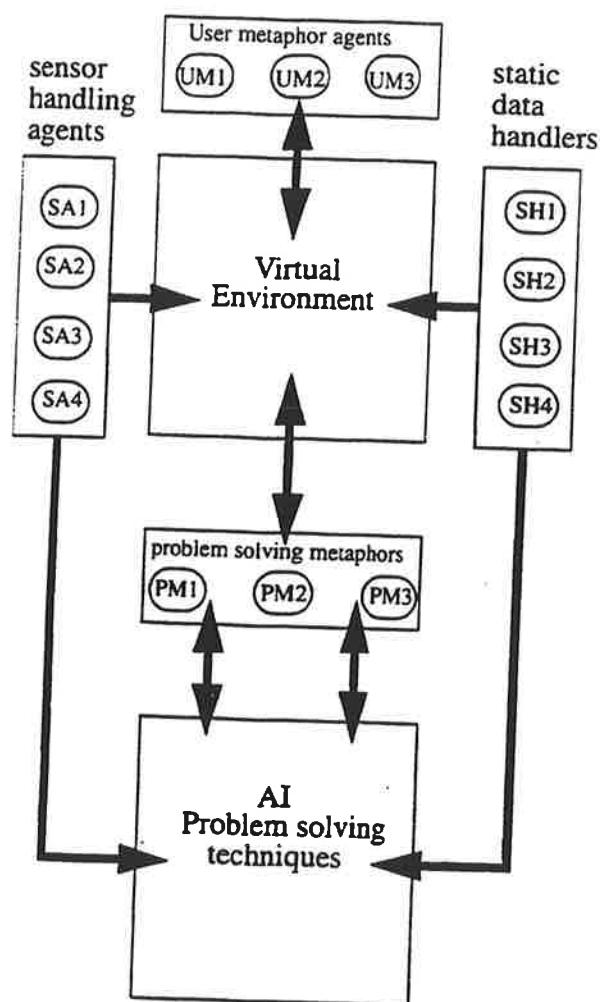


figure 2: VPE-architecture

But the dynamical information introduces a very important requirement namely: real-time behaviour. Real-time behaviour means not exactly reacting in very short intervals of time but reacting in guaranteed intervals of time such that the presented information still makes sense. Furthermore the

notion of asynchronous events is related to real-time behaviour in that the change of entity information does not always come when one is expecting it. This means that when a commander is 'walking' through the synthetic world, the world may be updated. Hence, the performance of the user interaction with the environment may not be disturbed by keeping the environment up to date.

All this may lead to a multi-agent architecture in which virtual environment maintenance, user- and application interaction are handled by different agents (see figure 2). Additionally such a multi-agent approach may turn out to be more flexible as different types of sources of information (database information, sensors, other applications) may be used to populate the environment.

And kings...

The applicability of AI-technology to improve the overall effectiveness of command and control has been addressed in several studies. Programs like Euclid 6.1 specifically deal with the design of a real-time C³I-workstation in which the use of AI-technology is of key concern. But as promising as AI may be, it will not be the ultimate solution for modern command & control problems as long as the user interaction possibilities are restricted to keyboard, screen and mouse. The possibilities of AI however should not be not restricted to these devices. It is not that strange to assume that the intelligent behaviour of the human being not only comes from its complex brain, but also from the independent capabilities of its senses.

James Albus identifies three levels, or degrees, of intelligence (Albus 1991) which are determined by:

- The computational power of the system's brain (or computer),
- The sophistication of algorithms the system uses for sensory processing, world modelling, behaviour generating, value

judgement, and global communication,

- The information and values the system has stored in its memory.

Albus too states that intelligence can be observed to grow and evolve, both through growth in computational power, and through accumulation of knowledge of how to sense, decide and act in a complex and changing world. In artificial systems, growth in computational power and accumulation of knowledge derives mostly from human hardware and software engineers.

It is the second point of Albus's three levels that is of most interest when assessing the success of artificial systems. It seems that we are quite capable in modelling the world and to talk about entities in it. The vulnerability of the most systems lies in the sensory processing and qualitative (not quantitative!) value judgement.

Sensory processing: perception takes place in a sensory processing system. Sensory processing algorithms integrate similarities and differences between observations and expectations over time and space to detect events and recognize objects, features and relationships in the world. Sensory data input from a variety of sensors over extended periods of time are fused into a consistent unified perception of the state of the world. Data and Information fusion is one of the hot topics in current AI-research (e.g. the International Data fusion Demonstrator project) (Keene and Perre 1990). The contribution of a VPE to sensory processing is that the user can act as an intelligent high level sensor using the sensor information as presented in the VE, either to sense things that machines are not yet capable of, or to recognize gaps in the sensor distribution.

Qualitative value judgement: this is the bottleneck in the applicability of current AI systems since they discriminate between what is good and bad, rewarding and punishing, important and trivial, certain and improbable

by means of quantitative measures. Value judgement is needed in both the evaluation of the observed state of the world and of the predicted state resulting from planned activities.

It is true that quantitative judgement tends to shift towards the direction of qualitative judgement by using: probabilities of correctness, believability and uncertainty parameters. But the judgement still is made on the basis of quantities. As every professional chess player can assure you, the attractiveness or repulsiveness of a chess move is not judged by some numeric calculation but merely by the vague notion of quality.

One of the problems with understanding quality is that one needs a qualitative judgement of the literature dealing with this notion, e.g. (Pirsig 1974) and (Pirsig 1991). But it has clearly something to do with experience, some quantitative measures, and the current state of mind in which factors like: confidence, uncertainty, pleasure, pain, success observed, success expected, hope, frustration, despair, fear, etc. play an important role.

Quality is irrational in the way one can not assign metrics to it. But in decision making it often behaves as the final touch after the rational decision making where quantities form the basis. It is exactly there where VPE's can enhance the intelligent behaviour of artificial decision making processes by using the human qualitative reasoning capabilities. In other words AI may be used to determine alternative courses of action which can be presented to user. AI can even add its own judgement to each of the alternatives.

TRAINING VS. REALITY

Ideal command & control systems should be their own training devices. The only real difference is that the system is not coupled to the real world but uses a simulator for sensor data. As a good C³I-system provides views on different echelon levels (i.e. management &

operator) these views can be used by trainer and trainee. Again VPE's offer an excellent opportunity for trainer and trainees to participate in the same problem in different roles.

Besides Training and command & control, VPE can offer another important feature namely: briefing and debriefing via visualization and analysis of tactics and forces development, what-if analysis and (fast forward) play back of recorded sensor data including focusing on specific situations.

VALIDITY OF CONCEPTS

Another intriguing possibility of VPE's is the capability of concept validation. When searching for solutions one is restricted to a solution space which is defined by the concepts one defines as valid. In other words a valid solution is only valid if the system which has to execute that solution accepts it.

Sometimes it can be very hard to find a valid solution within those boundaries. In fact the solution may very well be to alter the system in turn to find a solution in the newly defined solution space. For example, doctrine may prescribe the use of tank regiments and armoured infantry but after examining the theatre of operations it may become clear that the use of helicopters would be very nice. The use of helicopters however is not captured in the doctrine. A VPE may be used then to develop these new doctrines (e.g. use of rapid-reaction forces) by stepping outside the standard solution space.

CONCLUSIONS

The increasing volume, diversity and complexity of the available data, partially due to the application of the information technology pushes the limitation of comprehension and absorption of human decision takers. This coupled to the need of rapid response leads to human decision makers shifting from cogni-

tive decision making to more and more instinctive decision making. It is stated that VPE's can buy us the time to shift back to a cognition. Furthermore they can enhance command and control by supporting human qualitative reasoning. Virtual environments however have to grow in maturity to be able to create VPE's both in terms of hardware requirements (which we believe will be solved in the near future) and the available metaphors in the VE (to extract and manage information within the VE). Research from both the VE- and AI communities should focus on the latter.

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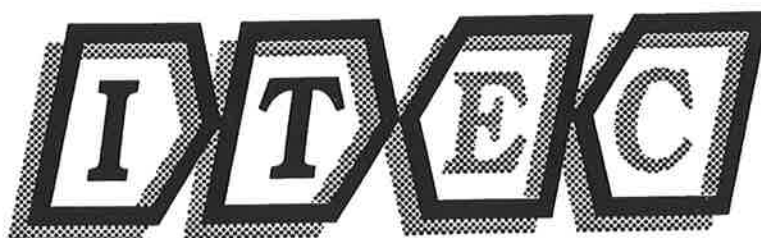
BIOGRAPHY

Cornelis W. d'Huy was born in 1967. He received the B.S. degree in computer science from college of Advanced Technology in The Hague and the M.S. degree in computer science from the "Vrije" university in Amsterdam. He is with the Physics and Electronics Labora-

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International Training Equipment Conference and Exhibition Proceedings



**The Netherlands Congress Centre
The Hague, The Netherlands**

April 26–28, 1994