Complexity is pervasive in many modern military systems and in the environment in which they must operate. Generally, complex systems are composed of interconnected parts that, when combined together, exhibit behaviours that are difficult to predict and control. The complexity of the environment is also an important issue. The understanding of complex situations (CSs), which comprise most military systems and their environment, is becoming increasingly important for the military community.

Many domains such as simulation, information visualization and knowledge elicitation, are already tackling the complexity issue. The IMAGE suite integrates various tools from these domains in order to improve, accelerate and share the comprehension of CSs. A distinctive approach of IMAGE consists in its iterative nature, which aims at incrementally refining a comprehension model through quick hypothesis testing and advanced data visualization. This paper presents its simulation tool called Multichronia.

Multichronia is a generic visual interactive simulation (VIS) exploration framework that combines concepts of VIS, data farming and computational steering. It provides users with the visual history of an informal simulation experiment. It also includes the multichronic tree concept that offers mechanisms for interacting with and visualizing the status of multiple simulations running simultaneously. Multichronia also includes an interactive “design of experiment” (DOE) module that implements sampling, optimisation and interpolation functionalities for complementing VIS tools. As a result, the exploration of the parameter space is facilitated. CSs can therefore be studied under many operating conditions. Multichronia’s implementation is sufficiently generic so that it can be adapted to many existing simulation tools.

The IMAGE approach has been implemented successfully and its efficiency to improve the understanding of CSs has been measured via an experimental cognitive psychology approach with human subjects. During this experiment, users exploited the IMAGE suite of tools in order to understand a convoy scenario that exhibits many complex behaviours. This paper presents the role that Multichronia plays in this experiment and how it could have facilitated the understanding of CSs.
IMAGE - Interactive Simulation To Increase Complex System Understanding

Dr. François Bernier
Dr. D. Laurendeau, Dr. F. Rioux, F.M. De Rainville, M. Lizotte

MSG-082 Modelling and Simulation of Complex Systems
in Public Safety and Military Operations

5 May 2010
Outline

- Complex situation
- IMAGE Project
- Simulation and complexity
- Multichronia
- Demonstration
- Experimental validation
- Conclusion
Complexity

At the constituent level
- Many linked, entangled elements
- No centralized command
- Many scales in time, size and space

At the behaviour level
- Exchange with their environment
- Adaptation (self-organisation) and evolution
- Emergence
- Non-linear, feedback loops

Consequences
- Resilience, self-repair
- Operate at the edge-of-chaos
- Hard to predict and control

Source: Advanced Technology Assessment
Complex Situation

Complexity is an important aspect of current and future defence operations (coalition, diverse issues, diverse power and influence, public opinion)

- Taliban
- UNAMA
- CIDA
- MSF
- GoIRA
- ISAF

**Pillar 1**
- Security

**Pillar 2**
- Governance
- Rule of Law
- Human Rights

**Pillar 3**
- Social Development

**Sector 1**
- Security

**Sector 2**
- Governance
- Rule of Law and Human Rights

**Sector 3**
- Infrastructure
- Natural Resources

**Sector 4**
- Health

**Sector 5**
- Agriculture
- Rural

**Sector 6**
- Economic Governance
- Private Sector Development

Gender Equity (cross-cutting theme 1)

**Counter Narcotics**

**Regional Cooperation**

**Anti-Corruption**

**Environment**

**CF**: Canadian Forces
**MSF**: “Médecins sans frontières”
**UNAMA**: United Nations Assistance Mission in Afghanistan
**CIDA**: Canadian International Development Agency
**GoIRA**: Government of the Islamic Republic of Afghanistan
**ISAF**: International Security Assistance Force Afghanistan

IMAGE

- IMAGE is a technology investment fund project initiated in 2006
- Objective: Identify tools and process to improve/accelerate understanding of complex situations

Producing and sharing a common vocabulary and conceptual graphs

Many components work in synergy to produce a common representation

Explore the dataset to make sense of it

Moving in the space of variables and walking along the simulation

Transforming conceptual graphs into executable models
Simulation Approaches Related to Complexity

- Less interactive
  - Design of experiment strategies
  - Data farming
  - Agent based distillation
  - Massive scenarios generation
  - Meta-modeling
- More interactive
  - Visual interactive simulation
  - Computational steering
  - Multichronia
Computational Steering

« Researchers want to steer the calculus in real-time; They want to change parameters [...] and see the effect immediately. They want to drive the scientific discovery process. They want to interact with their data. » (McCormink et al., 1987)

- Real time interaction
- Scientific calculus
- Massively parallel computation
- Aims at understanding
Multichronia Functionalities

- Graphical representation of the simulation runs
- Independent of the simulation tool and the scenario
- Interactive control of the simulation
- Interactive design of experiments
- Provide an history of the exploration strategy
- Concentrate on the temporal aspects
- Facilitate the hypothesis tests
Multichronic Tree

A. Beginning of simulation
B. End of simulation
C. Axis of reference
D. Parameter modification
E. Diverging point
F. Alternate simulation
G. Selected simulation
H. Location on the axis
I. Continuous parameter change
J. Design of experiment

R & D pour la défense Canada • Defence R&D Canada
Interactive Design of Experiment (iDoE)

Automation tools that maintain the interactivity with the user while providing visual feedback of the simulation progress

- Calculus distribution
- Sampling, optimization and interpolation tools
  - Ex: Scrambled Halton, nearly orthogonal latin hypercube
A Case Study – Coevolutionary Convoy Mission

- We developed the simplest (but still complex) deterministic complex situation. It is composed of two levels of complexity:
  - Tactical (less complex): A convoy must defend against IED and RPG attacks → 726 outcomes
  - SOP (more complex): The population allegiance influences the convoy mission. The convoy and the insurgents evolve (coevolution) → $10^{233}$ outcomes
Eye-Sys

Multichronia
Experimental Validation

- 36 analyst/scientists participated in an experiment (564 hours)
- Each participants was asked to understand a complex situation using one of the configuration: baseline, IMAGE desktop, IMAGE CAVE
- IMAGE desktop example

<table>
<thead>
<tr>
<th>Tactical (less complex)</th>
<th>SOP (more complex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMAGE Desktop 75 minutes</td>
<td>Questionnaire 15 minutes</td>
</tr>
<tr>
<td>Questionnaire 15 minutes</td>
<td>IMAGE Desktop 75 minutes</td>
</tr>
<tr>
<td>Questionnaire 15 minutes</td>
<td>X 2</td>
</tr>
</tbody>
</table>

R & D pour la défense Canada • Defence R&D Canada
Experimental Results - Performance

Participants were asked to find the best strategy to optimise the convoy integrity over 100 evolutions. This value is a measure of their comprehension. We calculated the distribution of each group.
Experimental Results – Descriptive Statistics

Participants actions in Multichronia were logged during the experiment. Baseline used a lighter version of Multichronia (no divergence point, one branch at a time, etc → a simple simulation tool).

In summary

- Multichronia is used 27% of the time
- The average number of simulation generated is the same (light vs. full)
Participants generated many simulations to answer the questions. Many of these simulations are better answers than those given by the participant. We call them missed solutions in simulated runs (MSSR) fallaciousness.
Conclusion

- IMAGE improves the understanding of complex situations
- The experiment continues with 36 more candidates
- The simulation tool (Multichronia) is extensively exploited
- Correlations between performance and tool usage are not common
- The task analysis is providing some answers
- Many other interesting features have been identified
  - More interactive interface (ex: cut & paste, move)
  - More integrated iDoE
  - More functionalities