Simulation Technologies

Thoughts and Pointers

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Need for DARPA Investment?

• Assertion:
  – Much of the simulation technologies in use in the virtual and constructive simulation communities today is a result of DARPA investment over 20 years ago

• Question:
  – Where is investment needed today to create the simulation capabilities for the next generation of soldiers?
Use of Simulations to Support Operations

• Accepted functions:
  – Mission planning and COA development and analysis
  – Mission rehearsal

• Something new:
  – Use of simulation to support ongoing operations
  – Predict future states of battle
  – Predict the direction the battle is headed
  – Support rapid COA development

• This notion has the support of PEO C3T, PM Battle Command, TPIO Battle Command, and agencies within USAF.
Deep Green is NOT an Approved DARPA Project
The Challenge

- **Anticipatory Planning**: “You know you’re going to re-plan anyway, so why not do it ahead of time?”
- **Adaptive Execution**: “Commit to plans of action at the last possible moment to maintain flexibility and initiative.”
- **Expert Mission Execution**: “An expert pool player is the person who can set up his second and third shot. This system must help the commander understand how his decisions affect the second and third ‘shots.’”

### Why?

- Combat operations in the contemporary operating environment are characterized by “rapid changes in everything, even the mission.” MAJ Todd Strickland, Canadian Army, upon his return from Afghanistan.
- We don’t have systems that help us manage this level of uncertainty.

Compress the time needed to make decisions and improve the quality of the decisions.

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**New Battle Command Paradigm!**

• Continuously monitor the current battle
• Predict possible future states
• Use information not available during a “planning phase” to focus *in situ* planning efforts
• Proactively assist in creating options for the commander – *well ahead of the current fight!*

When the plan goes awry – or unforeseen opportunities present themselves – Deep Green has assisted in the creation of options for the commander – *before they are needed.*

Today, when the plan goes awry, we go into a *reactive* mode, in which we create courses of action, analyze them, and then choose.

An industrial-age process.

An information-age process!
Lean Forward Headquarters

• If we assume large, secure pipes, we can move much of the analysis capability on our command posts to the “rear”

You see space for about 15 decision makers, but for each work station you see behind this wall are 2 to 5 other people and workstations doing the analysis to feed information to the decision makers!
Merging Disparate M&S “Domains” (slide 1 of 5)

Take Simulations to the Fight!

The user should not be able to tell whether he’s fighting a real battle or conducting training.

Two major thrust areas:

- Merge battle command and training systems into one, rather than kludging them together as an afterthought
- Make simulation systems more accessible to the warfighter

Battle Command Systems = Training Systems

Available Anywhere

User Modifiable

Simulation System

Warfighter Accessible Simulations

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We need a single synthetic environment that supports different, simultaneous views, some “constructive,” some “virtual,” and others.
Merging Disparate M&S “Domains” (slide 3 of 5)
Training = Analysis = Experimentation

• The distinction between simulations for training and simulations for analysis and experimentation needs to go away.
  – We need to be able to seamlessly use simulations for tactics and doctrine exploration, training, mission rehearsal, COA development, and analysis of future combat systems
  – “Good enough for training” is a bad expression
    • If we take simulations to war, we need to rethink the definition of “good enough”
Merging Disparate M&S “Domains” (slide 4 of 5)

Merging “Simulations” and “Games”

- Must leverage commercial *technologies*, but we shouldn’t rush to use off-the-shelf simulation *products* just because they are immersive and pretty
  - What is under the hood?
  - What technologies are relevant to military use cases?

Leverage *all* available technologies to create capabilities we don’t have today, such as
- the ability to gain insights into how the enemy might react to our TTPs,
- seamless transition between levels of abstraction,
- laboratory to test behavior theories,
- 24/7 training capability with reduced overhead.
Merging Disparate M&S “Domains” (slide 5 of 5)
Seamless Integration of “Live” with Synthetic

- We need technologies to merge the real and synthetic worlds
  - Reduce the number of OPFOR
  - Present soldiers with weapons effects (e.g., tracers, splashes, impacts) and other things not possible with the current generation of systems.
Needed Investment Areas
(1 of 3)

• New classes of algorithms are needed
  – Multi-resolutions algorithms are needed to reduce or eliminate the need for agg/dis-agg

• Better, verifiable and validatable, cultural models to model the background “clutter” – populations, not individuals or small groups
  – Example: If you want to model a city (the people who go to work, take their kids to day care, etc.) in a verifiable and validatable – not just plausible – way, can this be done at multiple levels of resolution?
  – If so, what are the dials I could adjust to make “Dial a City” look like Mexico City rather than Kuwait City, what would those dials be?
  – If I adjusted those dials, how would I know the resultant city simulation is correct, not just plausible
Needed Investment Areas  
(2 of 3)

• There is a need to build simulations that are themselves learning agents
  – Able to compare their outcomes with actual results, assign “blame,” and adjust parameters in a semi-automated or automated way

• Qualitative “physics”
  – More natural, more human reasoning about the battlespace
  – Combining this “new” notion of qualitative simulation of the battle with the more traditional quantitative methods
**Technical Challenge: Learning**

- Making the system better over time
- Intelligently tailoring the system to the user

User Modeling technologies to tailor the system to the users’ information needs

Become better at computing metrics associated with possible futures in state-space graph.

Hybrid learning technologies to become better at creating and choosing courses of action for analysis.

Bootstrap Learning could be folded into Deep Green later.

Learn to better predict enemy tactics from record of previous experiences.

Use *learning* and control theory to improve predictive accuracy of tools.

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Needed Investment Areas
(3 of 3)

• New technologies for verification and validation are needed
  – A collection of validated components does not make a validated system
  – A collection of verified components does not make a verified system
  – Cannot exhaustively test – simulations are too complex
  – Cannot randomly sample – too hit and miss
  – Cannot apply algorithmic proofs of correctness
  – Need better ways to update the data that drives our simulations
  – Need better ways to create behaviors that drive our simulations

• Simulations need to become more accessible to soldiers
  – Easier to manage and use
  – Easier to modify and tailor

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Questions?
How it works...

1. From some state, the Commander and staff generate options for all sides.

2. Deep Green uses simulations predict some number of qualitatively-different possible futures.

3. The predictions about the various options are presented to the commander, including assessments of logistic and ISR impacts.

4. The Commander chooses an initial options to pursue.

5. Deep Green attaches monitors to them when they are predicted, but well before they occur!

6. Information is received from the current, ongoing operation.

7. As a result, the monitors predict increased likelihood that the red (bad) and light green (pretty good) futures will occur and decreased likelihood that the dark green (good) node will occur.

Note that the more likely futures have no options for the commander if it occurs.

Commanders and staffs generate options if the red or light green nodes occur.

A really important difference is that with Deep Green commanders are choosing a possible future and a path to it, not just a static course of action sketch.

Time

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How it works (cont.) ...

Deep Green simulations predict some number of qualitatively-different possible futures from the red and light green states.

Information is received from the current, ongoing operation that indicates:
- The operation is likely in this state
- The red and light green futures are becoming more likely
- The dark green state is very unlikely

Large portions of the graph are pruned.

The commander has options if the enemy is successful and pulling the operation into the red node or if he is successful at pulling the operation to the light green node.

The commander and staff generate options at these nodes as Deep Green receives information that they are becoming more likely

This process continues indefinitely.

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The Original Vision of CPoF

Deep Green works to achieve the unfulfilled, original vision of CPoF in these areas.

These were good ideas in 2002. They remain good ideas.

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Deep Green Approach

Focus efforts along the projected trajectory of the *actual operation*

Present pre-analyzed options to the commander without going into a reactive mode

Prune branches that become unlikely

Add only qualitatively different, representative, possible futures to graph

Evaluation of states is based on three metrics: value (utility), flexibility (options), and likelihood.

- Non-deterministic Markov Decision Processes and Markov Logic to manage branch *recommendations*
- Continuous Time Bayesian Networks to predict where the battle is heading
Players of a commercial game select their “promotion tracks” (e.g., political, military, social, or economic power).

Players represent competing sectarian leaders, political figures, etc. in the nation-building game.

Tools to allow players to author their own experiences, technologies, bots, etc.

MMOG players are both playing the game and are part of the synthetic space.

Dial a Region

- Provides Background “Non-Player Characters”
- Dials allow behavior of the city or region to be culturally relevant and validatably correct within some tolerance

Simulation Engine (WebSAF)

- Manages physical, cultural, economic, and social interactions
- Some combination of MMOG and military SAF technologies

Terrain and Environment Services (ERC)

Communications Services

Something Like Google Earth

SAF Terrain Services

Military Live, Virtual, and Constructive models can “jack into” WebSAF to conduct training, analysis, experimentation, etc., 24/7.

Using the Synthetic Space as a behavior theory “laboratory” provide improvements to currently available cultural models

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