Applications of Dynamic Systems Theory to Effects-Based Operations and Adversarial Modeling

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• Introduction
  • EBO & System-on-System Engagements
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• Formal Model
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• Discussion
System-On-System Engagement: Objectives

• To better understand, and subsequently model the vast number of interactions between entities in the battlespace.

• To produce a theoretical framework able to capture those interactions, bridging the realms of the physical (environment) and the cognitive (agent).

• To predict unintended consequences of action (both bad and good), and learning stimulus-response patterns of agents for exploitation (PSYOPS).

• To better understand organization in large-scale systems in order to more effectively disrupt our enemies while reinforcing our own organizations.
Effects-Based Operations

Leadership
Transformation
Transportation
Resources
Forces
Military entities are not always directly responsible for the decisions made in the battlespace. Much larger picture to be considered, and potentially influenced.
Why is Systems-Level Modeling So Important?

Broader options in conflict. Avoidance of casualties. Effects propagate throughout the system.
Why is Systems-Level Modeling So Important?

Physical Effects... Isolate and destroy.
Why is Systems-Level Modeling So Important?


Misinformation

Field Officers

Commander

Tank Operator

Tank
New Challenges

• Can impacting one agent’s beliefs have an effect on other agents who are “close” to him?
• Can this be modeled using a “system-of-systems” model?
• What kind of mathematical locutions shall we resort to?
• What does all of this buy us in the end?
Lexicon

- Information Parameters: describe belief and ethical concern functions.
- Alphabet: collection of information parameters for an organization.
- Agents: specified by an alphabet.
- Organization: Collection of agents sharing the same alphabet.
Interaction Space

- “Distance” between two agents belief in a certain proposition.
- Agents defined in this space are assumed to have knowledge of all beliefs which define the dimensionality.
- Modeled after the Kullback-Leibler information-theoretic metric.

\[ \lambda = \alpha_{ibn} \log \left( \frac{\alpha_{ibn}}{\alpha_{jbn}} \right) \]
Defining Interactions

Interactions defined as multiplicative relation.

Normalized by ethical consideration, and by “closeness” between agents beliefs.

Interaction wrt an individual belief is shown on the bottom left.
• First-order differential equation describing the change in belief with respect to other beliefs.

\[
\Delta(\alpha_{ibn}) = \frac{\partial I_{ij}}{\partial t}(\alpha_{ibn})
\]

• Solution concept is a set of these equations.

\[
\begin{align*}
\Delta(\alpha_{ib1}) &= \frac{\partial I_{ij}}{\partial t}(\alpha_{ib1}) \\
\Delta(\alpha_{ibp}) &= \frac{\partial I_{im}}{\partial t}(\alpha_{ibp})
\end{align*}
\]

• Very similar to the infamous “three-body problem” in physics.
Simple a1/a2 Interaction

- Two beliefs: alpha(b1) and alpha(b2).
- Interaction only affects agent 1 (alpha 1 & 2 held constant for agent 2).
- Model the change in alphas with time as two first-order diffeq’s.

\[
\Delta \alpha_1 = \frac{b_1(t)}{b_1 \cdot \ln \left( \frac{a_1(t)}{b_1(t)} \right)} + \frac{b_2(t)a_1(t)}{b_2 \cdot \ln \left( \frac{a_2(t)}{b_2(t)} \cdot a_2(t) \right)}
\]

\[
\Delta \alpha_2 = \frac{b_2(t)}{a_2 \cdot \ln \left( \frac{a_2(t)}{b_2(t)} \right)} + \frac{b_1(t)a_2(t)}{b_1 \cdot \ln \left( \frac{a_1(t)}{b_1(t)} \cdot a_1(t) \right)}
\]
Some Preliminary Results

• This plot shows the change in alphas given different ethical parameters for each agent.

• The boxed region represents the most unstable regions (where equilibrium could be most easily broken).
Some Preliminary Results

• This plot shows the changes in alpha given similar ethical parameters for each agent.

• In general, much more stable.
Discussion

• Higher-order interactions are easy to model through supervenience, but makes the equations significantly more complex.
• Successfully modeled “system-of-systems” cascading belief revision for agent organizations.
• As soon as computing power catches up, and assuming our intelligence is reasonably accurate, we hope to be able to:
  – Isolate important figures in the organization by exploiting “closeness” parameters.
  – Influence those figures, and have a reasonable idea of how organizational dynamics may be altered.
The End

Questions?