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Team 6: Utility of Distillation Modeling for Countering IEDs

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INTRODUCTION

This Team participated in an ongoing study to examine the utility of distillation modeling in the Counter-IED (Improvised Explosive Devices) fight. In September, as part of that study, an Agent-Based Modeling workshop examining hard questions in the Counter-IED battle identified a set of problems that can be addressed by agent-based models and related methods such as data farming. The questions covered C-IED needs in various categories including: insurgent network evolution and adaptation; red-teaming and technical gaming; C-IED initiative assessment; and recidivism. This team reviewed the output from the September workshop on agent-based modeling, extracted problems that can feasibly be addressed in a rapid prototyping process, and began to design a software experiment that will address a selected problem.

We begin with some background information on our overall question, lay out our objectives and the effort for this IDFW 19 work, and conclude with a way ahead for follow-on work.

Background

In June 2009, JIEDDO began a study to examine the applicability and utility of agent-based modeling (ABM) and related techniques to its mission:

"The Joint Improvised Explosive Device Defeat Organization shall focus (lead, advocate, coordinate) all Department of Defense actions in support of Combatant Commanders' and their respective Joint Task Forces' efforts to defeat improvised explosive devices as weapons of strategic influence." JIEDDO Mission Statement, DoD Directive 2000.19E, February 14, 2006

The goal for this ongoing study is to address the following two questions:

- "Does ABM and related capabilities have applicability to JIEDDO questions and problems?"
- "How should ABM and related capabilities be applied to JIEDDO questions and problems?"

The answers to both "Does?" and "How?" may be different for different classes of questions or specific questions. As a result, part of the purpose of the ABM study is to provide analysts straightforward procedures to determine when ABMs might be applicable and what tools and experimental design is appropriate for their questions.

The ABM study encompasses two components or phases: 1) an educational component to gain an internal understanding and capability in these processes, and 2) an

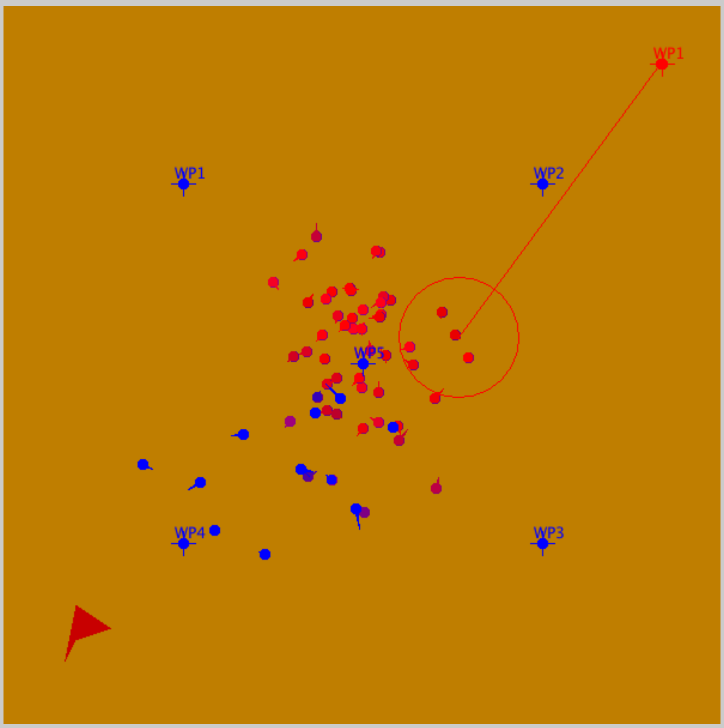

Figure 1 – Pythagoras "Peace" Scenario Spatial View

analytic component to apply these processes to questions of tactical, operational, and strategic interest to JIEDDO.

As one activity of Phase I or the Education Phase, an ABM Workshop was held in September, which focused on a set of JIEDDO questions and IED related problems and provided an opportunity for JIEDDO partners to give an overview of their current and planned work. The workshop consisted of five teams, producing 24 task plans that described the potential use of ABMs and other techniques to address relevant questions. Task plans included topics such as:

- Self-organizing graphs of data relationships
- Indirect Network Attack
- Identifying Important Link Layers for Impacting the Insurgent Networks in Afghanistan
- Define "High Value Individual"
- Emergence of an Insurgent Cell
- Insurgent Networks

The scope of related techniques of interest for addressing these study topics includes: agent-based models and modeling environments; social networking analysis tools; data farming tools; and analysis and visualization capabilities for model outputs.

As part of Phase II or the Analytic Phase of the ABM study, Team 6 at IDFW 19 began the task of selecting a subset of the questions of interest related to countering IEDs at the tactical, operational, and strategic levels and then identifying and applying appropriate ABMs and other relevant techniques to address those questions.

Objectives

Team 6's objectives for IDFW 19 were to:

- Examine Task Plans generated by the JIEDDO ABM Workshop
- Select potential candidate(s) for follow–up study and analysis
- Analyze and detail the question(s) being addressed
- Establish requirements for:
    - Modeling environment
    - Data requirements
    - Analysis tools
- Prepare plan ahead for activity between IDFW 19 and leading up to IDFW 20

IDFW19 EFFORT

The team began by examining the 24 task plans and selected a set of potential candidates to examine in further detail. These candidates fell into the category of "Attack the Network", one of three JIEDDO primary operations in the Counter-IED battle (the other two operations are "Defeat the Device" and "Train the Force"). These candidates are hard IED questions related to attacking the network and included questions such as:

- What do insurgent networks look like? Who is in the network? Who is not?
- How do we distinguish networks that should be attacked vs. networks that should be attritted vs. networks that should be co-opted?
- Will removing specific nodes destabilize a network? What are the 2nd and 3rd order effects? What are the potential unintended consequences?

Given that a network perspective is a primary component of the questions, the team decided to start looking at network analysis and visualization tools within the context of an abstracted "insurgent" scenario in the agent-based model Pythagoras. These tools may provide insights into JIEDDO topics of interest such as "Emergence of Insurgent Cells." We started with some simple networks to understand the issues and will progress to more complexity in follow-on work.

Why networks? Networks are useful representational schemes for understanding relations and interactions between agents (in our case, individuals) and events. Types of relations between two or more agents include such things as similarity (homophily) or spatial (distance) comparisons. Interactions might include events such as sensing or shooting, or other acts between agents. A network view, by using a different representation of relational data, has the potential of discovering underlying relationships that are hidden from

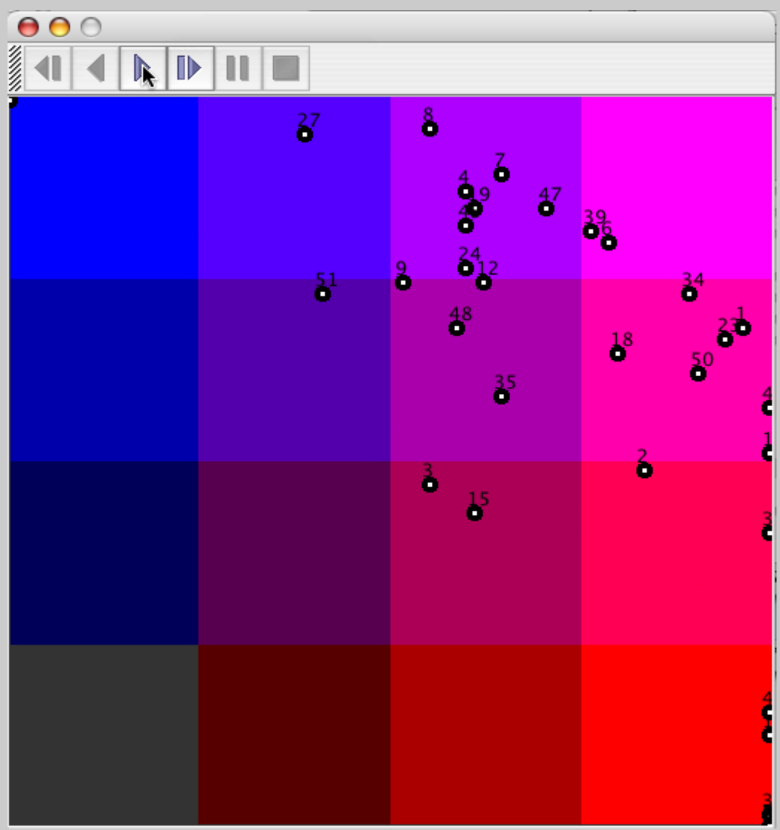

Figure 2 – "Peace" Scenario - Color Space View

other techniques, yet complements those techniques at the same time.

The next sections discuss the issue of modeling networks in an ABM, the Pythagoras scenario we used as an aid to understand network tools and analysis, and some results and surprises from our work.

Extracting Networks from ABMs

Since our ultimate goal is to understand and analyze insurgent networks, we wanted some means to model networks in an ABM implicitly and not explicitly, i.e., where the networks evolve dynamically based on agent attributes and behaviors and environmental characteristics and not fixed as input to the model. For example, both MANA and Pythagoras use a communications network to specify which agents send messages to other agents. However, those networks are fixed such that agent A cannot send a message to agent B if those links were not established as input to the model.

We then examined the use of an interaction-based network, where interactions between agents generate a dynamically evolving network. Pythagoras uses color attributes, i.e., red, green and blue (RGB) values for agents that are affected by changes in agent state, or a number of agent-agent interactions, such as shooting or communication. Pythagoras also allows the user to specify affiliation between agents by how “far” an agent is from another agent in color space, i.e., the distance (either Euclidean or Manhattan) between points based on the RGB values. The affiliations belong to four categories: Unit, Friend, Neutral and Enemy, so each agent has one of these affiliations for every other agent and these affiliations can be asymmetrical.

We next defined an affiliation network by using an RGB distance threshold such that if the RGB distance between two agents was less than the threshold, then a link was established. This network evolves over time based on agent RGB changes associated with interaction events, and was the focus of our network extraction efforts. We collected network data from a single run of a simple Pythagoras scenario, which we describe next, and visualized that data using several open-source tools.

Pythagoras “Peace” Scenario

The "Peace" scenario is provided as part of the Pythagoras distribution (we made some changes in the initial distribution of agents). The scenario is composed of a single Red Instigator, a population of 50 Purple Locals, and a small Blue force (10 agents). The Red Instigator is continually broadcasting pro-red/anti-blue messages to all the agents

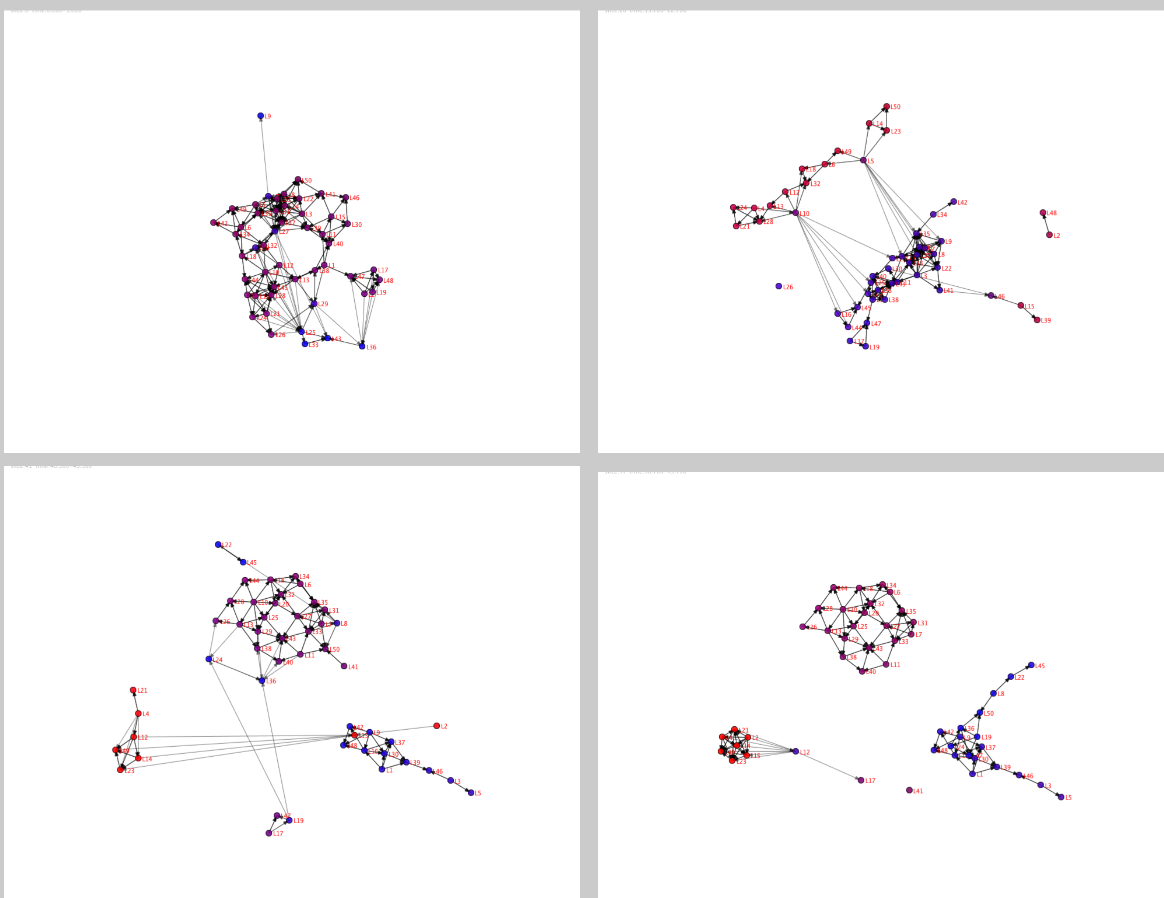

Figure 3 – “Peace” Scenario Network View

(although the messages currently have no effect on Blue), and the Blue force interacts "positively" with the Locals.

At each time step, the Red Instigator broadcasts a message that changes Purple Local agents within range of the broadcast by making them more "Red" and less "Blue". Concurrently, Blue agents move around and interact with Purple Locals within their range by making them more "Blue" and less "Red". These interactions have a random component, so that the competition between the Red and Blue messages affects each Local agent differently. A snapshot of one time step, showing a spatial view of the scenario, is depicted in Figure 1.

At each time step, we collected data representing each interaction that caused a color change of a Local agent, as well as the current color of all the Locals (because the Red and Blue agents didn't change color, our focus was on the evolution of the Local affiliation network).

In the next section, we describe two different visualizations of that data as well as some observations on how data farming might be applied to the visualization of network data, and not just for farming over input parameters of the model.

Results and Surprises

Figure 2 displays a "Color Space" view for one time step of the scenario. While not a network view, it does give a different perspective of the data, showing how each agent relates to the other agents based on their Red and Blue color attributes (Green was not used). The "closer" the agents are to other agents in this "space" indicates whether they are tied together in the network.

To derive a network view, we used the color distance and a threshold value to indicate which agents were affiliated with other agents. Figure 3 shows four affiliation networks for four separate snapshots in time. In each network, a node is a specific agent, and a link indicates that the two agents on either end of the link are within the threshold distance we specified. As the agents interact, their color changes resulting in the creation and deletion of links. And as those links evolve, other structures, such as cliques, form. Our goal is to understand the formation of these structures and how they are affected by changes in the input parameters of the model.

To display our results, we used the software package SoNIA (Social Network Image Animator - http://www.stanford.edu/group/sonia/), as well as some code we wrote during the workshop to translate Pythagoras data into a form suitable for display by SoNIA.

During our work, we encountered two surprises:

1. Extremely simple color distribution and interactions in Pythagoras lead to complex network interactions; and,
2. Data Farming over visualization/analysis parameters could provide additional insight.

WAY AHEAD

The plan for ongoing work between now and IDFW 20 and beyond will focus on modeling insurgent networks and continuing to look at network extraction and visualization tools and techniques, specifically:

1. Gain a better understanding of network analysis algorithms, animation, etc., especially as they relate to time-series or longitudinal data;
2. Expand the scenario to a more complex insurgent model, e.g., adapting a clique model previously implemented in Pythagoras;
3. Continue using Pythagoras, leveraging previous work and possibly running experiments on DOD HPC resources;
4. Examine the derivation of network statistics time-series and end-of-run MOEs as part of Data Farming analysis, optimizers, and ART (Automated Red Teaming) drivers; and
5. Examine methods of visualizing and comparing collectives of multiple networks, obtained by data farming across network parameter spaces.