Evolving Agents for Network Centric Warfare

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1. INTRODUCTION

The advances in information technology largely influence our life style in various aspects. The changes in the underlying economics, information technology, business processes and organizations are affecting the very character of war and are leading to the fundamental shift from platform-centric warfare to network centric warfare (NCW), also known as network centric operation (NCO) [1]. Since its emergence in 1983 [10], the debate between proponents and opponents is hotly continuous. The proponents suggest that networked entities may produce information superiority, which in turn dramatically increases combat power. The theory that power is increasingly derived from information sharing, knowledge sharing and command speeding up has been supported by results of recent military operational experience [4]. The advantages of NCW have been recognized as:

- Small-size networked forces can perform missions effectively at a lower cost;
- New tactics can be adopted in combat, e.g. "swarm" tactics. A larger force may be separated into several small swarms. These swarms do not need to keep communicating with each other at all time. Through networking they are aware of each other. If one swarm gets into trouble, other swarms will detect this and give help to it immediately.
- The mechanism for decision making on the battle field has changed. It is easy to get help with geographically dispersed experts with aid of networking;
- The sensor-to-shooter time is reduced. The soldiers in the field may take actions based on their own raw intelligence from sensor's displays instead of waiting for orders.

The opponents [4, 7] advocate that NCW faces many challenges. For a networked force, information overload may occur. Although the bandwidth is improving, it is still a limitation for data transmission. The most important point is that NCW has not been tested sufficiently in real wars. It is not possible to verify and better understand NCW in real engagements. Fortunately red teaming, agent-based distillation, complex system theory, network theory and other modern information technologies may help us understand NCW. Recognizing warfare as a complex adaptive system [5, 8, 9, 6] opened the doors for a number of agent-based distillation combat systems to emerge. This includes the Irreducible Semi-Autonomous Adaptive Combat (ISAAC) [5] and the Enhanced ISAAC Neural Simulation Toolkit (EINSTein) [6] from the US Marine Corps Combat Development Command, the Map Aware Non-uniform Automata (MANA) [8, 3] from New Zealand's Defence Technology Agency, the Conceptual Research Oriented Combat Agent Distillation Implemented in the Littoral Environment (CROCADILE) [2] and the Warfare Intelligent System for Dynamic Optimization of Missions (WISDOM) developed at the University of New South Wales at the Australian Defence Force Academy (UNSW@ADFA), Australia [11]. However existing agent-based distillation combat systems were developed mainly on platform centric warfare and current agent architectures, which limit their ability to test NCW.

This paper presents the features of the second version of WISDOM (WISDOM-II). WISDOM–II is re-designed and re-developed on a novel network centric multi-agent architecture (NCMAA).

2. NETWORK CENTRIC MULTI-AGENT ARCHITECTURE (NCMAA)

NCMAA is purely based on network theory. The system is designed on the concept of networks, where each operational entity in the system is either a network or a part of a network. The engine of the simulation is also designed around the concept of networks. We capitalized on the rich

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literature on network theory to develop the NCMAA and WISDOM–II.

NCMAA adopts a two–layer architecture (figure 1). The top layer, influence network based on the influence diagram, defines the relationship types and how one type of relationship influences other types. Each of these relationship types is reflected in the bottom layer by a set of agents who interact using that relationship. For example, agents that can see each other would be connected in the lower layer, and agents that can communicate with each other would also be connected in the lower layer. The influence of vision on communication would form a connection in the top layer.

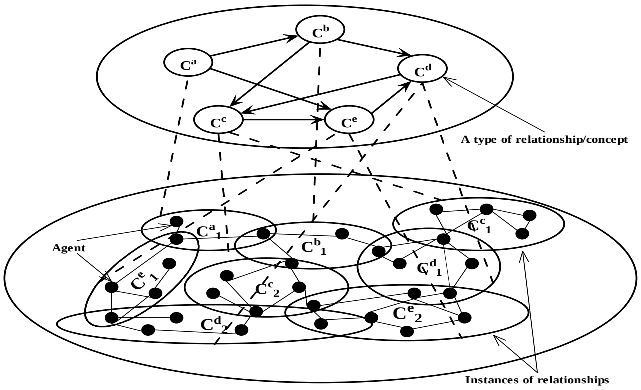

Figure 1: Two-layer architecture in NCMAA

A finite state machine is attached to each network to define the operational dynamics of the agents involved with that network. At each timestep, an agent selects and executes one of the actions that causes the network state to be transferred to another state.

Each agent in NCMAA is defined by a series of states, triggers, and actions. An agent state is defined by a series of properties which are problem specific. If an agent is in a certain state, the trigger is activated and an action is taken by the agent, which leads to a change in the agent's state.

3. WISDOM VERSION II

The design of WISDOM–II is centred on the theory of NCW. WISDOM realized and applied the core tenet of NCW - information superiority increases the power of combat dramatically - into the system. WISDOM–II emphasizes the effect of information sharing, information access, situation awareness sharing, knowledge sharing and speed of command. WISDOM-II does not only use the spirit of CAS in explaining its dynamics, but also centre its design on the fundamental concepts of network dynamics and interactions in a CAS.

Generally speaking, there are five components in WISDOM-II. The first three components are used to model the internal behavior of warfare while the last two components are two analysis tools.

- C3 component – including command, control and communication
- Sensor component – retrieving information from environment
- Engagement component – including firing and movement activities
- Visualization component – presenting various information with graphs
- Reasoning component – interpreting the results during the simulation process

Five types of networks are defined in WISDOM–II; these are the command & Control (C2), vision, communication, situation awareness, and fire networks. Four types of agents are supported in WISDOM-II: combatant agent, group leader, team leader and general commander. Agents are defined by their characteristics and personalities. Each agent has nine types of characteristics: health, skill, probability to follow command, visibility, vision, communication, movement and engagement. Initial levels of health, skill, visibility and vision are set by the user. They may be different for each agent type. The general commanders also can build plans and give orders to combat groups. Each personality parameters is defined by two values: a magnitude and a direction vector.

The movement of each agent is determined by its situation awareness and personalities. In each time step, the agent can only move to its neighbor cells based on the overall influence of all agents. A movement decision making mechanism is used. Strategic decision is made by general commander of each force based on the common operating picture (COP), which is the global view of the battle field for that force. Decision making on the force level utilizes the same environment the agents are embedded in, but on a higher resolution.

One of the most important aspect in military operation is logistics, where medical treatment system is one of the key components. The model of the artificial hospital is first introduced in WISDOM-II. Each team may have a hospital in the team base, which is defined by the number of doctors and the recovery rate. If the team has a hospital, the wounded agent will move back to the hospital for treatment. Each doctor can treat only one wounded soldier at each time step and the health of that treated soldier will be increased by the recovery rate. If all doctors are already treating existing agents, the wounded soldier will be put in the queue to wait for treatment. When the agent is fully recovered, it will move back to the battle field to the location nearby its squad leader. If its squad leader is in the hospital or it is the squad leader, it will return to the cell around the team base.

WISDOM–II collects information for each entity as well as for the interaction between entities. A large number of statistics get collected. We then feed these statistics to a reasoning engine, where a natural language reasoning is provided to the user. We also provide capabilities such as interactive simulation.

4. SCENARIO ANALYSIS

A simple scenario has been built to verify our model. Red force is a traditional force with a large number of soldiers and traditional weapons while blue force is a networked force with a small number of soldiers and advanced weapons. There are two surveillance agents in blue force, which do not have any weapon but they are invisible to red force. The scenario settings for each force are shown in table 1.

Table 1: Scenario settings

	Blue Force	Red Force
Number of Agents	11	50
Vision	9 short, 2 long	50 medium
Communication	Networked	medium range
Weapon	2 No weapon, 8 P2P 1 explosive	50 P2P

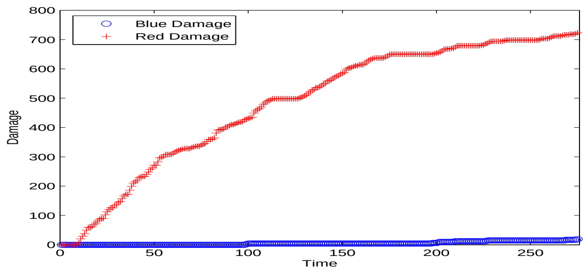

Figure 2: Damage of each force over time

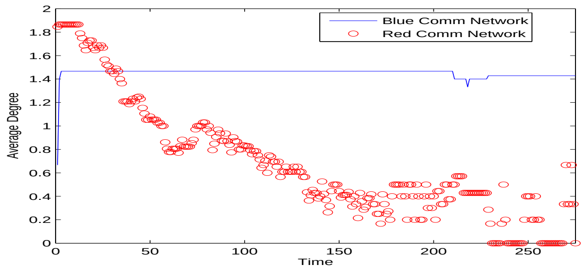

Figure 3: Average degree of blue and red communication network over time

Figure 2 presents the damage of each force over time. The damage of red force is much larger while there is much less damage of blue force during the simulation. Red force has over four times number of agents than blue force. This suggests that communication plays a very important role in combat. Two blue surveillance agents collect information and send them back through communication. Based on COP, the blue agent with powerful weapon, which is long range and explosive weapon, may then shoot their enemies. However, the red agents only have local information. They do not know where their enemy is. Therefore, they cannot win the game.

Figure 3 presents the average degree blue and red communication network over time. It supports our intuitive view above. The average degree of the blue communication network is always larger than that of the red communication from about the time step 35. This implies that the information cannot be transmitted efficiently and effectively among red force. They know much less than blue force. So they always get fired upon.

Our scenario demonstrates that fewer number of the networked blue agents can overtake a large number of the red agents. Obviously, one cannot generalize from a single run when using stochastic simulation.

Agents in WISDOM–II can evolve. We adopt two types of evolutionary environments. The first, is on the tactical level, where we evolve the low level decision making mechanisms such as movement of agents and personality parameters. The second is a co-evolution system for the strategic decision making process of the agents.

In the final poster the details of the system and the experiments are discussed along with the results we obtained through evolution for the tactical and strategic levels.

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