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Teaching Strategic Center of Gravity Analysis through Learning Agent Technologies

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"One must keep the dominant characteristics of both belligerents in mind. Out of these characteristics a certain center of gravity develops, the hub of all power and movement upon which all our energies should be directed.[1]*"*

Carl Von Clausewitz

If a combatant eliminates or influences the enemy's strategic center of gravity, the enemy will lose control of its power and resources and will eventually fall to defeat. If the combatant fails to adequately protect his own strategic center of gravity, he invites disaster.[2]

Abstract

This paper presents an overview of a new approach for learning about Center of Gravity (COG) Analysis. Through the use of Learning Agents, students at the U. S. Army War College are discovering new insights into COG analysis. They both teach and learn from an intelligent agent software program called Disciple, created in the George Mason University Learning Agents Laboratory (LALAB). This innovative application has been deployed in several courses at the Army War College. This paper will describe a multi-faceted research and development effort that synergistically integrates research in Artificial Intelligence, Center of Gravity analysis, and practical deployment of an agent into Education.

Introduction

Students at the Army War College are experiencing a new education environment while they learn about Center of Gravity analysis. Through the use of Learning Agents, these future strategic leaders discover their reasoning process for the identification and selection of strategic and operational COG candidates. How experts find this center of gravity is the purpose of our research at the Army War College. The George Mason

University Learning Agents Laboratory (LALAB) and the US Army War College Center for Strategic Leadership (CSL) are conducting joint basic and experimental research on the development of instructable agents for strategic center of gravity (COG) analysis, with support from Defense Advanced Research Projects Agency (DARPA), Air Force Office of Scientific Research (AFOSR) and the US Army.

This joint research has multiple complementary objectives. One objective is to develop the technology that will enable subject matter experts without computer science or artificial intelligence experience to develop instructable agents that incorporate their problem solving expertise. These agents could then be used as intelligent decision-making assistants, or as tutoring systems. A second objective is to apply this technology to the problem of center of gravity determination, analysis and application. This objective aims at testing the developed technology and also at developing a practical methodology and tool for solving the COG problem. Finally, the educational objective is to enhance the learning process of senior military officers through the use of intelligent agent technology. In addition, we want to use the results of this research in future courses at the US Army War College, providing the students hands-on experience with the latest knowledge-based tools.

Disciple – The Learning Agent

The Learning Agents Laboratory (http://lalab.gmu.edu) has elaborated a theory and methodology, called Disciple, for the development of agents by subject matter experts, with limited assistance from computer scientists or knowledge engineers[3]. The Disciple approach relies on a powerful learning agent shell that can be trained to solve problems by a subject matter expert, requiring only limited assistance from a knowledge engineer. The subject matter expert interacts directly with a Disciple agent, to teach it to

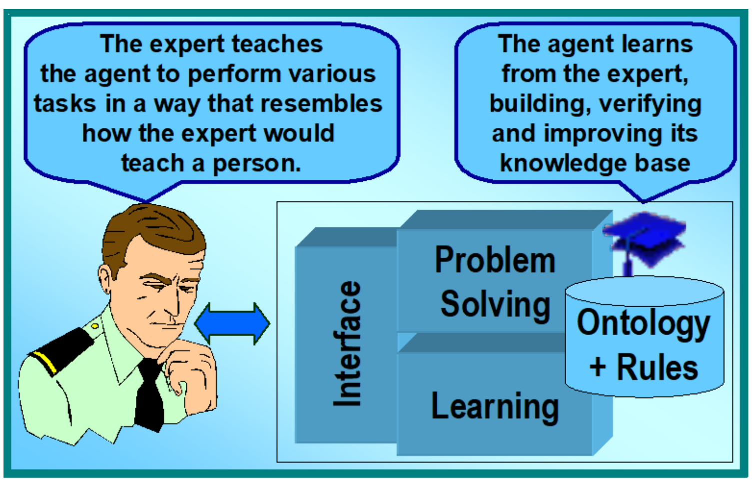

Figure 1: Expert - Disciple interaction

solve problems, in a way that is similar to how the expert would teach a human apprentice, by giving the agent examples and explanations as well as by supervising and correcting its behavior (see Figure 1). The agent learns from the expert by using a multistrategy learning method that integrates several complementary learning strategies, including learning from examples, learning from explanations, and learning by analogy. As a result of this interaction, the agent develops its knowledge base to incorporate the problem solving expertise of the human expert.

The Center of Gravity Problem

Military literature distinguishes between three levels of conflicts: a strategic level focusing on winning wars, an operational level focusing on winning campaigns, and a tactical level focusing on winning battles.[4,5] One of the most difficult problems that senior military leaders face at the strategic level is the determination and analysis of the center of gravity for friendly and opposing forces. Originally introduced by Clausewitz in his classical work "On War" (1832), the center of gravity is now understood as representing "…those characteristics, capabilities, or localities from which a military force derives its freedom of action, physical strength, or will to fight".[6] If a combatant eliminates or influences the enemy's strategic center of gravity, then the enemy will lose control of its power and resources and will eventually be defeated. Similarly, if the combatant does not adequately protect his own strategic center of gravity, he will be defeated.[7]

Correctly identifying the centers of gravity of the opposing forces is of highest importance in any conflict. Therefore, in the education of strategic leaders at all the senior military service colleges there is great emphasis on the determination and analysis of the centers of gravity. In spite of the apparently simple definition of the COG concept, even the experts have great difficulties in applying it. COG determination requires a wide range of background knowledge, not only from the military domain, but also from the economic, geographic, political, demographic, historic, international, and other domains. In addition, the situation, the adversaries involved, their goals, and their capabilities can vary extensively from one scenario to another. When performing this analysis, experts rely on their own professional experience and intuitions, without following a rigorous approach.

Recognizing these difficulties, the Center for Strategic Leadership of the US Army War College started an effort in 1993 to elicit and formalize the knowledge of a number of experts in center of gravity. This research produced the COG monograph, "Center of Gravity: Determination, Analysis, and Application" (see Figure 2.). This publication was the result of a two-year study by senior "experts" and case studies performed by Army War College students from all Services. Also produced by this study was a procedural model to conduct COG analysis in three phases: 1) Situation Analysis; 2) COG Determination and Analysis; and 3) COG Application.[8] This COG research was at the basis of the application of the Disciple approach to the center of gravity problem, leading to the development of the Disciple-RKF/COG learning agent. Disciple-RKF/COG incorporates a general object ontology[9] that consists of a hierarchical description of the concepts from the COG domain, such as, opposing force, alliance, coalition, types of governing bodies, etc.[10] Using this ontology as a generalization hierarchy for learning, Disciple can be trained by a military expert to identify center of gravity candidates for various military scenarios.[11]

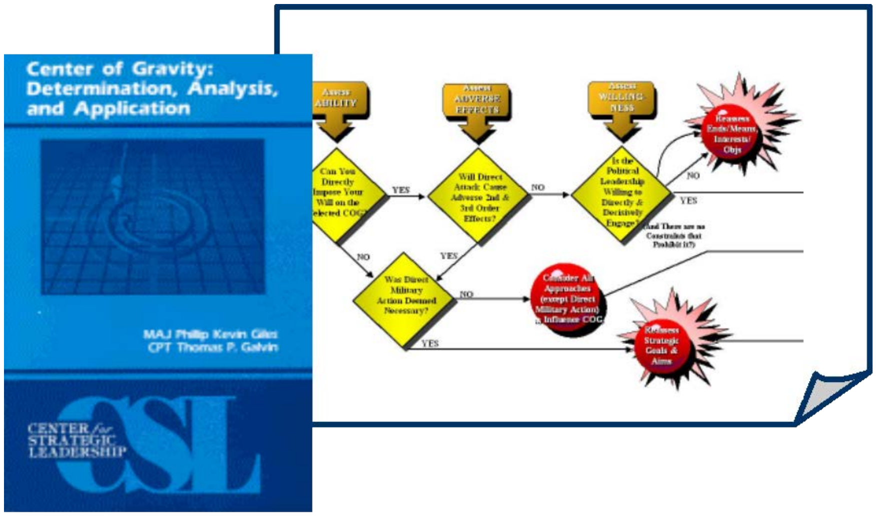

Figure 2: CSL monograph and procedural model on center of gravity

In The Classroom

During the Academic Years 2001 and 2002, Disciple-RKF/COG was used in a sequence of two courses at the U.S. Army War College: Case Studies in Center of Gravity Analysis (COG), and Military Applications of Artificial Intelligence (MAAI). In the first course, the students used Disciple to develop the following case studies in center of gravity analysis: Malaya 1941-42, Leyte 1944, Inchon 1950, Vietnam 1968-75, Grenada 1983, Okinawa 1945, Korea 1951, Falklands 1982, Panama 1989, Somalia 1992-94, and Sicily 1943. Each student interacted with the Scenario Elicitation module of Disciple, being guided by Disciple to describe the relevant aspects of his or her scenario. From this interaction Disciple generated a report in natural language containing a description and an analysis of the scenario. In addition to this report, Disciple also developed an object ontology that constitutes a formal representation of the scenario. At the end of the course, the students completed a questionnaire on their perception of Disciple. An important conclusion from their answers was that, on a scale from strongly disagree to strongly agree, 8 out of 10 experts agreed that the scenario elicitation module is easy to learn and easy to use.

During the Military Applications of Artificial Intelligence course the students used an extended version of Disciple for two purposes: 1) to learn about basic areas of Artificial Intelligence, such as knowledge representation, problem solving, knowledge acquisition and learning, and 2) to develop intelligent agents for the identification of strategic center of gravity candidates (as their class project). The students were organized into five two-student teams. Each team used Disciple to develop an intelligent agent for COG identification, based on a different strategic scenario. These scenarios, carried forward from the Case Studies in Center of Gravity Analysis course, were the following: Leyte 1944, Inchon 1950, Falklands 1982, Grenada 1983, Panama 1989. Four of the five teams included a student that has previously taken the COG course and was therefore continuing to use the scenario from the earlier course. In contrast to the COG courses, in the MAAI course the students used all the modules of Disciple, as part of their class projects: the scenario elicitation module, the domain modeling module, the task formalization module, the rule learning module, the rule refinement module and the problem solving module. Each team succeeded to train a personal Disciple agent to identify strategic center of gravity candidates based on the team's scenario.

The last two three-hour sessions of the Military Applications of Artificial Intelligence course consisted of a controlled experiment. The experiment was videotaped to ensure the conditions from the earlier class project work were maintained. Each of the five teams received a version of Disciple with a knowledge base containing a generic object ontology but no specific knowledge, tasks, or rules. The teams also received a 7-page report describing a new scenario: the US planned invasion of the island of Okinawa in 1945. After studying the scenario, each team went through all the phases of agent training: scenario specification, modeling, task formalization, rule learning, rule refinement, and autonomous problem solving. After each phase, a knowledge engineer verified the results of each team and the teams under the supervision of the knowledge engineer made any necessary corrections. At the end of the experiment each team succeeded in teaching its Disciple agent to identify several center of gravity candidates. The developed knowledge bases were correct enough to also propose reasonable center of gravity candidates for new scenarios.

At the end of this experiment the students completed a detailed questionnaire containing questions about the main components of Disciple. One of the most significant results was that 7 out of the 10 experts agreed, 1 expert strongly agreed and 2 experts were neutral with respect to the statement: "I think that a subject matter expert can use Disciple to build an agent, with limited assistance from a knowledge engineer." We consider this experiment as being a very significant success. Indeed, to our knowledge, this is the first time that subject matter experts have successfully completed end-to-end agent development, with very limited assistance from a knowledge engineer. A more detailed presentation of the experiment and of the obtained results is posted at http://lalab.gmu.edu/RKF/cog/default.htm

The collaborative research efforts on Disciple-RKF/COG continue during the 2001/2002 Academic Year with: 1) the development of a more powerful version of the Disciple-RKF/COG instructable agent that addresses the identified limitations of the current version; 2) the extension of the practical COG analysis methodology to cover more of this domain; and 3) the use of the new research results in the US Army War College courses. The COG elective course will use Disciple in a tutorial role, as a tool to learn about center of gravity analysis. The MAAI course will focus on the construction of instructable agents by students and will finish with another agent development experiment. Future plans call for the expanded use of Disciple-RKF/COG as an intelligent tutoring system.

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