TACOP: A Cognitive Agent for a Naval Training Simulation Environment

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ABSTRACT
This paper describes how cognitive modeling can be exploited in the design of software agents that support naval training sessions. The architecture, specifications, and embedding of the cognitive agent in a simulation environment are described. Subsequently, the agent's functioning was evaluated in complex, real life training situations for naval officers.

Categories and Subject Descriptors
I.2.0 [**Artificial Intelligence**]: General – *Cognitive simulation*; I.2.1 [**Artificial Intelligence**]: Applications and Expert Systems; I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence – *Intelligent agents;* I.6.3. [**Simulation and Modeling**]: applications; J.7. [**Computers in Other Systems**]: Military.

General Terms
Design, Human Factors.

Keywords
Cognitive agent, naval training, simulation environment.

1. INTRODUCTION
Decision-making in complex and dynamic multi-agent environments (e.g., military missions) requires a significant effort. For training that skill, a realistic multi-agent setting is needed. For this purpose, often simulation software is used, representing the specific domain and relevant scenarios. Within such an environment and being in constant interaction with his team members and opponents, the trainee fulfills his task. In this process, an instructor provides feedback on the trainee's behavior. So, in order to train one student, three or more persons are needed, which makes such trainings very expensive.

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When human agents would be replaced by software agents, the costs would reduce substantially. Such software agents should be capable of generating behavior and decisions that are as appropriate as those of their human counterparts. Therefore, they should incorporate cognitive characteristics, next to expert knowledge. Using cognitive modeling techniques [1], the cognitive characteristics can be utilized. An additional advantage is that, in contrast with human agents, the behavior of these software agents is fully controllable.

The resulting, computational, cognitive agents could replace human agents, such as: (1) the opponent, by representing tactical decision-making, (2) the instructor, by comparing trainee decisions with modeled decisions and subsequently generate feedback, and (3) team members, by mimicking their decision-making. The use of agents for such roles is gaining increasing interest [2, 3].

In the next section, we will sketch the domain under consideration and present the selected scenario. In Section 3, we present the computational, cognitive agent model designed for that scenario. In Section 4 and 5, the application of the agent within the simulation environment and the evaluation are discussed. We end (in Section 6) the paper with a discussion.

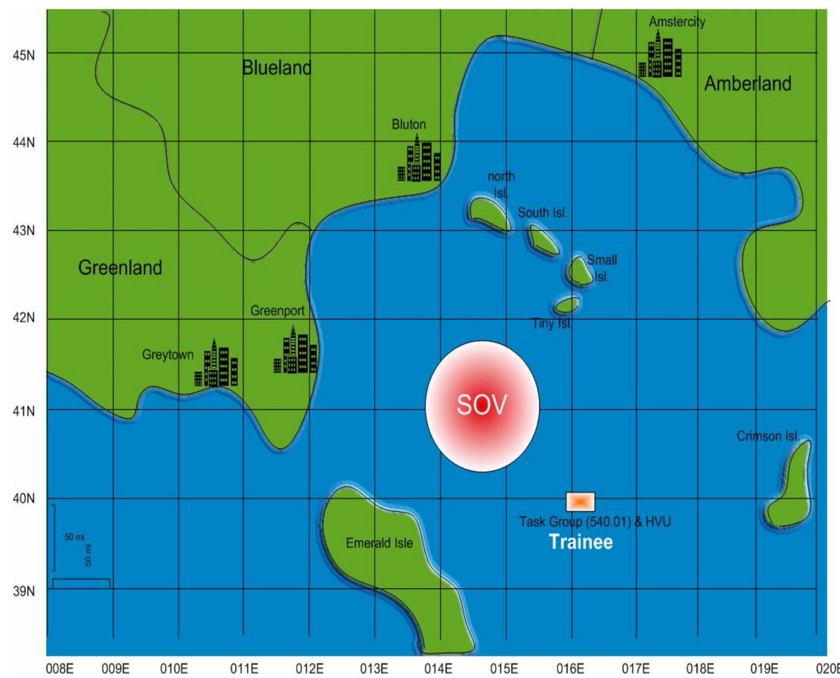
2. THE TRAINING DOMAIN
The Royal NetherLands Navy (RNLN) is concerned with training (future) naval officers in decision making. Recently, the RNLN has recognized the potential of using software agents to represent human decision making [4] for training purposes. With such trainings, it is of the utmost importance that the training resembles all relevant aspects of real life situations as accurately as possible.

In real life situations, the command central officers decide the best way to utilize the weapons, sensors, and navigational systems aboard a ship. However, the information needed to do so is bounded by the ship's limitations. Consequently, the officer has to base his or her decisions on information that is sometimes unreliable and incomplete. Moreover, the continual change in the environment makes it difficult to predict consequences of decisions beyond the immediate. The challenge for the command central officer is to think of a course of action that is tactically sound and will not be expected by the opponent.

For some time, clashes have been taken place between Amberland and Blueland. NATO is on Bluelands side and manages Task Group no. 540.01. An amphibious transport ship that has emergency aid on board for the victims of Blueland is part of this task group. The mission of the trainee is to safely arrive with this High Value Unit (HVU) at Bluton (i.e., the capital of Blueland). Besides the HVU, four frigates, that can defend themselves and the HVU, are part of the convoy. The enemy's (TACOP's) goal is to stop the HVU from arriving at Bluton. TACOP is in charge of two ships of the type Sovremennyy (SOV).

At the beginning of the training, the trainee only receives information about the approximate location of the two SOVs and about the fact that these two ships exist and want to stop the HVU from arriving at Bluton. TACOP receives similar information; i.e., about the kind of ships it faces and their approximate location.

The two training goals are the student's development of the skills to i) correctly assess when to split up his force and ii) to select the right ships for this split, based on the correct assumptions.



Box 1: Tactical scenario for which the TActical Cognitive OPponent (TACOP) was developed.

Training in tactical decision making in surface warfare is an example of training an open task in a complex and dynamic environment. Students learn tactical theory and practice tactical decision making. The training consists of repeated practice of tactical decisions in order to improve these decisions.

Students practice tactical decision making using a semi-automated system called the Action Speed Tactical Trainer, which can simulate the command central in a naval battle. Within this system, human agents are required to program the reactions of opponents and other parties to the actions of the students during the exercise.

2.1 Scenario

The RNLN is interested in the development of a multi-agent system that can train a student, where cognitive agents (instead of other persons) play the roles of team member, instructor, and enemy. This research presents an agent who represents an enemy: TActical Cognitive OPponent (TACOP). A simulation environment and scenario were developed, in which the trainee interacts with the TACOP, see Box 1 for a specification. In addition, two training goals for the student were specified. All this was done in close cooperation with the instructor of the Operational School of the RNLN.

After the specification of the tactical scenario and the training goals, the instructor of the Operational School was requested to share his tactical knowledge about the scenario. During an initial interview, the knowledge essential for the cognitive agent to behave natural was determined. Furthermore, a set of plausible goals, strategies, and actions for the enemy was composed for the selected scenario. Extra attention was paid to ensure that TACOP's behavior would support the training. In a later phase, deficiencies in the knowledge concerning the proper behavior of the TACOP in various circumstances were eliminated by a structured interview.

3. COGNITIVE AGENT ARCHITECTURE AND SPECIFICATION

With the knowledge gathered about how TACOP should behave in the various situations of the scenario, a conceptual framework in which the agent could be modeled was chosen. The choice was led by the prerequisite that the selected framework incorporates the means for both reactive and proactive autonomous behavior. The selected BDI architecture, incorporating Beliefs, Desires, Intentions as well as their interactions, is a well known paradigm for generating such behavior [5, 6, 7]. See Figure 1, for the agent's global BDI model.

Although the agent's BDI model is generic, the specific interpretation of its conceptual components is scenario specific and is generated using the expert's tactical knowledge. The following subsections will elaborate on this generation process.

3.1 Belief Generation

The agent's beliefs define his knowledge and reasoning. They are generated through various mechanisms and applied on various complexity levels. Simple beliefs get formed passively through sensor perception; e.g., when the radar sensor fires, it triggers the belief that a track is detected. Complex beliefs get actively formed when the agent is in a certain state of mind (formed by its beliefs, desires, and intentions) and reasons about it. The belief about which radar track is the nearest is such a belief; it is only generated when there is an intention to shoot at a track.