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Agent-Oriented Knowledge Elicitation for Modeling the Winning of "Hearts and Minds"

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***Abstract*—Agent-oriented modeling is a top-down approach for modeling and simulating the behaviors of complex systems. This research addresses the application of agent-oriented modeling to eliciting and representing knowledge for social simulations. We provide an overview of agent-oriented modeling and describe a case study on conflict resolution that has an impact on winning "hearts and minds" of the occupied territory's population. After that we propose a method for eliciting and representing knowledge for social simulations by means of agent-oriented modeling. The models created by means of agent-oriented modeling can be implemented on several simulation platforms, such as NetLogo, Jason, and JADE.**

I. Introduction

THIS article is concerned with composing practical computer-based simulation scenarios for local conflict resolution in the context of counter-insurgency. In military terms, the most important and valuable strategy is the winning-over of the occupied territory's population. This kind of military strategy is known as winning the "hearts and minds" of the population. The support and trust of local population are necessary for continuous efforts towards the consolidation of peace, social justice, economic stability, and human rights, so that the country's reconstruction process can be stronger and more prosperous [1], [2].

Compared to conventional wars between nation-states, counter-insurgency is asymmetric in several aspects. Its operational environment is irregular, characterized by high rate and rapid changes, but also considerable constraints. Dimensions, such as material (disparity of arms between the opposing sides), legal (disparate status of the parties of the conflict), and moral (sides are not morally equal), distinguish asymmetric conflicts from traditional warfare [6]. This multi-dimensionality makes the modeling and simulation of asymmetric warfare complicated but for training purposes highly relevant task.

The first step to be taken to achieve adequate agent-based simulations for complex problem domains is to create a balanced set of models that are able to capture the problem domain from different perspectives and at different abstraction layers. In our view, agent-oriented modeling [3] offers such a balanced set of models.

Asymmetric warfare is one of the problem domains where agent-based simulations should be applied because it involves heterogeneous autonomous entities that include humans, physical subsystems, and software components whose behaviors depend on the situation at hand. Because of the complexity of such problem domains, all scenarios to be simulated should be carefully constructed to assure that they are realistic and useful. This is exactly the reason why, as it has been pointed out by [10], "methodological questions are more and more in the focus of research on agent-based simulation". Different methodological approaches for developing agent-based simulations have been proposed [10], [11], [12], [13]. This article is confined to the first stage of developing agent-based simulations: eliciting and representing knowledge for computer-based simulations. This is a very important stage in developing social simulations because it involves collaboration between social scientists and computer scientists. Our experience in a defense-related project has shown that agent-oriented models considerably facilitate such inter-disciplinary collaboration.

Previously, we have used agent-oriented modeling for developing simulation environments for military operations in urban environment [4]. In the domain addressed by this article, we deal with long-term social processes of winning "hearts and minds" of the population. The rest of this article is structured as follows. Section II provides an overview of agent-oriented modeling. Section III describes the case study of conflict resolution in an Afghan village. Section IV describes how agent-oriented modeling has been applied to the knowledge elicitation and representation for the case study. Finally, Section V draws conclusions.

II. Agent-Oriented Modeling

Agent-oriented modeling [3] is a top-down approach for modeling and simulating the behaviors of complex systems, which include social phenomena. Agent-oriented modeling enables to analyze and model a given problem domain from three balanced and interrelated viewpoint aspects: interaction, information, and behavior. The core of agent-oriented modeling is the viewpoint framework that is represented in Table I, which contains the types of models proposed by agent-oriented modeling. In addition to

representing for each model the vertical viewpoint aspect of interaction, information, or behavior, Table I maps each model to the abstraction layer of analysis, design, or platform-specific design. At the abstraction layer of platform-specific design, agent-oriented models are turned into dynamic models – simulations.

Each cell in Table I represents a specific viewpoint. For example, the viewpoint of interaction design is captured by agent models and interaction models. It is noteworthy that the interaction, information, and behavior viewpoint aspects of agent-oriented modeling straightforwardly correspond to the respective social, information, and individual background factors for agents' behaviors that have been independently coined in [7].

TABLE I. THE MODEL TYPES OF AGENT-ORIENTED MODELING

	Viewpoint aspect		
Abstraction layer	Interaction	Information	Behavior
Analysis	Role models and organization model	Domain model	Goal models and motivational scenarios
Design	Agent models and interaction models	Knowledge models	Behavioral scenarios and behavior models
Platform-specific design	Platform-specific design models		

III. THE CASE STUDY

The case study is based on the description of conflict resolution presented in [5]. Conflict resolution is not a goal in itself but rather provides a potential entry point for Blue Force (a term used for friendly forces, e.g., International Security Assistance Force [ISAF] in Afghanistan) when, for example, preventing violence or acting upon violence.

According to [5], there is a conflict between Barmack and Ahmed, who are both relatives and dwellers of a village in the Pashtun region of Afghanistan. They are also small landowners. Barmack owns 10 low grade acres of dry land, about 1 km north of the village. On this land graze 30 goats. Ahmed, Barmack's neighbor, also owns 10 low grade acres of dry land contiguous to Barmack's land. Ahmed owns 25 goats. One morning ten of Barmack's goats are missing. Barmack thinks Ahmed has stolen his goats in order to sell them far from the village. Barmack goes to the village and voices his complaint against Ahmed.

Both Barmack and Ahmed do not hesitate to fight to death to save their honor. Each of them starts to contact his close family (brothers, cousins, etc.) for creating a kind of committee – *Lashkar* – of five people to punish the opponent's behavior. The conflict is now potentially a violent conflict.

In parallel, ten elders (called "*Spingari*") are interested in solving the conflict. There are two motivations for the elders' behavior:

- A common social value of the community is to bring peace to the community via the formation of village council known as *Jirga*. This value is also known as *Jirga value*. Elders who participate in the Jirga are followers of this value. By following this value, they are rewarded with additional honor (enhanced reputation).
- There is personal material interest by the elders. Indeed, many elders have relationship with Ahmed or Barmack (some have relationships with both). If a violent fight destroys a property of one party or kills the party, the elders might suffer from the loss. For example, one elder is the uncle of Barmack and the brother-in-law of one of Ahmed's uncles. As the uncle of Barmack, he benefits from petty chores from Barmack's kids [5].

For solving the conflict, the elders go to see Ahmed and Barmack to convince each of them to choose three proxies among the elders who will represent them at the Jirga. If Ahmed and Barmack accept the proposal, they know that they must comply with the resolution made by Jirga because of the common Jirga value.

The decisions by Ahmed and Barmack are now affected by different factors:

- Compliance with the revenge value;
- Compliance with the Jirga value;
- Their self-interest.

Blue Force has an interest in the conflict if there is either strong likelihood of violence of the losing tribe or a rumor or evidence that one party has Taliban support. The Blue Force may react to rumor or evidence of Taliban involvement in different ways. For example, the Blue Force may intervene upon a rumor, or it may investigate the rumor or evidence and only then act upon the issue. The Blue Force may also remain neutral in spite of a rumor or evidence. Both remaining neutral and preventing violence has an effect on winning "hearts and minds" that has to be simulated.

When eliciting knowledge for simulations, we have to consider that violent conflict resolution raises the likelihood of violence between conflicting tribes. For example, the case when losing party has Taliban support and Blue Force attempts to prevent violence has different effect on winning "hearts and minds" compared to the situation when conflict is peacefully resolved and Taliban is not involved. In the simulation, the population should be divided into three groups: positive towards Blue Force, positive towards Taliban, and neutral population. Both Blue Force and Taliban can get support from among neutral population.

In case of peaceful conflict resolution, both Ahmed and Barmack decide to comply with the Jirga. The Jirga meets for five days, three hours a day, in the centre of the village under a tree. Ahmed and Barmack attend the Jirga. Each of them exposes his story. The members of Jirga ask questions. After the investigation, it appears that the ten goats were stolen by someone else. The Jirga decides to let Barmack express his forgiveness to Ahmed for falsely accusing him. Barmack's problem is recognized by the community, and five farmers are told to give one goat each. In such a way, they follow the group solidarity value. Many people come to the elders to congratulate them on their performance on the Jirga. Their prestige is enhanced since they solved the problem.

IV. Eliciting and Representing Knowledge

In this section, we outline a knowledge elicitation and representation process that is appropriate for developing social simulation systems. The process consists of a set of questions that facilitate the development of agent-oriented models and simulations. Answering each question produces one or more models of agent-oriented modeling [3]. The questions have been adapted and modified based on [14]. Because of the limited space in this article, we will focus on the models yielded by the questions here, proceeding by viewpoints of agent-oriented modeling.

From the viewpoint of *behavior analysis*, a *goal model* can be considered as a container of three components: goals, quality goals, and roles [3]. A goal is a representation of a functional requirement of a simulation system. A quality goal, as its name implies, is a non-functional or quality requirement of the system. Goals and quality goals can be further decomposed into smaller related sub-goals and sub-quality goals. The hierarchical structure is to show that the subcomponent is an aspect of the top-level component. Goal models also determine roles that are capacities or positions that agents playing the roles need to contribute to achieving the goals.

A starting point for the knowledge elicitation process is the highest-level goal – *purpose* – of the simulation system to be developed. In social simulations, the purpose is typically the process or phenomenon that is being studied. In the case study of conflict resolution, which forms an important part of winning "hearts and minds", the purpose of the simulation is as simple as "Resolve the conflict". The highest-level goal model for the simulation system is shown in Fig. 1. In the figure, rectangles stand for functional goals and clouds – for quality goals. Roles are denoted by stick figures. The goal model depicted in Fig. 1 shows that solving the conflict has two aspects: fighting and finding the truth. These aspects obviously exclude each other but to keep the goal model simple, we do not represent this in the model because the problem domain analysis phase of social simulations typically involves intense discussions between non-technical social scientists and computer scientists.

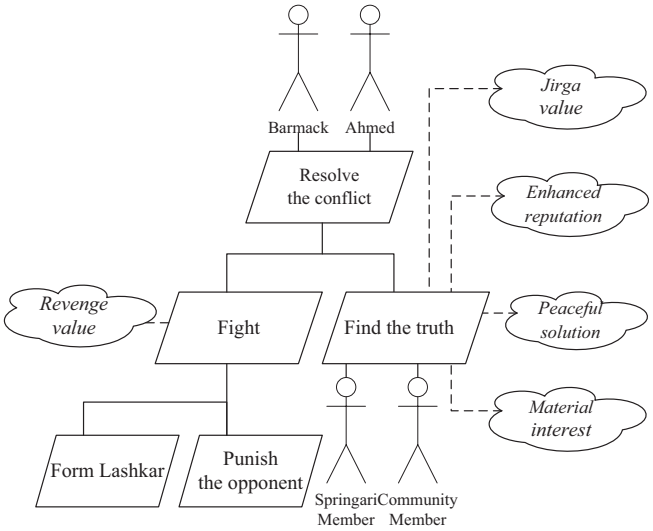

Figure 1.The goal model for solving the conflict

Table II. The role model for Ahmed

Role name	Ahmed
Description	The role of Ahmed during the conflict
Responsibilities	Form Lashkar; Fight Barmack; Decide compliance to Jirga; Choose 3 representatives for Jirga; Participate in investigation; Prove the innocence
Constraints	Material interest; Revenge value; Jirga value

From the viewpoint of *interaction analysis*, the properties of roles are expressed by *role models* and the relationships between the roles – by *organization model* [3]. An example role model for one of the parties – Ahmed – is represented in Table II. As usual, the role is described in terms of the responsibilities and constraints applying to the agent that will perform the role. Please note that some responsibilities modeled in Table II conflict each other. This is normal because the responsibilities that are eventually fulfilled are determined by the knowledge that agents playing the respective roles hold at the given moment. The knowledge by agents is modeled from the viewpoints of information analysis and information design.

The organization model for conflict resolution is represented in Figure 2. According to the organization model, the Springari Member role relies on the Party role for services and commodities (e.g., foodstuffs). Both the Party and Taliban roles depend on the Community Member role for support; the Jirga Member role controls the Party role because of the social policy of heeding the voice of Jirga, which is modeled as the quality goal "Jirga value" in Fig. 1.

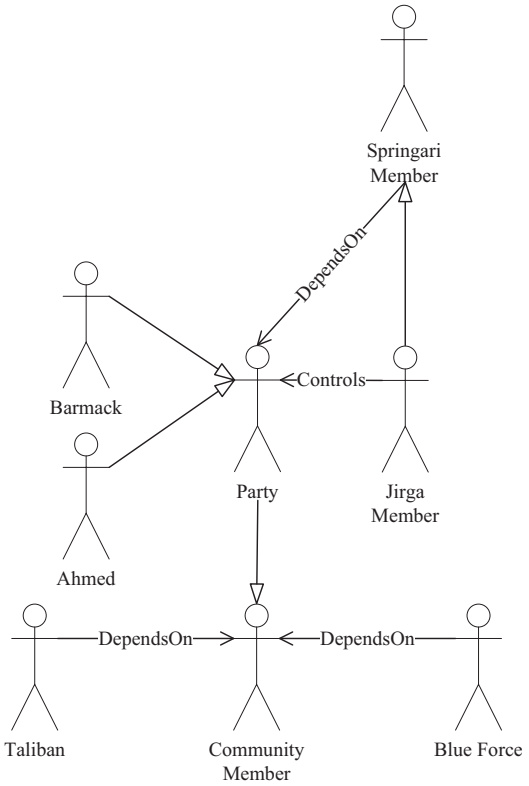

Figure 2. The organization model for conflict resolution

From the viewpoint of *information analysis*, *domain model* represents the knowledge to be handled by the socio-technical system. A domain model consists of domain entities and relationships between them. A domain entity is a modular unit of knowledge handled by a simulation system [3]. For example, to fulfill its responsibilities successfully, an agent playing the role Party in a simulation needs to access the knowledge entities Village and Household, where Village consists of Households.

From the viewpoint of *interaction design*, *agent models* transform the abstract constructs from the analysis stage, roles, to design constructs, agent types, which will be realized in the implementation process. Deciding agent types for simulation systems is simple because usually there is an agent type corresponding to each role. In addition to agent models, *interaction models* represent interaction patterns between agents of the given types. They are based on responsibilities defined for the corresponding roles [3].

From the viewpoint of *information design*, it is essential to represent both private and shared knowledge by agents. An agent's *knowledge model* represents knowledge about the agent itself and about the agents and objects in its environment [3].

Finally, from the viewpoint of *behavior design*, we model how agents make decisions and perform activities. There are two kinds of models under this viewpoint. A *behavioral scenario* describes how agents of the given types contribute to achieving the goals set for the system. *Behavior models* describe the behaviors of individual agents by representing how behaviors depend on the events perceived and knowledge held by agents [3]. Behavior models for the case study embody response functions [8] that determine how agents in simulations make decisions based on knowledge on social values.

At the abstraction layer of *platform-specific design*, agent-oriented models are turned into dynamic models – simulations – that show the effects of the behaviors of individual agents as well as provide information on emergent behavior by the simulation system as a whole. As interactions between the agents involved are highly complex, performing simulations is the only way of predicting their outcome. Appropriate simulations can help to understand the expected behavior of each individual agent and an entire system over time. Therefore, agents can be used for simulating real life situations and exploring the behaviors of humans forming complex simulation systems with "human-in-the-loop" capability.

V. Conclusions

We proposed a knowledge elicitation and representation method for developing agent-based simulation systems for social processes. Social processes are studied by a variety of scientific disciplines such as social sciences, psychology, cultural anthropology, etc. The methods used by these disciplines differ from those used by exact sciences in that the underlying mathematics, computational algorithms, and proofs are usually not addressed for social systems. Instead, social processes are described by social relationships, expected outcomes, and theories. For this reason, social scientists and computer scientists have different theoretical backgrounds and practical experiences. This makes understanding each other and coming to the common vision for models and simulations difficult, especially because social systems are inherently complex and their simulations reflect that complexity [9]. To decrease the complexity, we therefore need to create structured but simple representations of problem domain knowledge. Agent-oriented modeling has proved to be a very suitable approach that facilitates collaboration in this context.

VI. Acknowledgement

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