A Method of Conceptual Modelling for Realistic Training Scenarios

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Abstract: Training is crucial for improvement of the capabilities of both military and non-military personnel. In this paper, we argue for the need of conceptual modelling for the creation of training scenarios. This research proposes a particular method for developing training scenarios for complex domains based on agent–oriented modelling. The advantage of agent-oriented modelling is that it enables to describe a problem domain from three balanced and interrelated aspects – interaction, information, and behaviour, and at three abstraction layers: analysis, design, and simulation. Thus, we can obtain agent-directed simulations for elaborating selected aspects of emergent behaviour to support development of practical training scenarios in a partially known environment.

1 INTRODUCTION

Training is of critical importance in preparing both militaryand non-military personnel for peacekeeping missions. Composing practical scenarios for training to cope in an environment with several potential asymmetric threats is far from trivial. In this study we rely on realistic case studies.

A tabletop exercise is an exercise that is designed to test the ability of a group to respond to a situation. In a typical tabletop exercise, a facilitator creates a setting in which each player plays a predefined role. The facilitator also describes the situation to be responded to and the physical environment.Training is often conducted as a role play in the form of a tabletop exercise. In training exercises of this kind predefined training scenarios are used. In the exercise, the participants act out the scenario, whereby the scenario changes in response to their actions and random factors, which may be determined by rolling dice or drawing cards. This implies that the results of a tabletop exercise cannot be predicted as they always emerge from conducting the concrete exercise.

Computer-based training opens new possibilities for conducting tabletop exercises. The method we use for computer-based training is based on representing individuals or groups of individuals as agents, where an agent is defined as an entity that is (a) reactive; (b) proactive; (c) social; and (d) situated in some environment. The particular training scenario emerges from agents' activities, thus - by tuning agent's behaviour one can tune the simulation behaviour. A clear advantage of this method is that training doesnot depend on the number of trainees because some roles in training can be played by software agents and one or more roles – by trainees. Moreover, with this kind of training, we can also explore experiments with different psychological profiles of trainees played by software agents. As a result, we can create many different team setups and embed a trainee or trainees in them. There is no tabletop exercise that can provide this kind of experience. In a tabletop exercise, the goals to be achieved by the scenario, as well as the activities to be performed by different participants and the criteria for evaluating these activities should be clearly outlined. As it has been pointed out in (Vattam et al., 2011), preparation of training scenarios rooted in agent-based simulation, starting from agents themselves, requires a proper conceptualization of the problem domain at hand. This paper proposes a method of conceptual modelling for computer-based training, where the training scenarios are created based on a set of conceptual models. The method is overviewed in Section 2. The process of conceptual modelling is described in Section 3 by elaborating an example from (Shvartsman et al., 2010). Finally, conclusions are presented in Section 4.

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2 THE METHOD

The method that we use for conceptual modelling for realistic training scenarios is *agent-oriented modelling* (Sterling and Taveter, 2009). We prefer this method over other alternatives because it straightforwardly enables to model a system of goals to be achieved by a training scenario, as well as the activities to be performed by players in the scenario different participants and the criteria for evaluating these activities should be clearly outlined. We also have a lot of positive anecdotal experience of applying AOM in the related domain, where AOM was successfully applied for developing a training resource to teach secondary school students to respect people with Asperger's Syndrome.

Agent-oriented modelling is an approach for modelling and simulating the behaviours of complex socio-technical systems where a problem domain is first conceptualized in terms of the goals to be achieved by the system, the roles required for achieving them, and the domain entities embodying the required knowledge. The roles are thereafter mapped to the agents playing the roles, the goals – to the activities performed by the agents, and the domain entities – to the items of knowledge held by the agents. As we are concerned with "human-in-the-loop" simulations, the term "agent" subsumes both human agents and man-made agents – softwareagents simulating humans. Conceptually, we consider models as abstractions reducing the complexity of a system for better understanding of the system's particular aspects and their impact on its behaviour.

The types of models proposed by agent-oriented modelling (AOM) are represented in Table 1. In addition to representing for each model the abstraction layer (analysis, design, or simulation), Table 1 maps each model to the vertical viewpoint aspect of interaction, information, or behaviour. Each cell in the table represents a specific viewpoint. We will next give an overview of agent-oriented models relevant for understanding this article proceeding by viewpoints. These models are distinguished by using a bold font in Table 1.

From the viewpoint of *behaviour analysis*, a *goal model* can be considered as a container of three components: goals, quality goals, and roles (Sterling and Taveter, 2009). A *goal* is a representation of a functional requirement for the simulation system, describing the phenomenon or process to be simulated. 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 subgoals and subquality 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. The notation for representing goals and roles is shown in Table 2 (Sterling and Taveter, 2009).

From the viewpoint of *interaction analysis*, the properties of roles are expressed by role models. A *role model* describes the role in terms of the responsibilities and constraints pertaining to the agent(s) playing the role.

From the viewpoint of *interaction design*, *interaction models* represent interaction patterns between agents of the given types. They are based on responsibilities defined for the corresponding roles. In this paper, we represent interaction models by means of action events and non-action events. An *action event* is an event that is caused by the action of an agent, like sending a message or starting a machine. An action event can thus be viewed as a coin with two sides: an action for the performing agent and an event for the perceiving agent. A message is a special type of action event—*communicative action event*—that is caused by the sending agent and perceived by the receiving agent. On the other hand, there are *non-action events* that are not caused by actions. Non-action events include exogenous events. An *exogenous event* is a kind of event whose creating agent we are not interested in.

Finally, from the viewpoint of *behaviour design*, *behaviour models* describe the behaviours of individual agents (Sterling and Taveter, 2009).

Table 1: The Model Types of Agent-Oriented Modelling.

	Viewpoint aspect		
Abstraction layer	Interaction	Information	Behaviour
Analysis	**Role models** and organization model	Domain model	**Goal models** and motivational scenarios
Design	Agent models and **interaction models**	Knowledge models	Scenarios and **behaviour models**
Simulation	Platform-specific models		

3 CONCEPTUAL MODELLING

In this section we show how a trainingscenario that has been used, assessed, and elaborated in numerous psychological experiments (Parmak et al., 2010) can be conceptually modelled by AOM for computer-based simulations with emergent behaviour. The firstmodel to be created is the goal model that determines the overall purpose of the simulation and its subgoals. This model serves to discuss the purpose of the simulation with all the stakeholders involved: military commanders and experts, trainers, trainees, adventure games'experts, etc. As is reflected by Figure 1, the overall purpose of the simulation is to evacuate the building. Achieving the purpose can be divided into the following subgoals, each of which represents a particular aspect of the evacuation: penetrate into the building, help the injured, ensure safety inside, ensure safety outside, and collect and pass information. Each subgoal can, in turn, be divided into third-level subgoals. Figure 1 represents the refined subgoals for the "Help the injured" subgoal. For clarity, the other subgoals are elaborated in separate figures which we do not present here because of space constraints. Achieving a goal may be characterized by a quality goal which in the given context represents the criteria for evaluating the extent to which the goal in the simulation has been achieved. The goal model also shows the roles that are required for achieving the goals of the simulation scenario. The roles are separately modelled further on in this section.

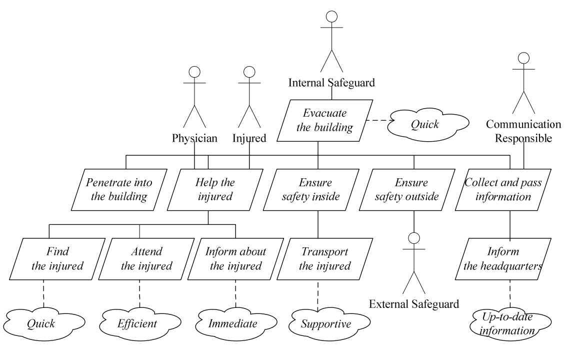

Figure 1: The goal model for the urban operation.

As was described in Section 3, the roles are described in terms of the responsibilities and constraints applying to the agents that will perform the roles. Because of the scope of this paper, we present in Table 2 only the model of the roles External Safeguard.

Having defined the goals for the scenario to be simulated and the roles comprised by the scenario, we can start designing simulations in such a way that any role in the simulation system could be performed by either a human agent or a software agent. This enables to perform training simulations in teams of any size and evaluate the performance of individual human agents. We illustrate platform-independent design by presenting in Figure 2 an interaction model for the scenario. The interaction model depicted in Figure 2 includes the roles of three purposeful agents – External Safeguard, Internal Safeguard, and Communication Responsible – whose goals comply with the goals set for the simulation scenario by the goal and role models. In addition, the interactions involve the role Physician that is not represented in this figure. Corresponding to the notation represented in Figure 1 and according to the explanations provided in Section 3, the interaction model represents the interactions between agents performing the above-mentioned roles as action events. In addition, the interaction model includes two non-action events representing the cave-in and appearance of strangers. Distinguishing between action events and non-action events is crucial in the simulation of military operations. We have decided to model the non-action events as exogenous events because both of them are generated by the simulation environment. Please note that the notation used in Figure 2 does not prescribe any order for the occurrence of events.

Table 2: The Role Model of External Safeguard.

Role name	External Safeguard
Description	The role of the external safeguard of the building during the operation
Responsibilities	Ensure safety outside the building Inform the Communication Responsible about any potential threats Receive the injured from the Internal Safeguard along with the instructions Inform the Communication Responsible about the injured received and the instructions
Constraints	Quick, efficient, informed, and helpful behaviour

The behaviour of an agent playing the role of External Safeguard can be described by rules, such as the following ones:

```
ON Strangers THEN Inform Communication
Responsible
ON Strangers THEN Wait N Sec; Inform
Communication Responsible
ON Strangers THEN Engage Strangers
ON Strangers THEN Take Strangers
Hostage
ON Strangers THEN Interrogate and
Search Strangers
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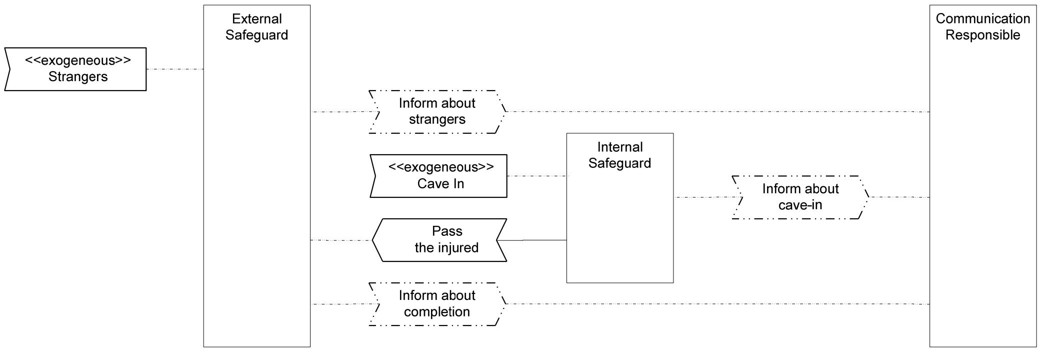

Figure 2: Interaction model for the scenario to be simulated.

The first two and the last three rules presented above are to be applied as alternatives rather than in parallel. For example, upon the appearance of strangers, an agent performing the External Safeguard role may inform another agent playing the Communication Responsible role right away or only after waiting for a specified number of seconds. Similarly, the same agent may react to the appearance of strangers in one of the following three ways: (a) engage strangers right away, that is, open fire at them; (b) take strangers hostage “just in case”; (c) interrogate and search strangers on the spot. What alternatives are chosen also depends on the psychological profiles of the simulated agents. How the profile can be represented and how it influences agent behaviour depends on platform-specific design, that is, on the agent architecture and platform chosen. This will be described in our future papers.

4 CONCLUSIONS

Conceptual modelling is of crucial importance for developing appropriate training scenarios for complex social processes such as addressing asymmetric threats in a city environment or winning hearts and minds. We demonstrated how a training scenario can be developed by means of AOM. In these kinds of training scenarios, emergent behaviour can occur *at least* in one of the following two ways: (a) through different latencies of simulated exogenous events; (b) through different alternative behaviours of participating agents and the combinations of their behaviours and interactions. In our future work, we will demonstrate how a family of training scenarios can be generated from conceptual models based on agents’ behavioural and interaction patterns.

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