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Agent-Oriented Modelling for Simulation of Complex Environments

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Abstract—**This article addresses the application of agent-oriented modelling to composing scenarios for simulating problem domains consisting of heterogeneous entities that include humans, physical subsystems, and software components whose behaviours depend on the situation at hand. The article presents an overview of agent-oriented modelling and addresses the application of agent-oriented modelling and simulation for context-aware crisis management and military urban operations. We develop an approach for constructing vignettes of situation-aware behaviour to be further simulated by means of software agents and describe the creation of practical context-aware training scenarios. Finally, the article explores a platform currently in use for possible execution of agent-based simulations. Our approach is applicable in practice for testing typical behavioural vignettes in specific scenarios using the platform. Unique benefit of the proposed approach is its usability to observe how real subjects form their decisions to behave in certain situations.**

I. Introduction

THIS article addresses the problem of composing practical computer-based training scenarios for context-aware crisis management and military operations in urban terrain. To achieve context-awareness, we utilize both agent-based and context-aware computing. The purpose of the latter is to let systems react to users based on their (simulated) environments. In other words, context-aware computing leverages context information to improve the interactions among users and their environments. The kinds of problem domains where our agent-oriented method can be applied consist of heterogeneous autonomous entities that include humans, physical subsystems, and software components whose behaviours 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. In this article, we describe the creation of context-aware scenarios for training purposes. In developing the scenarios, we use the top-down approach of *agent-oriented modelling* [1] where a problem domain is first conceptualized in terms of the goals to be achieved by a *socio-technical system*, the roles required for achieving them, and the domain entities embodying the required knowledge.

Conceptually, we consider models as abstractions reducing the complexity of a system for better understanding of its particular aspects and their impact on the system's behaviour. Naturally, application of a model ought to be "based upon the aspect of the agent's behaviour under investigation as well as the level of aggregation of individual agents and their effects" [15].

Running models of agents involved – simulations – show the effects of the behaviours of individual agents as well as provide information on the complex feedback dynamics required for the understanding of emergent behaviour by the system as a whole. As interactions between the agents involved are highly complex, performing simulations is the only way to predict their outcome. Appropriate simulations can help to understand the expected behaviour of an individual agent or an entire system over time.

A problem domain can be simulated by either developing a new simulation environment for it or by utilising an existing simulation environment. The first approach has been used by the third author in performing simulations of business-to-business electronic commerce [2], distributed manufacturing [3], cooperation between different stakeholders at airports [4], and aircraft turnaround processes at airports [5]. For all the problem domains mentioned, simulation environments were developed from scratch by using the JADE agent platform [6]. A new problem domain currently addressed by us is military operations in an urban environment. Differently from the other projects mentioned [2, 3, 4, 5], in that domain we intend to utilise an existing simulation environment, which is already used for training purposes by the Estonian Defence Forces, rather than developing one from scratch. In both cases, a problem domain at hand should be diligently analysed to enable realistic simulations. This article aims to generalise based on the projects mentioned and the ongoing project and offer an approach for constructing situations to be simulated by means of agent-oriented modelling. The rest of this article is structured as follows. Section II describes the related work in modelling and simulation. Section III gives an overview of agent-oriented modelling. Section IV describes the problem domain of military operations in an urban environment. Section V designs by means of agent-oriented modelling the scenario to be simulated based on a given case study. Section VI illustrates platform-specific design of the case study scenario on the VBS2 simulation environment. Finally, Section VII draws conclusions.

II. Related Work

Context-aware computing is only gaining momentum. It has been pointed out at [16] that "the concepts of *situation, context, event, goal, intention, action, activity, behavior* need further studies from a number of different points of view, including the views of situation in linguistics, cognitive science, human factors, computer science and artificial intelligence, as well as in both industrial and military applications". The paper [14] emphasizes an extremely challenging nature of context-aware crisis management: "Uncertainty arises in these environments in several ways: (i) information can be incomplete, (ii) information can have varying degrees of confidence, (iii) information can be inconsistent or contradictory, (iv) information can be numeric but yet interpreted in terms of common sense approximations, and (v) information can evolve over time with respect to (i)–(iv)." The aspect of proper models in this context is difficult to underestimate, despite of its challenging nature. This environment, more than any other factor, strongly influences combat identification (e.g., cognitive processes, situational awareness, and visual discrimination), movement, and the capabilities of (the systems of) the contending parties [9].

III. Agent-oriented Modelling

Agent-oriented modelling proposed in [1] is a holistic approach for analysing and designing socio-technical systems consisting of humans and technical components. In the context of this article, a socio-technical system is a simulation system with "human-in-the-loop" simulation capabilities.

Agent-oriented modelling proposes a set of canonical models. The models for analysing a problem domain describe the functional goals of a socio-technical system to be designed, the quality goals describing how the functional goals should be achieved, the roles required for achieving the goals, and the domain entities capturing the knowledge to be represented within the system. Design models of agent-oriented modelling describe what human and man-made (e.g., software) agents are required for achieving the goals, what private and shared information these agents possess and process, and how they interact and behave. Analysis models and design models are complemented by platform-specific design models that describe the implementation of the socio-technical system on a particular software platform. The types of models proposed by agent-oriented modelling are represented in Table I. In addition to representing for each model the abstraction layer (analysis, design, or platform-specific design), Table I 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 proceeding by viewpoints.

From the viewpoint of *behaviour analysis*, a *goal model* can be considered as a container of three components: goals, quality goals, and roles [1]. A *goal* is a representation of a functional requirement of the socio-technical 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 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. Roles are modelled in detail in the viewpoint of interaction analysis. The notation for representing goals and roles is shown in Table II. This notation is used in Section V for presenting agent-oriented models in the example case study. Goal models go hand in hand with *motivational scenarios* that describe in an informal and loose narrative manner how goals are to be achieved by agents enacting the corresponding roles [1].

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. *Organisation model* is a model that represents the relationships between the roles of the socio-technical system, forming an organization [1].

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 socio-technical system [1].

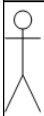
From the viewpoint of *interaction design*, *agent models* transform the abstract constructs from the analysis stage, roles, to design constructs, *agent types*, which will be realized in the implementation process. Deciding agent types for simulation systems is simple because usually there is an agent type corresponding to each role. *Interaction models* represent interaction patterns between agents of the given types. They are based on responsibilities defined for the corresponding roles [1].

In this article, we represent interaction models by means of action events and non-action events [1]. 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—for example, the fall of a particular stock value below a certain threshold, the sinking of a ship in a storm, or a timeout in an action. The notation for modelling both kinds of events is represented in Figure 1. Non-action events also include exogenous events. An *exogenous event* is a kind of event whose creating agent we are not interested in. As has been pointed out in [4],

TABLE I.
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
Platform-specific design	Platform-specific design models		

TABLE II.
NOTATION FOR MODELLING GOALS AND ROLES

Symbol	**Meaning**
	Goal
	Quality goal
	Role
	Relationship between goals
	Relationship between goals and quality goals

exogeneous events need to be generated by the given simulation system. For example, the appearance of strangers in the scenario to be described in Section V can be modelled as an exogeneous event that is generated by the simulation system.

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 [1]. Knowledge model is particularly important when designing a simulation system from scratch. Since in the case study described in this article we rely on an existing simulation environment instead, we have chosen to represent knowledge only by the domain model.

Finally, from the viewpoint of *behaviour design*, we model how agents make decisions and perform activities. There are two kinds of models under this viewpoint. A *scenario* is a behaviour model that describes how the goals set for the system can be achieved by agents of the system. *Behaviour models* describe the behaviours of individual agents [1].

IV. URBAN OPERATIONS

We use agent-oriented modelling in the context of urban operations. Compared to conventional wars between nation-

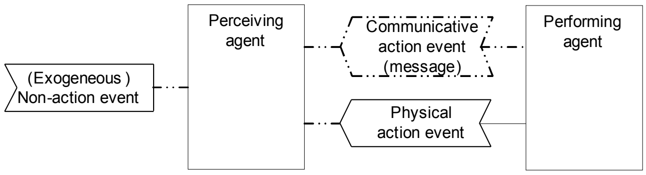


Figure 1. The notation for modelling events.

states, multidimensional operations of modern warfare are asymmetric in several aspects. Operational environment in a future battlefield is irregular, characterised by high rate and rapid changes, but also considerable constraints. An example of this kind of operational environment is urban operations to be addressed in the next paragraph. Dimensions, 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 [11]. This multi-dimensionality makes the modelling and simulation of the environment of unconventional warfare complicated but for training purposes highly relevant task.

In the setting described, the nature of recent conflicts, where the population is targeted on the political, social, economical, and physical front, and the current rate of urbanisation, has shifted the attention to urban operations, maybe more than in any other time in history. It is also fair to assume that the battlefield of tomorrow is dominated by the urban environment. An urban area is a terrain where man-made construction and the presence of non-combatants are the dominant features. Urban operations are defined as all operations planned and conducted across the range of military operations on, or against objectives within, an urban area [7]. Urban operations have the following three facets:

- Urban area (terrain, a system of streets and buildings);
- Civilians (all non-combatants in operation area);
- Military operations (*interactions* of combatants of both sides in order to attain an object).

The combination of physical terrain, civilian population, and urban systems fundamentally distinguishes urban operations from other types of operations. To guarantee operational success, it is crucial to consider psychological readiness and especially limits of human capabilities of own forces. Creating working simulations of urban operations for the best possible training presupposes the ability to predict emergent behaviour of the agents in situations. Models must be able to deal with the dynamicity of human behaviour while taking account that it is not always rational. Behaviour is based on agents' sets of beliefs and a multitude of variables that potentially influence those beliefs: *individual*, *social*, and *information* background factors [12]. For military use, this aspect of modelling has been recently highlighted and referred as individual, organisational, and societal (IOS) models [10].

Because of the dynamic nature of urban environment, designing realistic scenarios for simulations of urban operations is not a trivial task. Neither is trivial the evaluation of such scenarios. Appropriate methods are required for coming up with realistic scenarios. One of such methods could be *agent-oriented modelling* that was described in Section III. It is noteworthy that the interaction, information, and behaviour viewpoint aspects of agent-oriented modelling that were explained in Section III rather well correspond to the respective social, information, and individual background factors for agents' behaviours mentioned above that originate in [12].

V. "Agentification" of Simulations

The dynamic nature of crisis management and urban military operations in particular is driving the need for new types of computational models that focus on human behaviour, especially on human behaviour in social units, such as organisations and societies ([10], p. 23). As was pointed out in Section IV, urban environment is characterized by uncertainty and intense *interactions* between various kinds of agents and between agents and their environments. In other words, one needs to introduce the context of interactions leading to situational awareness of the agents involved. A reasonable way to achieve that is by proper "agentification" of simulation scenarios based on agent–oriented modelling. By "agentification" we mean employing agent-related abstractions for modelling and simulation. "Agentification" is thus broader than just using software agents in simulations. Most military simulation environments available today view simulations in terms of objects to be manipulated rather than interacting agents. However, these environments can be used in an agent-oriented fashion but a different mindset is required for doing this. According to this mindset, models must deal with inherent uncertainty and dynamic adaptation that characterise human behaviour and should be capable for modelling both rational and non-rational behaviour ([10], p. 6). This kind of mindset can be achieved by using agent-oriented modelling for analysing the problem domain at hand and composing a simulation scenario for it. We will next illustrate this claim by the case study that is based on a game scenario for the field simulation to be used in training. The scenario has been worked out with the help of adventure games´ specialists [8]. The scenario is one of the scenarios that have been used, assessed, and elaborated in numerous psychological experiments [8]. We will next turn the scenario into the simulation scenario by using the kinds of models suggested by agent-oriented modelling and overviewed in Section III. We prove our point by using just a subset of agent-oriented models.

The first model 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´ specialists, etc. As is reflected by Figure 2, 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 2 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.

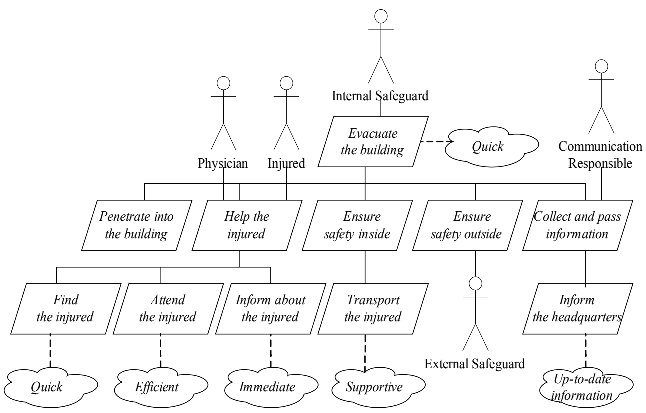


Figure 2. The goal model for the urban operation.

Table III presents a motivational scenario for the case study. The motivational scenario describes in a loose narrative manner how the goals represented in the goal model are to be achieved by agents playing the roles included by the goal model.

The roles put forward by the goal model are modelled in Tables IV - VIII. As usual, the roles are described in terms of the responsibilities and constraints applying to the agents that will perform the roles.

After having defined the goals and roles for the simulation scenario, we will characterize the relations between the roles involved. This can be done by the *organization model*. In our example, the organization model depicts relationships between the roles Injured, Physician, Internal Safeguard, External Safeguard, and Communication Responsible. It is also shown in Figure 3 that an agent performing the role Communication Responsible reports to an agent performing the role Headquarter. The role Headquarter is not a part of the simulation scenario because it is played by an external agent that collects information from an agent performing the role Communication Responsible.

We also need to describe the resources used by agents playing the roles to achieve the goals of the simulation scenario. In the simulation scenario, each *resource* is some unit of information used by agents. The resource types of the scenario are listed in Table IX. The second column of the table shows the roles related to the resources. Each resource is briefly characterized in the "Description" column.

Combining the organization model with resources yields us the domain model represented in Figure 4. As was described in Section III, *domain model* is a kind of conceptual model of a system which describes the entities embodying knowledge in the system and the relationships between them. According to the domain model shown in Figure 4, the resource type Injuries is associated with the

TABLE III.
THE MOTIVATIONAL SCENARIO FOR THE SIMULATION

Scenario name	An urban rescue operation
Scenario description	The building that is located in the enemy`s territory and shielded our warriors was hit by a bomb. The rescue team has to perform the following tasks: • Penetrate into the building; • Find the warriors killed; • Find and evacuate the warriors injured; • Find and detonate possible explosives. During evacuation, the following events occur: • Civilians appear outside of the building; • Small cave-in occurs in the building.
Quality description	The building is in ruins, low, and dark. There are bodies and many obstacles in the building. Because of the danger of cave-in, the tasks have to be accomplished as soon as possible and definitely within 30 minutes. All the members of the rescue team are equipped with radio transmitters. The members of the rescue team have to provide other team members and the headquarter constantly with up-to-date information.

Table IV.
THE ROLE MODEL FOR 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

Table V.
THE ROLE MODEL FOR PHYSICIAN

Role name	Physician
Description	The role of the physician during the operation
Responsibilities	Penetrate into the building Find the bodies in the building Tell the injured apart from the dead Inform the Communication Responsible about the injured and dead found Attend the injured Pass the injured to the Internal Safeguard along with the instructions
Constraints	Quick, efficient, informed, and helpful behaviour

roles Injured, Physician, Internal Safeguard, and External Safeguard. More precisely, information about injuries flows from an agent performing the role Injured to the agents playing the roles Physician and Internal and External Safeguard. The resource type Cave-In is associated with the

TABLE VI.
THE ROLE MODEL FOR INTERNAL SAFEGUARD

Role name	Internal Safeguard
Description	The role of the internal safeguard of the building during the operation
Responsibilities	Penetrate into the building Ensure safety inside the building Find and detonate possible explosives Inform the Communication Responsible about any potential threats Support the Physician in attending the injured Pass the injured to the External Safeguard along with the instructions by the Physician
Constraints	Quick, efficient, informed, and helpful behaviour

Table VII.
THE ROLE MODEL FOR COMMUNICATION RESPONSIBLE

Role name	Communication Responsible
Description	The role of the communication responsible in the operation
Responsibilities	Collect and pass information to the headquarter
Constraints	Quick, efficient, informed, and helpful behaviour

Table VIII. THE ROLE MODEL FOR INJURED

Role name	Injured
Description	The role of the injured in the operation
Responsibilities	Tell the physician about the injuries
Constraints	Precise information

roles Internal Safeguard and Communication Responsible, i.e., an agent performing the role Internal Safeguard informs an agent playing the role Communication Responsible about the cave-in. Also, an agent performing the role External Safeguard informs an agent playing the role Communication Responsible about the injured who has been evacuated. For this purpose we have introduced the resource type Evacuated which is associated with the roles External Safeguard and Communication Responsible. The last but not the least resource is that of the type Situation. This resource presents the information collected about the evolving situation in the urban operation. An agent performing the role Communication Responsible passes this information to an agent performing the role Headquarter.

As the final step of problem domain analysis, we represent the environments to be simulated and how they are related to the roles of the scenario. By an *environment* we mean a set of surrounding conditions for agents that mediates the interactions among agents and their access to resources [1]. We represent the environments by the environment model depicted in Figure 5. The simulation scenario involves two environments: City and Building. The roles Physician, Internal Safeguard, and Injured are enacted in the Building environment, while the roles External Safeguard and Communication Responsible are enacted in the City environment. The Injured role is enacted in both environments. The city consists of several buildings and the building contains several bodies and obstacles. All this may

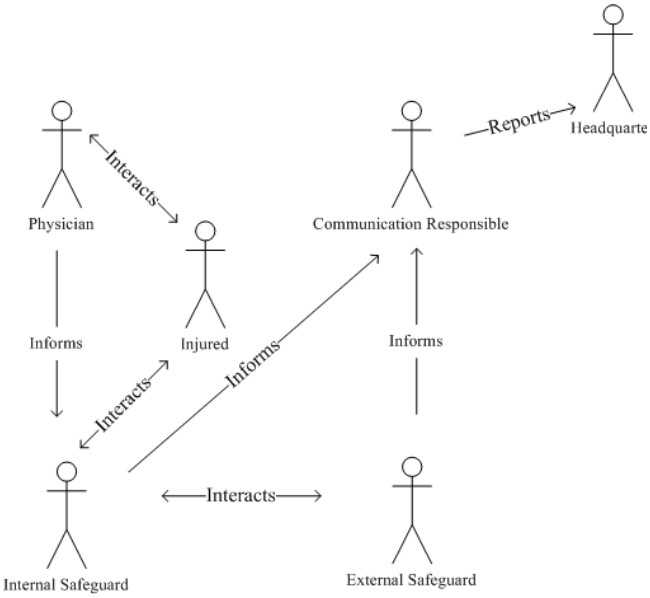


Figure 3. The organization model for the simulation scenario.

TABLE IX.
THE RESOURCES OF THE SIMULATION SCENARIO

Resource	Roles	Description
Injuries	Injured, Physician, Internal Safeguard, External Safeguard	Information about the injuries
Cave-In	Internal Safeguard, Communication Responsible	Information about the cave-in
Evacuated	External Safeguard, Communication Responsible	Information about the injured who has been evacuated
Situation	Communication Responsible, Headquarter	Information collected from agents performing the roles Internal Safeguard and External Safeguard

sound trivial but is definitely required for creating the simulation scenario.

Having defined the goals for the scenario to be simulated and the roles comprised by the scenario, as well as the information resources involved by the scenario, their relationships to roles, and the environments in which the scenario occurs, we have created a minimal set of analysis models. Our next task is to design 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 6 an interaction model for the scenario. The interaction model depicted in Figure 6 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 provid-

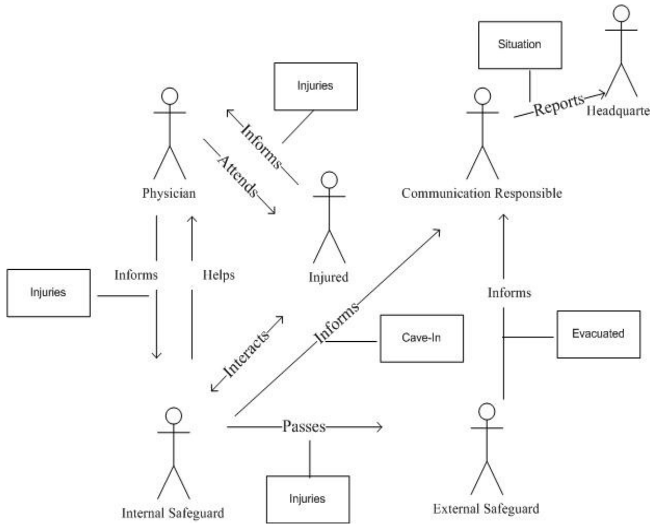


Figure 4. The domain model for the simulation scenario.

ed in Section III, 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 exogeneous events because both of them are generated by the simulation environment. How these events can be defined for a particular simulation environment is exemplified in Section VI. Please note that the notation used in Figure 6 does not prescribe any order for the occurrence of events.

What does explicit capturing of interactions buy us in simulations? First of all, the simulation environment can generate exogeneous non-action events at different times within certain intervals. Second, the simulation environment can randomly vary interaction latencies between agents playing the roles. These aspects give us a freedom to

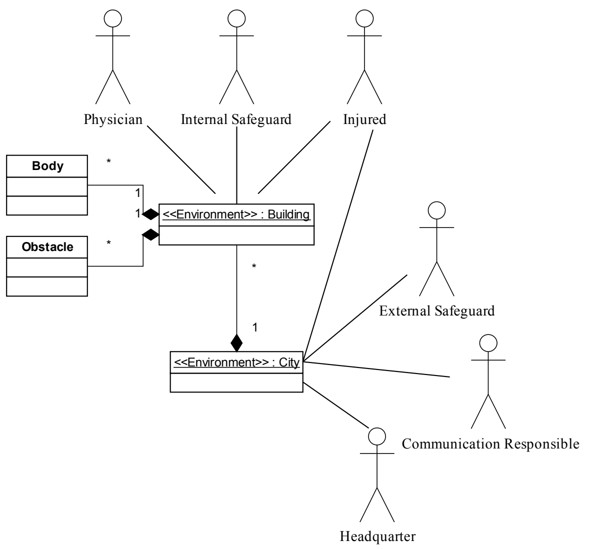


Figure 5. The environment model for the simulation scenario.

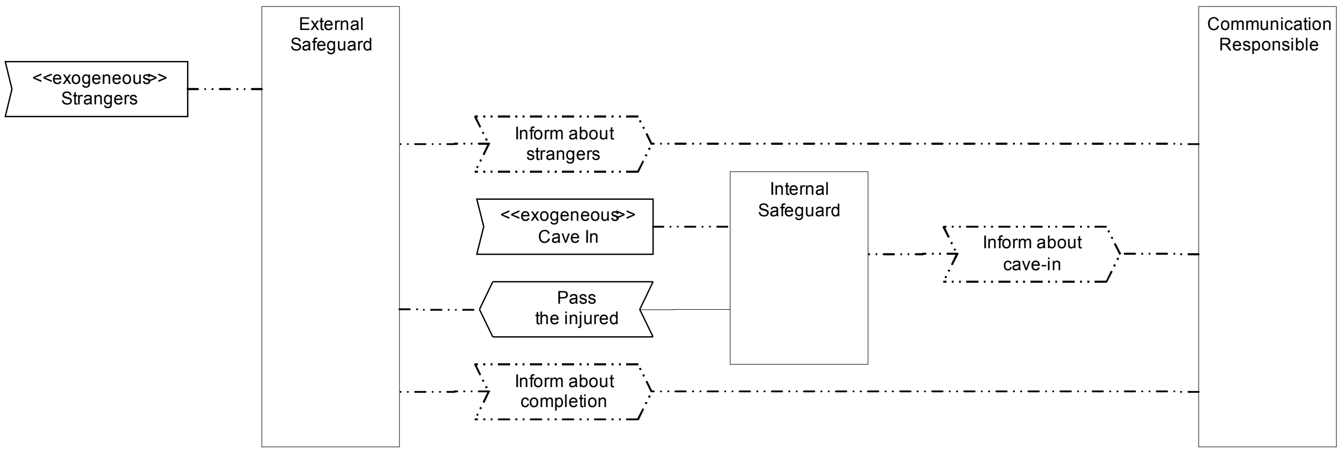


Figure 6. Interaction model for the scenario to be simulated.

manipulate with unpredictable environmental variables which are characteristic to real military operations. Third, we are not dependent of a group size because we can have one or more roles played by humans and the rest of the roles played by software agents. In such a way we can combine "real" interaction latencies with simulated ones. Since simulated latencies follow a random pattern, as a result we will have an *emergent behaviour* of a kind.

Mimicking an operational reality with this kind of design, we can find out how a human would react to different events occurring in the environment or caused by other agents. In addition, we can also experiment with various parameters that define the behaviours of individual agents. As the behavioural aspect is a complex one and therefore deserves further attention and research efforts by our multidisciplinary research team, we will address it as an important part of our future work. In this article we will confine the treatment of individual agent behaviours to a small example to be presented in Section VI.

VI. Platform-specific Design

We have chosen Virtual Battlespace 2 (VBS2, http://www.vbs2.com/) [13] as the platform for agent-oriented simulations. The rationale for this choice is twofold. First, VBS2 is one of the simulation platforms used by the Estonian Defence Forces. Second, VBS2 serves as a good example for simulation platforms that have been designed without agents on mind but that nevertheless can be used in an agent-oriented fashion. As implementing agent-oriented simulations is still work in progress, we illustrate platform-specific design for VBS2 by the snapshot shown in Figure 7. The snapshot reflects the experiments we have performed with VBS2 until now. The experiments have revealed that the agent-oriented analysis and design models presented and explained in Section V provide a sufficient backbone for performing agent-oriented simulations within the VBS2 environment. The details of such simulations are being elaborated and represented as a set of platform-specific models but the main structure of the simulations is in place. The snapshot shown in Figure 7 illustrates how the exogeneous event Strangers modelled in Figure 6 can be represented by means of VBS2.

VII. Conclusions

We have addressed composing computer-based training scenarios for context-aware crisis management. In this article, we described the creation of context-aware scenarios for training staff for military operations. The method we have applied for developing the scenarios is agent-oriented modelling [1]. We described how the problem can be modelled in an agent-oriented fashion by creating the goal model, role models, and domain model for the scenario and turning them into the environment model, interaction models, and platform-specific models. The contributions of this article are as follows:

- Employing agent-oriented modelling for structuring a networked domain so that it would lend itself to agent-oriented simulation;
- Offering a conceptual top-down approach for performing training simulations with VBS2 in teams of any size and evaluating the performance of individual human players;
- Enabling the manipulation with unpredictable environmental variables which are characteristic to real military operations.

Realistic training is a major concern of today's militaries. It is very difficult to train a person to deal with something that has not been defined. For asymmetric operations, and hence for urban operations, asymmetry is an inherent threat. Consequently, we need to develop our training scenarios in the direction of modelling human behaviour. It is especially important to create computational models of interactive human behaviours in a particular context. We intend to support this by agent-oriented behaviour models.

In a practical sense, our approach is applicable for testing typical behavioural vignettes in specific scenarios. Each role played by a software agent can be replaced by a real player in our approach. The unique benefit of the proposed approach is its usability to observe how real subjects form their decisions to behave in certain situations. Using agent-oriented modelling, we can explore the behaviours of humans forming parts of complex socio-technical systems. Through these observations we can eventually reach the level of flexibility required for simulating any complex socio-

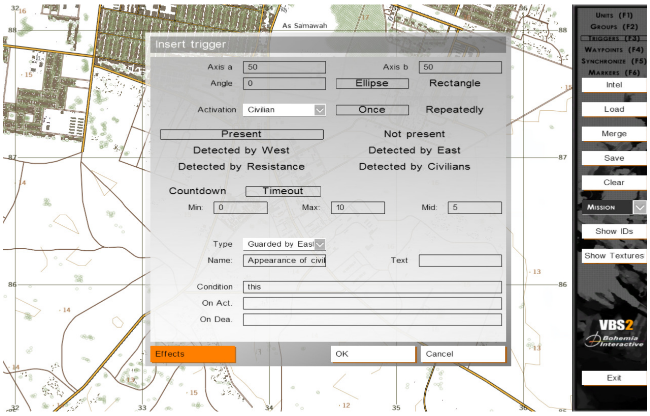


Figure 7. Defining the exogeneous event of the appearance of strangers.

technical system as a whole. We also plan to work out a visual environment for agent-oriented modelling that could be linked to several simulation platforms, both "conventional" and agent-oriented.

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