Educational Agents for the Training of Tunnel Operators

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ABSTRACT

The tunnel operator monitors and regulates the flow of traffic inside a tunnel, and takes actions in case an incident occurs. TNO has developed a training simulator that enables the operator to train incident situations. We are currently improving the simulator by developing intelligent agents that support a qualified operator, who trains himself, without the presence of a human instructor. This paper provides an overview of research activities in this project. In particular, it describes two types of educational agents, the authoritative *instructor agent* and the non-authoritative *companion agent*.

Keywords

Training, educational agent, crisis management, tunnel operator

1. INTRODUCTION

The tunnel operator is one of the key-players in tunnel incident situations. The task of the tunnel operator is to monitor and regulate the flow of traffic near and inside the tunnel, and to take actions in case an incident occurs (e.g. by closing traffic lanes). In case of an incident (e.g. a crashed truck catching fire), the tunnel operator is in charge until the principle fire-department officer arrives on the scene. Thereafter, adequate communication between the tunnel operator and the officer is of vital importance for developing a shared awareness on the nature of the incident and the strategy to control the situation.

Since incidents occur infrequently, operators have to train themselves regularly in order to maintain sufficient incident management skills. In 2003, TNO developed a training simulator that enables the operator to train incident scenarios (Figure 1) (Buiël and Middelham, 2005). The simulator presents the operator an incident-situation developing in real-time. The operator can take actions in order to reestablish a safe situation and can communicate with (simulated) crisis management personnel (e.g. the simulated fire-department officer). The simulator was built for the training of the operators of the longest car tunnel in The Netherlands, the Westerschelde Tunnel.

The tunnel training simulator is meant for initial training purposes as well as for retention training (Rypkema *et al* 2002). The retention training mode enables a qualified operator to train himself during working hours, without the presence of an instructor. As part of the Interactive Collaborative Information Systems (ICIS) project, we are currently improving the retention training mode by developing intelligent agents that support the learner. This paper provides an overview of the research activities in this project.

2. THE LEARNING OBJECTIVES FOR TUNNEL OPERATOR TRAINING

During *initial training*, the operator learns the different types of incidents that can occur inside the tunnel. These incidents vary from a small car incident (with bodywork damage only), to a large-scale fire incident with casualties. Depending on the scale of the incident, the operator has to take actions following one of the standard incident-procedures. The operator learns how to classify the incident, and attains skills in executing the measures prescribed by the corresponding incident-procedure. An instructor (e.g. a dedicated teacher) or coach (e.g. a senior tunnel operator) assists the learner operator by providing advice and performance feedback, and by proposing new training scenarios.

The *retention training* is meant to enable the operator to maintain the skills obtained during the initial training. Without retention training, it is likely that the obtained skills will degrade quickly, in particular the skills in handling large-scale incidents. Preferably, the operator can initiate retention training all by himself, e.g. during quiet working hours. In this case, the training simulator has to be stationed at or near the operator's workplace (the tunnel control room). Additionally, the need for human assistance and coaching has to be minimized, otherwise daily operational constraints will substantially limit the time available for retention training.

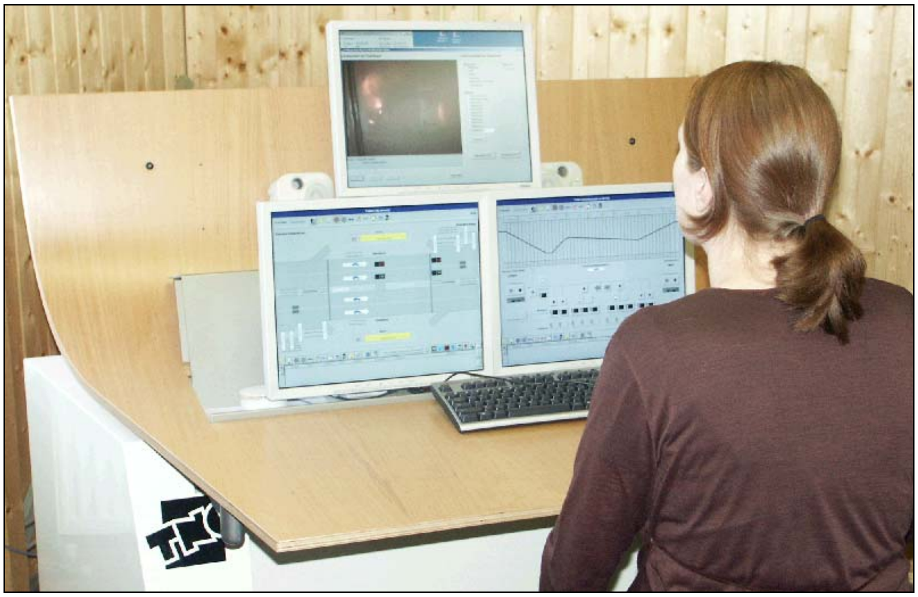


Figure 1 The tunnel training simulator

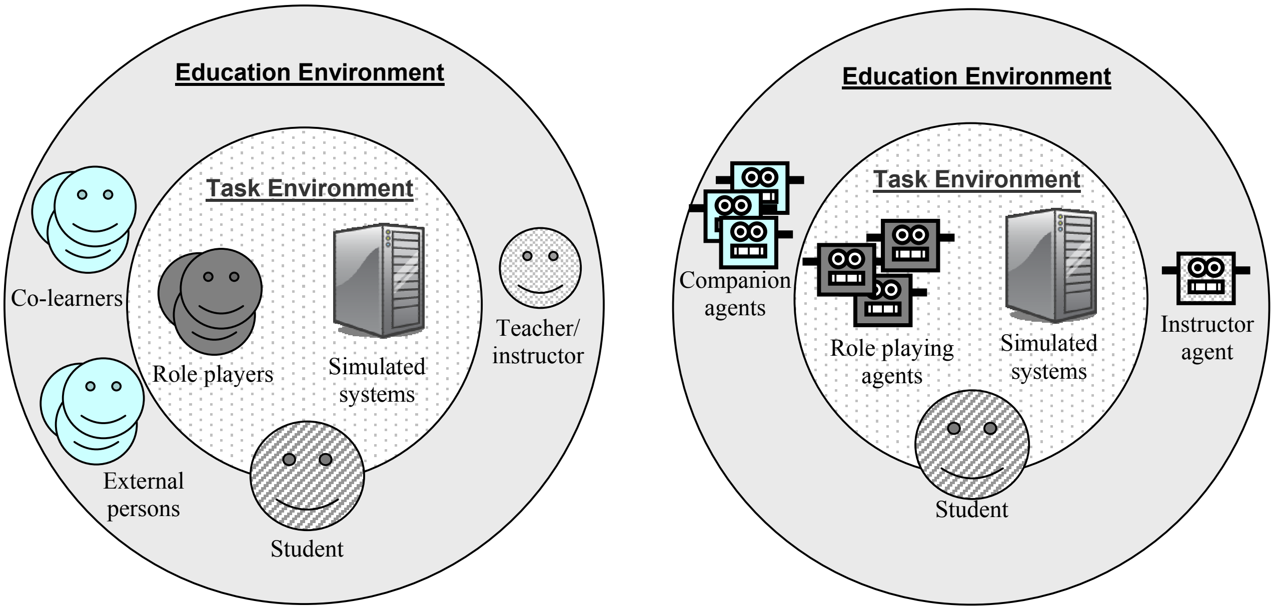
3. AUTOMATED TRAINING BY MEANS OF INTELLIGENT AGENTS

The described automated retention training requires a lot of automation. This is explained in Figure 2.

Figure 2a sketches a typical training environment for a simulator-based training. The environment consists of two components, the *task environment* and the *education environment*. The task environment is a representation of the future operational environment of the learner, where the learner can safely practice his task by interacting with simulated operational systems and live role players. The education environment encloses the task environment, and contains the staff and facilities that support the learner when he is learning in the task environment. Typically, the education environment includes an instructor, who coordinates the training, and one or more co-learners, who cooperate or compete with the learner. Additionally, the education environment may contain external personnel like advisors and discussion partners.

Figure 2b sketches the training environment for the *automated* retention training of the tunnel operator. All human roles in the normal simulator training environment now have to be automated and represented by intelligent agents. The resulting task environment contains a number of *role playing agents*. The resulting education environment contains an authoritative agent, the *instructor agent*, as well as a number of non-authoritative agents, the *companion agents*. The instructor agent sets the performance standards, provides performance feedback to the learner at the end of each training scenario, and selects training scenario's that match the learner's performance level. The companion agents challenge, advice, and/or assist the learner during the scenario execution. Following each training scenario, they stimulate the learner to perform introspection, i.e. to analyze his performance, and to find ways to improve his performance in a subsequent scenario.

In the tunnel operator training simulator, an instructor agent has been implemented by means of the TNO Computer Assisted Instruction system (CAI; §4). In order to improve the educational environment, we are currently investigating how to provide additional support to the training operator by introducing a companion agent (§5 and §6).



a) The most typical environment *b) Automated, agent-based environment*

Figure 2 Two environments for simulator-based training

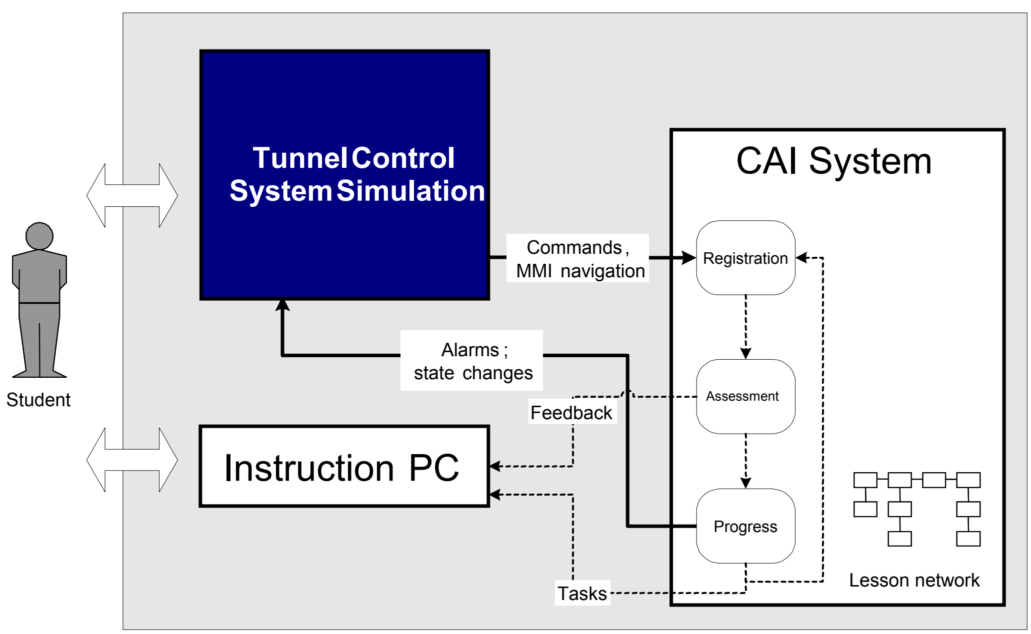
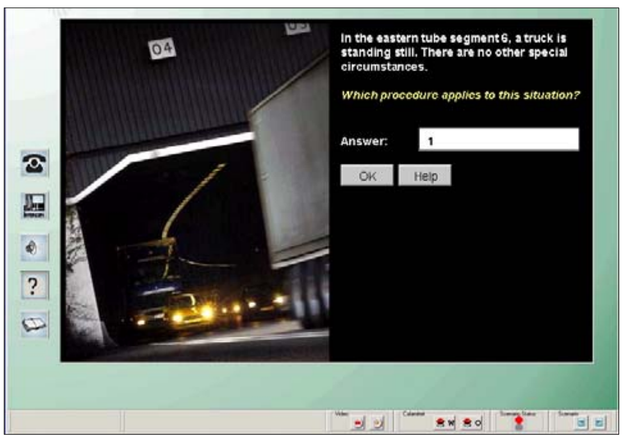


Figure 3 Instructor agent implemented by means of Computer Assisted Instruction

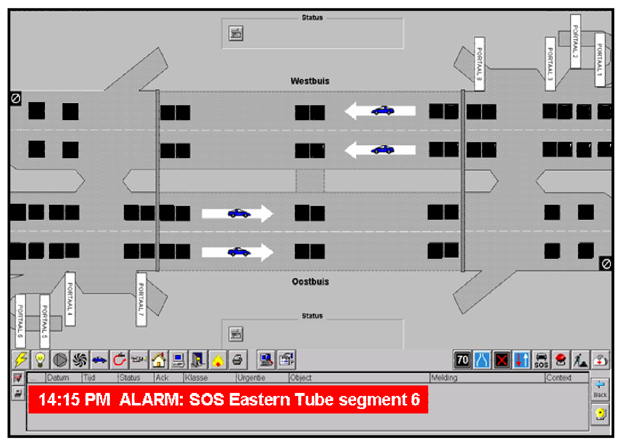
4. COMPUTER ASSISTED INSTRUCTION

Figure 3 shows the instructor agent implemented by means of the Computer Assisted Instruction (CAI) system (Kuiper, 1995). The system manages the execution of a series of training scenarios, the lesson network. During the execution of each training scenario, the CAI system observes and registers the activities of the learner. At the end of each lesson, the system assesses the task performance, by comparing the actual performance and the predefined performance standard. After that, it provides performance feedback to the learner, and chooses a subsequent lesson. Depending on the actual performance in the previous lesson, this next lesson can either be a repetitive, a corrective, or a subsequent (main) training scenario.

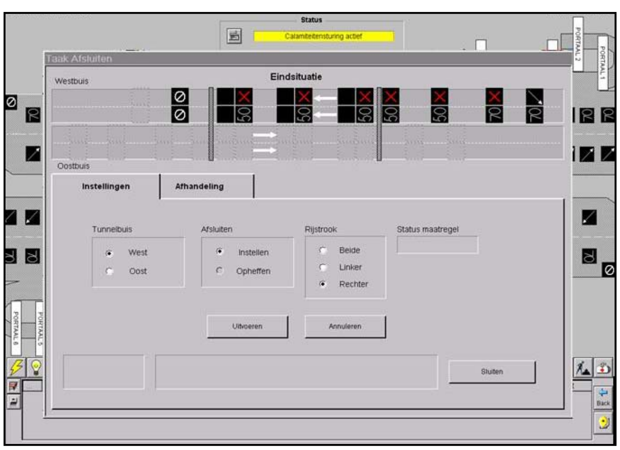
Figure 4 illustrates the interaction between the CAI system and the trained tunnel operator. In each lesson, the CAI system provides a new learning task to the learner by providing instructions on the Instruction PC (Figure 4a) and feeding alarm messages and tunnel system state changes into the simulated tunnel control system (Figure 4b). The learner performs the task by executing traffic measures on the simulated tunnel control system (Figure 4c). The learner can also send standardized information messages to simulated role players by means of a basic communication simulation (operated by means of the instruction PC; see the buttons on the left side of Figure 4a). The CAI system (1) monitors the user input on the tunnel control system and the instruction PC, (2) evaluates whether the chosen measures are correct, (3) determines whether the measures are executed in time and in the correct order, and (4) provides feedback on the Instruction PC (Figure 4d).



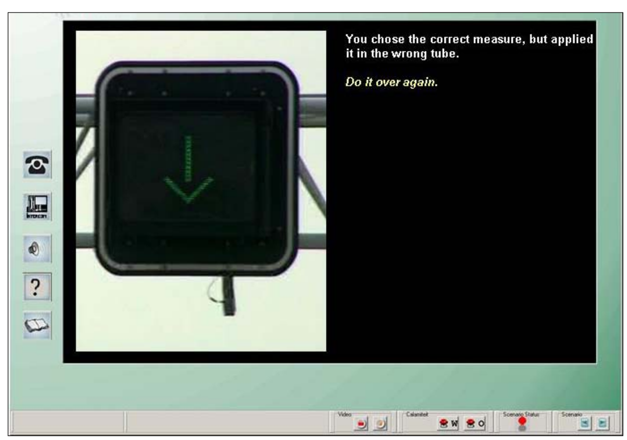
a) Instructions on instruction PC



b) Initial alarms on the control system simulation



c) Execution of traffic measures



d) Performance feedback

Figure 4 Example training scenario illustrating the interaction between the learner and the CAI system

5. WHY DO WE NEED COMPANION AGENTS?

The described instructor agent represents a traditional training method. An instructor chooses the exercises, evaluates task performance, and exactly tells the learner how to act in order to improve performance. Modern, self-directed training methods make the learner responsible for his own task proficiency (Stehouwer, Stricker and van Gemeren, 2006). Learners are stimulated to find new ways to improve their skills, preferably by experimenting and by cooperating with colleague learners. The former instructor changes into a coach who still sets the performance standards, but now only addresses the problems that need to be solved in order to further improve the learner's proficiency. The learner is challenged to find the problem solution without explicit instructions.

Interaction between learners is crucial to the success of self-directed training. Learners together discuss their task strategies, and think about alternative strategies that might improve task performance. In the case of the tunnel operator retention training, no co-learners are present. Here, a companion agent might facilitate self-directed training by playing the role of a virtual co-learner. The following framework for the interaction between the companion agent and the learner is proposed by Chou, Chan, and Lin (2003):

1. <u>One's working and one's watching (suggestion)</u>
   Either the learner or the companion agent performs a task, whereas the other observes the task execution. The observer can ask questions or provide suggestions.
2. <u>Sharing responsibility (collaboration)</u>
   Learner and agent together perform the task. First, the agent provides a basic task strategy and the learner refines it (or the other way around). Subsequently, the agent takes over part of the task execution at times when many concurrent actions need to be performed.
3. <u>Working independently and comparing work (competition)</u>
   Companion agent and learner independently perform the same task. Afterwards, they can compare their performance and discuss it by asking questions to one another.

The actual development of this companion agent is a challenging job. Since the companion agent effectively operates on the same proficiency level as the learner, its capabilities need to match those of the learner. Almost inevitably, the agent needs to exhibit some human characteristics, like the ability to radiate confidence and to express appreciation. E.g. by hardly radiating confidence, the agent can stimulate the learner to critically judge the suggestions provided by the agent. E.g. by hardly expressing appreciation for a suggested traffic measure, the agent can stimulate the learner to reconsider this measure. These human characteristics require the agent to possess and use verbal communication (message content and meaning, intonation, tone color, word craft, etc.) as well as visual communication (facial expression, body posture, clothing, etc.). In our research, we intend to develop a prototype companion agent with human characteristics, and evaluate its educational benefits by means of experiments in our tunnel training simulator.

6. A VIRTUAL OPERATOR ASSISTANT FOR SITUATION ASSESSMENT TRAINING

The development of our initial prototype focuses on the verbal communication between the learner and the companion agent during an incident assessment task. When assessing an incident, the tunnel operator has to interpret his most recent observations and classify the actual incident situation as one of the standard incident types. These observations can be based on images from cameras mounted inside the tunnel, or be based on observations from witnesses located inside the tunnel.

In the case of an escalating incident, the situation inside the tunnel can change quickly. Therefore, situation assessment is an ongoing task of the operator. From time to time, the operator needs to reassess the situation, and decide whether his current classification of the incident is still correct. This can be difficult, since human situation assessment is structurally affected by bias (Fewell and Hazen, 2005). As a consequence, the tunnel operator tends to rely on his initial observations, and will hesitate to adjust his initial incident classification when new events occur. Additionally, the operator tends to search for information that confirms his initial incident classification, and will avoid contradictory information.

Our initial prototype is a virtual assistant that supports the tunnel operator when he is training a complex incident scenario, where the scale of the incident increases incrementally. The agent will operate in accordance with the 'One's working and one's watching' interaction metaphor (§5). It can obtain facts based evidence about the situational awareness of the operator through verbal communication. Furthermore, it is able to question the operator about the underlying motivation for his choices and actions, e.g. by means of a question-and-answer dialogue in three steps:

1. Unobtrusively asking for the operator's actual incident classification ("Anything going on?");
2. Asking for observations that support this classification;
3. Asking for the actuality of the observations and the incident classification.

The answers to the questions make the agent understand why and when the operator obtains an (in)correct incident classification. By means of this knowledge, the agent can try to positively influence the activities of the operator and improve the effects of his training. The timing of the agent's interventions will be closely related to the current activities of the operator. E.g. at times when the operator did not detect a change of situation, the agent will intervene more frequent than before. At times when the operator did respond correctly, the agent will ask no further questions after asking for his current incident classification.

The agent's verbal communication will include both a text-based interface and a speech recognition module. In the future, we intend to transform the agent into an agent that operates in accordance with the 'Sharing responsibility' interaction metaphor. This agent will enable a mixed-initiative dialogue between the learner and the agent. In our presentation at ISCRAM 2007, we will provide a demonstration of the virtual assistant.

7. CONCLUSIONS

Automated retention training for tunnel operators by means of simulator-based training puts large demands on the simulator's educational functions. Intelligent agents are needed to provide performance feedback to the learner, and to interactively help the learner to find ways to improve this performance. TNO develops these educational agents and evaluates them by means of user experiments in order to find an educationally effective cooperation between the agents and the learner.

8. ACKNOWLEDGMENTS

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