A Student-Adaptive System for Driving Simulation

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Abstract

Driving simulators have to be student-oriented. We created the Virtual Driving Instructor (VDI), an intelligent tutoring multiagent system, which provides student-adaptivity. The VDI enhances the interaction between the driving simulator and the student. It uses regressive instruction and feedback, which are adapted to the student, presentation context and task, to help the student improving his driving skills. Collaborative agents realize this. Each agent deals with a sub domain of driving education.

1. Introduction

Driving simulators, such as the Dutch Driving Simulator developed by Green Dino Virtual Realities, offer useful opportunities for training to control and drive a car in traffic situations. With simulators objective measurements can be carried out on the student's driving behavior. The obtained values can be used to adapt the learning environment to the student.

To become a proficient driver, a person needs to acquire various skills, varying from simple to complex levels. This acquisition needs to be guided by a driving instructor. An intelligent tutoring system becomes an innovative technique to create a student-adaptive learning environment by using the individual measurements. The system evaluates the user's driving behavior in relation to the current situation and responds by providing feedback and adapting the simulated environment to the user's needs. For this, the system needs to understand the interaction between the user's and the environment's knowledge and respond to each individual user. In this paper, we present the Virtual Driving Instructor (VDI), an intelligent tutoring system that adapts the evaluation and feedback about the driving behavior to the current user of the driving simulator.

The goal of the VDI is to transfer expert knowledge of driving a car to a student. The VDI is successful if the following conditions are met:

- *Driving Skills*. The performance on all driving skills is sufficient. That means the student drives safe, smooth, and economical.
- *Procedural Skills*. The performance on all procedural skills is sufficient. That means no steps in any driving task procedure are skipped or swapped.
- *Traffic Insight*. The performance on traffic insight is sufficient. The student performs the right driving task at the right time.

In this paper we will discuss the interaction between the VDI and the student and focus on instruction and feedback to the student.

2. Interaction in the simulator

Driving involves an extensive interaction between the driver and the driving environment. As Norman [5] stated, part of the knowledge is in the world, and part of the knowledge is in the head. To responds appropriate to events, the driver has to perceive and understand what is happening in the world and apply his own driving skills and knowledge for that. An instructor has to look at the interaction of and gap between the two knowledge domains, for improving the student's knowledge and skills. Figure 1 shows the interaction between the driving simulator system and the student by data flows. The figure shows two important interaction elements of the system, the 'simulated world' and the VDI. The first concerns presenting visual and auditive information, such that the student perceives the world in which he is driving. The second responds to the student's driving behavior.

The student perceives what is happening in the simulated world (1). Subsequently, he responds to the perceived situation according to his own goals (2). This response may be instinctive or rationalized, and wrong or good. The VDI recognizes the student's driving behavior and relates it to the current situation (5) and previous behaviors. The VDI than may choose for action. If action is required, the system may either adapt the simulated world according to the student's needs (3), give educational feedback to the student (4), or do both.

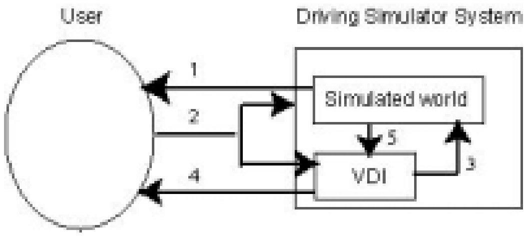

Figure 1. Interactions between driving simulator and the user

Weevers et al. [8] discussed the issues involved with the VDI's architecture and the techniques used to create an understanding of the current situations and performed driving tasks. In this paper, we will discuss how the VDI establishes student-adaptive interaction to improve the education of the learning environment.

3. Regressive instruction

Learning how to drive can only be achieved in practice. We think this is especially true for the last phase of the driver's development from a novice to an advanced level. A novice driver comes across many stages of acquiring different skills, in order to become a skilled driver. Each stage involves different driving tasks. A simulated environment offers opportunities to focus specifically on certain tasks. Michon [4] discerned three levels of driving tasks:

- Strategic level: This is the highest (abstract) level at which one may think of route planning and higher goals determination.
- Tactical level: At this level the driver selects and achieves short-term objectives. One may think of overtaking, merging and crossing an intersection. This level deals with driving maneuvers that can be decomposed in more basic skills
- Operational level: This level holds the most elementary operations, the basic car control operations like using the clutch, steering and accelerating.

In addition, there are different phases in which instructions about a certain task may be provided:

1. Motivating phase. The instructor may give the student a preliminary instructions about the approaching task
2. Mentoring phase: The instructor guides the student, while he performs the task
3. Evaluating phase: The instructor gives feedback after the student carried out the task.

Depending on the current student's driving skills and knowledge, these levels have to be embedded into the current state of the learning environment. A novice driver will start with operational tasks, while a proficient driver is applying tactical and strategic tasks. The levels will be reflected on the simulated world: Operational skills cannot be practiced at crowded intersections and tactical tasks, such as overtaking, require situation opportunities to actually practice that.

The feedback and instructions of the VDI to the student have to adapt to the three levels and the current student's level. We introduce *regressive instruction*: The VDI reduces the frequency of feedback and instruction with increasing skill levels of the student. As the student improves his driving skills the tasks become bigger and more comprehensive; the focus shifts from tasks at operational level, to tactical and strategic level. Therefore, the number of tasks will decrease. Furthermore, the improving student requires less guidance. The novice driver needs continuous instructions, while he is performing driving tasks. Feedback and instructions in all phases are important. However, as the student develops his skills he needs less task preparation from the motivating phase, less guidance from the mentoring phase, and less evaluation from the correcting phase.

The acquisition and training potential of skills in an Intelligent Tutoring System relies heavily on the ability to provide the students with extensive practice on various training exercises in conjunction with adequate instruction (Dong Mei Zhang [1]). Regressive instruction is applied to all (non-predetermined) situations. Since the simulation is partly unpredictable, which results in various situations, the driving exercises combined with the instruction result in good training capabilities of the VDI.

4. A student-adaptive system

Each novice driver has his own specific learning process. Amongst others, this depends on the student's personality, skills and intelligence. A driving instructor adapts the learning environment to the individual student. He may adjust the driving curriculum and feedback to suit the individual needs. Since the driving simulator provides a learning environment in which the student is the focus of attention, the system has to be able to adapt to each individual student. We developed a multiagent system to realize the adaptivity.

The VDI needs to possess and apply different types of awareness. According to Smiley and Michon [5], awareness is the domain-specific understanding to achieve goals for this domain. Within the domain of driving and instruction different sub domains with different goals exist. Each of these sub domains includes its own specific tasks. The VDI needs to recognize the driving behavior of the student and relate it to the observed current situation. Then, the VDI evaluates the performed driving tasks and decides whether feedback to the student about the performances is needed. In addition, all decisions have to be made within a framework of task focus. The VDI should guide the student to accomplish a complete driving curriculum step-by-step. We created agents that each deal with an awareness type.

4.1. The Situational Agent

The VDI needs to conduct analysis on the driving tasks and occurring traffic situations. The Situational Agent implements situation awareness, which recognizes and evaluates the student's driving behavior. It can only accomplish when it knows the possible occurring driving tasks and situation elements. The agent uses an adapted version of the extensive McKnight' and Adams' task analysis [3] on car driving. The integration of this listing with the various situational elements gives the VDI the understanding for contextual relations in the current situations (see Weevers et al. [8] for a more elaborate discussion).

Additionally, the Situational Agent keeps track of each student's performances on each (sub)task. By maintaining records on the current student level and progress for specific tasks, the agent can point out specifically to which aspect the VDI, and therefore the student, should pay attention.

Situations consist of different type of elements. Currently, the agent deals with one continuous (speed control), one dynamic (car following) and one static (approaching and crossing an intersection) aspect, which show promising results.

4.2. The Presentation Agent

Presentation awareness concerns presenting natural feedback to the student. This involves formulating and timing utterances in a natural and educational style. We implemented this awareness type into the VDI by creating the Presentation Agent. It schedules, formulates and presents the feedback and instructions.

4.3. The Curriculum Agent

Curriculum awareness relates to achieving goals for the driving curriculum, such as offering the student the exercises that suits his current driving skills. We made a first step by embedding the structure of the recently introduced new Dutch driving program the RIS (Driving Education in Steps) into the agent. Although dynamic curriculum regulation is still a next step, storing each student's performance in relation to specific driving aspects provides a good overview of each individual. Incorporating the RIS makes the Driving Simulator also attractive for the market, which will stimulate future developments and research.

5. Feedback to the student

Instructions and feedback to the student are one of the pillars of driving education. As we discussed, the feedback concerns different driving tasks at different skill levels and in three phases. For understanding the interaction between the driving instructor and the student, we carried out a two days empirical research on the practical experience of professional driving instructors at the Dutch national police school. This research provided insights into educational aspects, such as feedback timing and the formulation of utterances. The most important results, which are also used by the VDI, were that:

(1) The feedback usually is positively expressed. For example, the VDI should express that something will go better next time instead of stating that the student did something wrong;

(2) The student is being prepared for approaching complex situations by instructions. For example, when the student approaches an intersection, the VDI will tell this and point out the aspects to which attention should be paid;

(3) The instructor mainly focuses on the aspects the exercise is meant for. For example, in case the student is practicing overtaking behavior for the first time, the VDI should not start to complain about gear shifting mistakes. The student pays attention to just the overtaking process. Therefore, feedback should not confuse him to stay aware of other less important things.

5.1. Auditive instructions and feedback

As opposed to real driving lessons, the driving simulator may use different media, such as visual display and audio generation, for presenting the instructions and feedback. Wickens developed the multiple resource theory [9], which states that each type of data perception relates to its own resource with its own capacity. Therefore, different tasks, which utilize different resources, can be well executed concurrently. However, Verweij [7] revealed that auditory tasks may attract the full attention at the cost of the visual tasks.

An important aspect of driving instruction is that the student needs to perceive the feedback as soon as it is provided. This may not be accomplished by visual presentation, since humans only perceive visual data by looking at it. Since the student should be focused on the traffic situations, he should not have to shift his attention to an-other display. We think that feedback display in the windshield of the simulator also will be too distractive. To guarantee the feedback perception we chose for auditive feedback. To avoid distraction by memory consuming auditive data, the feedback should be as short, but informative, as possible.

5.2. Context and task related feedback

Holding [2] stated that providing the driver with feedback about the quality of his performance is useful for motivating and correcting, and improving his performance on tasks. Consequently, the VDI has to provide clear direct feedback on specific driving tasks.

The previous feedback system of the driving simulator provided the same feedback utterance within a predefined time period all over again (For example, “You are driving too fast” every five seconds with the same intonation). Experiences show that students perceived this as irritating and certainly not benefiting the learning process. To overcome this problem, the VDI needs to consider timing and utterance issues for feedback and instructions.

The collaborative processes of the Situation Agent and the Presentation Agent showed good solutions. The Situation Agent decides which tasks require most attention and therefore possible feedback. Furthermore, it keeps track of the feedback provided on specific tasks. The Presentation Agent considers the presentation context. It makes decisions independent from the instruction’s and feedback’s contents. It changes the utterances and intonation of task-related comments depending on related feedback within a given time period.. In addition, the Presentation Agent looks at the priority of the feedback. The student needs to perceive important comments, such as possible life threatening situations, immediately. However, the VDI may refrain from presenting less important feedback. Continuous feedback is irritating and causes mental overload. Priority scheduling solves this issue. McKnight and Adams [3] assigned priorities to the tasks in different situations. The Presentation Agent uses this task information to decide on feedback in the current presentation context.

All timing parameters were determined empirically. Users and our results from the research with the driving instructors indicated desirable moments of feedback.

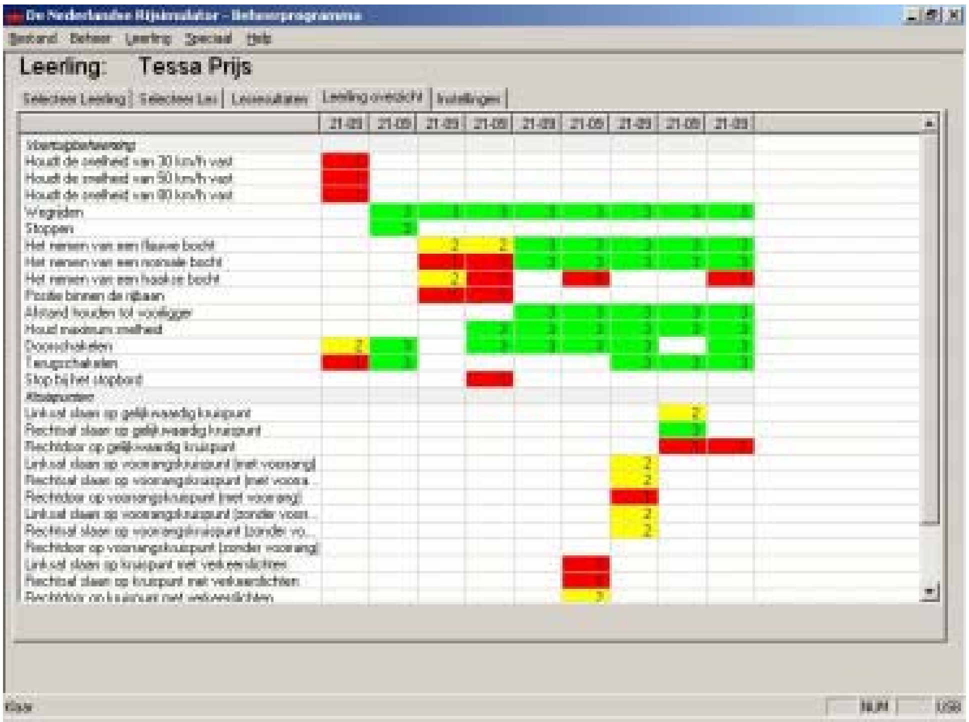

Figure 2. Resume of driving tasks and overview of instruction levels

6. Global performance and application

The VDI has the capability to adapt its comments to the performance of the student. The beginner will be treated different from the more advanced user. The student’s progress is tracked per driving task. In case the performance of the student drops after a while, the comments may revert to an earlier stage. For every driving task, the student goes through three phases. Each of these phases is handled differently by the VDI:

- *Conscious*. The student’s attention is mainly focused on the driving skills. The VDI takes the student by the hand and names each step in the procedure. This is called introducing and mentoring. The performance of the driving skills is evaluated by the VDI.
- *Semi-conscious*. The student has a reasonable control of the driving skills and procedure, but may have fallbacks. The VDI does not mention each step of the procedure any more, but still makes corrections if the student makes a mistake.

- *Autonomous*. The student does not make mistakes in the procedure and has acquired the driving skills. At that point traffic insight becomes more important. Does the student apply the driving task at the appropriate time? The VDI does not even command the driving task any more, to see if the student performs it on his own.

Green Dino, developer of VDI, has implemented the instructor in the Dutch Driving Simulator. At driving schools we tested the VDI on 17 years old students with no driving experiences. The students started with a module on vehicle procedures. In 5 lessons they learnt how to handle throttle, breaks, clutch, steering wheel, and so on. In the second module they learnt how to handle crossings procedures and give right. Each lesson took 30 minutes including an introduction and an evaluation. The introduction describes the drive tasks and procedures. The evaluation showed the performance on the task and the progression in instruction level. All the results are collected in an administration system and can be used for further analysis of the performance of students and system.

Students followed the 10 driving lessons at one day. At the end of the day the VDI gave 'green light' for driving in a real car. The VDI showed to be a perfect driving task and procedure trainer without the help of an instructor. These first results showed the strength of virtual instruction and the working of the VDI.

7. Conclusions

We have presented the Virtual Driving Instructor that realizes student-adaptivity in a driving simulator. The VDI implements several sub domains of driving instruction by the Situational, Presentation and Curriculum Agent. Since each agent takes some specific student related information into account, the collaborating processes emerge adaptation to each individual.

The VDI observes the interaction between conducted driving tasks by the student and the simulated situations. To bridge the gap between the student's and the environment's knowledge, it provides instructions and feedback to improve the student's driving skills. This follows the strategy of regressive instruction: the frequency of feedback and instructions reduce with improving skills. The presentation depends on the relation of the feedback to the actual task and the context of presentation. To avoid distraction from the actual tasks, the VDI provides the comments brief and auditively.

8. Future directions

One of the next steps in the VDI's development is functionality for user modeling. A good user model will influence the decision-making processes of the agents positively and enhance the student-adaptiveness of the VDI.

Currently, the input by the user is active and is realized by mechanic controls, such as steer, gas and throttle. There are many passive opportunities for additional input. We think of observing the user by measuring devices, such as eye trackers. They will provide important eye gaze behavior, which is essential for driving behaviors.

Future research includes feedback and instruction timing issues. The current parameters were determined empirically. Timing values depending on a student's personality and skill level have to be determined more accurately.

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