Intelligent Feedback for Simulation Based Training

Maite LOPEZ-GARATE, Alberto LOZANO-RODERO and Luis MATEY
CEIT and Tecnun, University of Navarra, Manuel de Lardizabal 15,
San Sebastián, 20018, Spain

ABSTRACT
This paper describes the architecture and the process of a system designed to provide intelligent feedback in Virtual Reality-based training simulators. This system will give multimodal feedback to the student as a response to his/her actions in real-time. We propose a two step process. The first step is designed to select the most relevant messages about the student’s activity. The second step selects the feedback message that will be communicated to the student. The process takes into consideration some factors such as the number and nature of the committed mistakes, the student's level, the intrusiveness of each kind of feedback, the time elapsed since the last feedback and so on. The instructor can customize the behavior of the feedback system by choosing the relevance of the parameters used in the feedback selection process. In this way, the feedback system can be helpful for the instructor, as he/she can use a suitable behavior in different types of training sessions (exams, further training, training for beginners and so on). Meanwhile, the instructor can focus on other instructional tasks.

Keywords: Feedback system, simulators, adaptive, training, virtual reality, customizable,

1. INTRODUCTION
A lot of promising studies have been done taking advantage of the Virtual Reality (VR) in education. One of the multiple advantages of its use is that the students can practice potentially dangerous tasks in secure conditions. Not only the risk is reduced, but also the cost of training in the real world. VR has been used in different learning domains as medicine [1], industry, military and driving. Moreover, in VR systems like STEVE [2] intelligent tutoring techniques are used, and the learning process of the student is individually guided.

This study is focused on the use of VR and Intelligent Tutoring Systems (ITS). Specifically, we tackle the problem with the help of a highly immersive truck simulator. The simulator allows the student to feel like driving a real truck thanks to the real truck cabin, the immersive visual output, the audio effects and the mechanic platform which moves to simulate terrain conditions, collisions, etc.

The truck simulator, as it works in real-time, generates much more information than other traditional computer based learning systems, so the control of the training session can be difficult. In this paper, we present the study aimed at automat ing the process of giving feedback to the students during the training sessions [3]. The feedback system has to extract those messages from the simulation that are relevant enough to communicate with the students. It also has to decide how to communicate with them. That is, it has to select the most suitable communication channels having into account that it can take advantage of the multimodal capabilities of the simulator. This functionality emulates the behavior of the human instructor, so it could be related to intelligent tutoring techniques, but only up to a point. Although ITSs consider the interaction with the student to be a very important factor in successful learning processes, they are usually focused on the instructional planning [4]. In addition, traditional ITSs do not have as wide interaction capabilities as real-time simulators have. In this sense, our approach is focused on how to select appropriate multimodal feedback as a reaction to the students’ actions. Thus, the problems we address are directly related to the analysis of the continuous data flow that represents the students’ activity in the simulator. While the human instructor is in charge of the instructional planning (changing the sequence of tasks, modifying the training sessions...), the feedback system is the responsible for giving immediate assistance to the student. Giving assistance involves reminding the student to do something, encouraging him/her, and so on. As a lot of different behaviors can be expected from such a feedback system, designing a customizable system is central to our proposal. The objective is to model different behaviors that the instructor would like the system to exhibit. Each behavior can be appropriate in different learning contexts, like exams, training sessions for beginners, further training... In this way, the tool can fit the preferences of the instructors so they find it helpful. Anyway, we also consider that the feedback system can be part of an ITS, although we will deal with this issue in our upcoming research.

In the following section we present the truck simulator used in the study and the starting point for the development of the system.

2. BACKGROUND
The base of the system is composed by a truck simulator (Figure 1), an Instructor Point (IP)(Figure 2) and a diagnostic component which are described in this section.

The simulator consists of a real truck cabin mounted on a dynamic platform which transmits movement sensations, force feedback on the steering wheel, 3 large flat screens that visually immerses the driver and a surround audio system. In this way, the student feels immersed in the driving environment.

The instructors control the training sessions from the IP during the driving lesson. There, the instructors can see the driving environment thanks to several displays. The IP has also a console where they can operate, control and evaluate what the students do. The instructors confront the students with various tasks tailored to let them show their skills in different situations: city traffic, motorway driving, etc. They can also modify the simulation conditions in real time. For example, density of traffic, vehicle failures, weather conditions like luminosity, ice etc. can be changed. During the training session, in addition to controlling the simulation, the instructors monitor the students’ activity. They assess their general performance, determine whether the students have made mistakes or not and deduce the
knowledge misconceptions that could have caused the mistakes. The instructors use this information to make instructional decisions about what is to be done next to correct the students’ mistakes.

The feedback system has to analyze the messages provided by the diagnostic component and decide which messages are relevant enough in order to interrupt the student and how to interrupt him/her. In the next sections the process and the architecture of the feedback system are described.

3. Our Approach

Our objective is to provide the student with assistance during the training session and to reinforce the work of the instructor. We only focus on the communication with the students in response to their actions. The instructor or the ITS (if it exists) will be the responsible for choosing the learning objectives or updating the student model. However, the objectives of the task and a simple student model, will be used when deciding how to give feedback to provide every student with feedback adapted to them. The general architecture of the learning system is shown in Figure 3.

As the system will give feedback instead of the instructor, we want that the systems behaves as the instructor wants. Therefore, the feedback system must be customizable for emulating desired behaviors or objectives.

The behavior of the instructor is characterized both by personal factors and by instructional factors. Not all the instructors interrupt the students with the same frequency. Some, interrupt them continuously while others let them explore with freedom [9] and learn from their mistakes [10]. The selected criterion usually depends on the objectives considered by the instructors in the training sessions, the learning level of the student, their skills, etc. Each of these factors, in addition to the personal characteristics of the instructors, determine the convenience of giving feedback or not, and how to do it at any moment.

A simulator has more communication channels with the student than a human instructor. For example, an avatar [11] can
4. THE FEEDBACK SELECTION SYSTEM

In this section, we describe the feedback selection system as well as the selection process and criterions that it follows. It is built as a FIPA agent [13] and the decision making process is designed by a rule-based system. Input data come from the diagnostic component [7] and as a result, the system generates sets of commands that handle the communication channels provided by the simulator.

The general process involves analyzing the information coming from the diagnostic component. This information includes continuous notifications about the correctness of the students' actions plus additional information when the student commits mistakes (type and severity of the error, its significance within the objective of the task, and so on). Analyzing this information, the feedback system must decide whether interacting with the student is convenient or not, and how to do it. We take into account that interacting with the student can imply to interrupt his/her activity, so the decision is taken following this main criterion: the feedback system must prioritize that the student continues practicing over interrupting him/her. This criterion is based on Hansen's research, who states that we remember about 35% of what we listen, about 45% of what we see and listen and about 70% of what we practice [14].

Two modules cooperate to make decisions and a third one is the responsible for the presentation of the feedback (i.e. to handle the communication channels in the simulator). The modules execute the following processes:

1. Feedback decision module: It discards insignificant messages among the messages that the diagnostic component sends to notify the actions that the student driver is performing.

2. Feedback selection module: It decides which the optimal feedback message is.

Next, we detail the two modules of the feedback system, the criterions that they use, the data that they need and the output that they generate. The third module, at this moment, only handles the communication channels in the simulator and does not contribute to the feedback selection, so it is not included in the sections below.

4.1 Feedback decision module

As the feedback system receives continuous notifications about the actions of the student, before deciding which feedback to give, it has to decide which messages to discard. The significance of every received message is estimated, and the messages with significance under a predefined threshold are discarded. When the module considers that a message is relevant, the next module determines which feedback must be given.

The instructor can customize the way that the significance is estimated in order to achieve different behaviors. As said before, some instructors are more intrusive than others. The instructor has the possibility of modeling the behavior of the feedback system choosing its intrusiveness. The higher the chosen intrusiveness is, the less messages will be ignored.

As shown in Figure 4, the first step to estimate the significance is to check if the student’s action was diagnosed as a mistake or as a success. We explain the decision module in the following sections.

![Figure 4. Feedback Decision Module](image)

4.1.1 Success

In case of success, the system will estimate the significance of the success depending on the number of times that the student has failed this action previously. The significance will be incremented as the student fails performing the same action. If the instructor chooses an intrusive behavior, the system assigns higher significance.

4.1.2 Mistake

In case that the student makes a mistake, the significance is estimated by means of four parameters. Each parameter is used to estimate the partial significance before calculating the final one. We indicate below which these parameters are, how the system estimates the partial significances and how the intrusiveness of the system affects in this estimation.

1. Time since the last feedback: The time elapsed since the last feedback was given is important in order to avoid overloading the student [15]. Therefore, the longer the time since last feedback, the greater the partial significance of the mistake. Low intrusiveness involves lower significance of the mistake.

2. Seriousness of the mistake: it represents the importance that the instructor assigns to a mistake from an educational
point of view. Thus it increases the need for feedback. Similar to the previously described parameter, high intrusiveness also involves higher values for the partial significance of the mistake.

3. The difficulty of the action: Difficult actions usually require usually multiple trials and training to master them. It is possible that the student can not success until he/she receives some information about how to perform the action. The system will estimate a higher partial significance as higher the difficulty of the action is.

4. Difference between levels: In domains like driving, designing a task that is strictly focused on a few objectives is not possible, and the student can face actions belonging to other instructional level. The actions of higher instructional levels, i.e., actions that the student does not master yet, are less significant than those related to actions of the current or lower instructional level. Thus, in the case of current or lower level actions, the partial significance is the maximum value and it decreases as the difference grows. Intrusive behaviors also increase the partial significance estimate.

After estimating all partial significances, the system estimates the significance of the error. The instructor chooses the weights of each parameter depending on the relevance he wants them to have in the decision process. The significance of the error is computed as the weighted average of all the partial results. The weight values have direct influence on the behavior of the system. Consequently, the election of these values is part of the customization process which is presented in section 5.

4.2 Feedback selection module
This module, will be the responsible for choosing which feedback to give to the student for each action that the feedback decision module has not discarded. When a real instructor chooses what feedback to give to the student, he decides what he wants to achieve with this feedback. That is, he will have to choose one feedback objective. The possible objectives of the feedback that this module considers are: warning the student, motivating the student after an incorrect or correct action (positive feedback), reminding how to avoid an error, explaining an error, offering more information, playing down significance of the error, informing the instructor or ITS about multiple repetitions of an error.

Different types of feedback can fit these objectives, and all of them will be expressed in positive tone as in [11].Deciding the type of feedback and the specific feedback that should be given implies that the system must know the possible feedbacks for the current action. That is why each action contains a collection of possible feedback messages, such as ‘beeps’, audio messages, visual warnings... In turn, each possible feedback has information about its intrusiveness, the channel used to give it and the feedback objectives it can fulfill. The intrusiveness of the feedback type is very important, because as said before, the system will prioritize that the student continues practicing, so for each error the system will tend to give the less intrusive of the feedbacks.

Figure 5. Feedback Selection Module

The selection module can be seen in Figure 5 and will be explained in the next sections.

4.2.1 Success
When the student success and the decision module does not discard the message, it means that he had failed several times before. Among the possible feedback objectives we have now, the one that motivates the student will be selected. When the feedback objective is chosen, the system chooses the feedback message.

4.2.2 Mistake
The feedback selection process consists in three steps that are detailed below. It takes into account the feedback types, the objectives they fulfill, the historical records of mistakes and the feedbacks given during the training session.

- Step 1: Discard unsuitable feedbacks

We have defined the possible objectives that the feedback messages can fulfill, but not all the objectives are suitable for helping the students to solve any mistake. The ‘warning’ objective can be an example. If the student has failed an action belonging to a higher instructional level, the student does not know yet how to face this action. A ‘warning’ message does not help the student to correct his mistake, but it only warns him about something he did wrong. The following parameters are used to decide which feedback objectives are unsuitable.

- Level difference: This parameter is also used by the feedback decision module. It indicates the difference between the level of the student and the instructional level of the action.
- Threshold of allowed mistakes: The system records the mistakes and successes of all the students for each action and the instructor determines the number of mistakes above the average that are acceptable. The threshold of allowed mistakes is the sum of the mistake average and the number of mistakes that the instructor accepts.
- Number of repetitions of the mistake: The system compares the number of mistakes that the student makes with the threshold of allowed mistakes.
o Seriousness: This parameter is also used by the feedback decision module. The instructor assigns a value to the seriousness of each action. For example, it represents the danger of the action in a real situation or the lack of knowledge in case the student does the mistake.

- Step 2: Choose feedback objective

The system will not choose the same feedback objective every time the student repeats the same mistake. In the process of choosing the feedback objective, the system uses the following parameter

- Predisposition to help the student by doing part of his/her work: In real driving lessons, the instructor sits beside the student driver and can manipulate the steering wheel and the pedals. As the frequency that the instructor does these actions is not always the same, we let our instructor choose this predisposition.

When choosing feedback, the system initially chooses to warn the students. Then, it reminds them about the mistake and later it explains the action they failed and it also offers further information. When the students fail a difficult action, the system tries to motivate them. On the other hand, when the action must be learnt in a higher instructional level, the system plays down importance or it helps them by doing part of their work. If the students continue repeating the same mistakes the system will inform the instructor or the ITS because they could decide to replan the class. This objective is selected in case that no other objective is selected.

- Step 3: Choose feedback

Once the system has chosen the feedback objective, and if because more than one message can be used to fulfill it, it has to choose which of the available feedback messages fits better the current objective. The election depends on the free channels and the intrusiveness of the suitable feedback messages.

After the system chooses which feedback message is going to show to de student, the communication module will be the responsible for the communicative act.

5. CUSTOMIZING THE FEEDBACK SYSTEM

Although the system can behave in different ways, every behavior must respect some basic rules: First of all, it must avoid giving messages unceasingly. Second, the student must clearly identify which action is related to the feedback. In order to achieve this, the system can not delay the feedback since the action is performed.

The instructor can customize the intrusiveness of the system, which drastically change the response of the system. Extreme cases and corresponding results are explained below:

1. Non-intrusive behavior: When the instructors choose a non-intrusive behavior, they prefer that the students learn alone.

2. Intrusive behavior: The instructors choose this behavior when they want every learning step to be controlled and that almost every mistake is responded.

The instructor can choose any intrusiveness between the two extremes. The behavior will change by giving more feedback and more intrusive types of feedback as more intrusive the chosen behavior is.

We also let the instructor decide the relevance of every parameter used in the decision making process by weighting them. Thus, the predominant parameters lead the behavior of the system. Besides, they can remove those parameters that they consider to be irrelevant weighting them 0.

We introduce below four preliminary behaviors for demonstration purposes, but they can be refined or new ones can be created:

- Inspector tutor: In an evaluation session, choosing zero intrusiveness, the feedback system does not interrupt the training session.

- Tutor for beginners: In training sessions for beginners, higher level actions will be ignored. In order to achieve this behavior, the level difference must have the highest relevance.

- Tutor for revision training sessions: If the instructor wants to give feedback about serious and low level actions, he has to choose the highest relevance values for the seriousness and the level difference parameters.

- Tutor for further training: Choosing very low relevance for “time since last feedback” and high relevance for “level difference”, the system gives feedback about almost all the mistakes of the current or previous levels. It only waits the indispensable time between feedbacks to generate understandable messages. This behavior can be used in extra support lessons, when the students have to learn fast and they have to concentrate on learnt actions.

6. CONCLUSIONS AND FUTURE WORK

When building a generic feedback system for VR-based training simulators, it is very important to take advantage of all the capacities that the simulator has to offer. The feedback system must choose the most appropriate feedback during the training session depending on the skills that the student drivers lack and trying not to overload them.

We propose a customizable and adaptive feedback system that gives feedback in a similar way as a real instructor would do. In order to achieve this, we propose a two step process. The fist step is designed to select the most relevant messages about the student’s activity. It takes into consideration some educational factors such as the number and nature of the committed mistakes, the student's level, the mistake level, and so on. The second step selects the feedback message that will be communicated to the student. We take care of the factors that impact on the student driver behavior, such as the intrusiveness of each kind of feedback.

Since the simulator is a multimodal system, in addition to the type of feedback that the instructor would be able to give, it is able to exploit some other types of feedback that are out of reach for a human instructor. This is one of the added values of the simulation. All these factors are interrelated but they influence on the feedback selection process at different levels.
By reason of this, we propose a feedback selection process that can value the significance of all the factors in different stages. In addition, as the role of the instructor is vital, the customization of the feedback system to behave as the instructor would like is also addressed.

In the next steps, we want to design appropriate feedback messages. The student will perceive feedback differently depending on the size, colors, location or duration of visual messages; or tone, volume and so on in audio messages. We will classify the feedback messages according to their effects on the students. The student perception of the intrusiveness and their effectiveness for the learning process will be considered. In addition, since the developers have to calibrate the system, (i.e. they have to perfect the behaviors to fulfill the instructor objectives) and they have to add the possible feedbacks for each action, we plan to improve the system in the future by means of an authoring tool.

7. REFERENCES


