Scenario editing tool to support learning and training in virtual reality simulators of construction machinery

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Abstract: This paper presents an edition tool to support the creation of scenarios and exercises for a simulator whose main objective is the training of people in the use and knowledge of construction machinery (currently four wheeled excavator, dumper, lift and platform).

The presented scene editor has terrain definition capabilities, such as terrain deformation and weather conditions. Also, a lot of common objects that are found in the under-construction sites can be added in a very intuitive way. Mobile objects, workers, connected objects and special areas are other element types that can be added to the scene.

The training tasks are defined using a built-in exercise editor, where the exercise designer configures the different exercise script that will be available in the simulator.

1 Introduction

The field of e-learning is often restricted to applications using Web-based technologies and reusable learning content compliant with standards such as SCORM. But there are other kinds of computer (thus electronic) tools aimed at providing learning or training people in specific skills. This paper discusses tools supporting an interactive training simulator, which can be considered a form of electronic learning.

The use of simulators as training tools for machine operators is spreading rapidly. Years ago, simulators were mainly used for leisure and in the military and aeronautic sectors. But recently, their use has also extended to new areas such as the automotive [Civ08] [Land08] [SSys08] [STSo08] [Truck08] [VSte08] [VTI08] and construction [CmLa08] [Sart08] sectors.

When the simulation of machines is intended to train people, the realism of the simulation becomes a relevant aspect. The simulation must resemble the real situation as much as possible. This realism is influenced by the way in which the dynamic behaviour of the machine is modelled and how it reacts to operator commands, the visual quality of the simulated elements and surroundings, and the interaction between the machine and the virtual working environment.

We present in this paper a specific editing tool for the design of simulated exercises and to prepare the virtual environments where they will be performed by the trainee. This work is based on developments carried out in the context of a project called Var-Trainer, which is described in the next section.

2 Project Var-Trainer

The general objective of project Var-Trainer was the design and development of a versatile real-time simulator, based on the utilisation of mixed reality (virtual & augmented reality) in order to train workers in the operation of construction machinery. Special attention is paid to safety aspects with the aim of reducing the accident rate in the construction sector.

Figure 1. A few training sessions with the excavator (top) and with the dumper (bottom).

2.1 Simulated Machines

The simulator is able to represent different construction machines, using one of two cabins with interchangeable controls, which demonstrates its versatility. These machines are: a wheeled excavator, a dumper, a work goods lift and a mast climb platform (MCP).

- The excavator and the dumper correspond to moving vehicles, where the trainee is inside a cabin. The excavator can dig in excavation zones (Figure 1, top) and the dumper is able to transport loads (sand or objects) (Figure 1, bottom).

- The lift and the MCP are placed on the facade of a building under construction. The biggest difference between them is that the trainee is located on the MCP (Figure 2, bottom), whereas the lift is controlled from the ground floor (Figure 2, bottom).

Figure 2. Some screenshots of training sessions for the lift (top) and the platform (bottom).

2.1 Var-Trainer hardware setups

The training system works on two different setups. One is a PC-based platform, using common joysticks or gamepads for control. This is the most suitable for a low cost platform, where the training can be done anywhere, as it does not require very specific or expensive hardware.

A more sophisticated setup uses a motion platform where a real machine cabin is placed. The trainee uses the real machine controls [Seg08], increasing realism in the training session. The platform is properly secured in a fenced area whose door must be closed during the training session to avoid possible accidents. An emergency button will stop all mechanical elements in case of a risky situation. Due to these measures, the installation of this simulator requires an appropriate location with the correct facilities to run the training sessions safely. For details about this setup, we refer the reader to [Seg08].

2.2 Training session characteristics

In both setups, a virtual world is presented to the trainee, where exercises are supposed to be properly performed with the chosen target machine. The difficulty of the exercises depends on the instructor who would take care of the training and the current knowledge of the trainee.

As part of the versatility of the system, the instructor can design the virtual environments where training exercises take place. Designing exercises involves three parts: visually designing the virtual environment including items that will play a role in the exercise, writing an exercise script and defining evaluation rules that will decide success or failure.

This paper presents the main characteristics and features the Scene Editor tool provides for the creation of the scenario and the exercise editing.

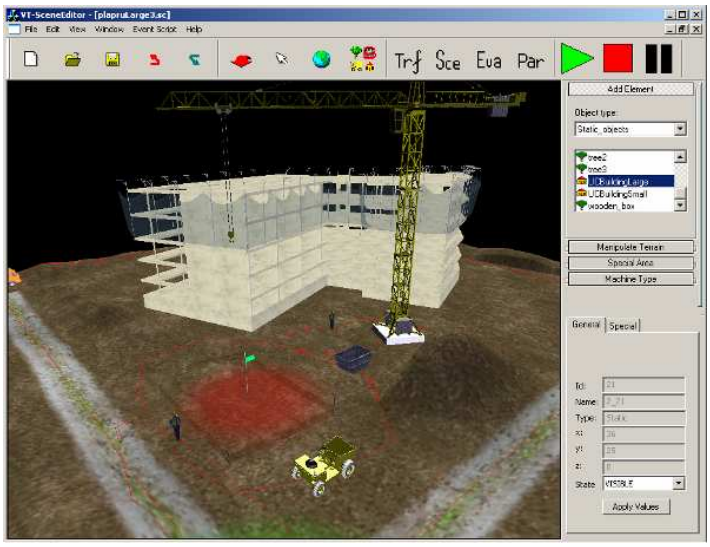

Figure 3. Scene Editor user interface. The 3D graphics are shown in the main area.

3 Description of work

The Scene Editor is a software application independent from the simulator, supporting the creation of the virtual environment that will be loaded into the simulation software. It is not intended to be a generic 3D modelling application, but a system with knowledge of the specific elements relevant to the learning experience.

3.1 The Scene Editor main capabilities

The Scene Editor is an interactive 3D graphics tool that allows instructors to design the environment for the simulated exercises (Figure 3).

The typical construction site scenario is composed of *(i)* the selected machine (excavator, dumper, lift or platform); *(ii)* the terrain, with some roads and special areas defined on it; *(iii)* the buildings in construction; *(iv)* human workers and *(v)* moving vehicles, such as trucks.

3.2 Terrain shape definition

The first step in the design of a scene consists of defining the shape of the ground. When creating a new scene the editor presents the user a flat square area that can be interactively deformed by adding bumps, slopes, hills, etc.

The training environmental conditions can be configured. In the simulator, those values will be used to modify the virtual sky rendering and the lighting conditions, in order to provide a more realistic impression to the trainee. The most important parameters are:

- Starting hour of the exercise. It defines the elevation of the sun and modifies the direction, intensity and colour of sun light. Special visual effects are shown to the trainee when the time is configured to be near dawn or dusk.

- Weather conditions. The weather during the exercise can be sunny; partly or fully covered; with or without several rain densities (see Figure 4). This affects graphics as well as features like friction, making the ground slippery in case of rain.

Figure 4. Different weather conditions: From top to bottom and left to right: Rainy, clear day in the morning, by night and at dusk.

3.3 Adding objects

The designer can interactively add objects, buildings, vehicles and workers to the scene. Mobile elements such as vehicles and people are assigned a path they will follow during the simulation.

The user can also define special areas in the environment with specific meanings. Examples of such areas are start or parking zones, waypoints and excavation areas. Only specially designated areas can be excavated by the simulated wheeled excavator.

The objects are categorized as follows.

- Basic Objects. They represent static 3D objects, e. g., houses, trees … (see Figure 5, right). They are externally loaded 3D models.

- Loads. They are basic objects, but with an added feature. They can be loaded and unloaded in the bucket of the dumper machine, in the lift and in the platform.

- Mobile Objects. They represent animated 3D model walking following a given path (see Figure 5, left). The speed can be given at design time or modified in runtime through the Exercise Editor scripting.

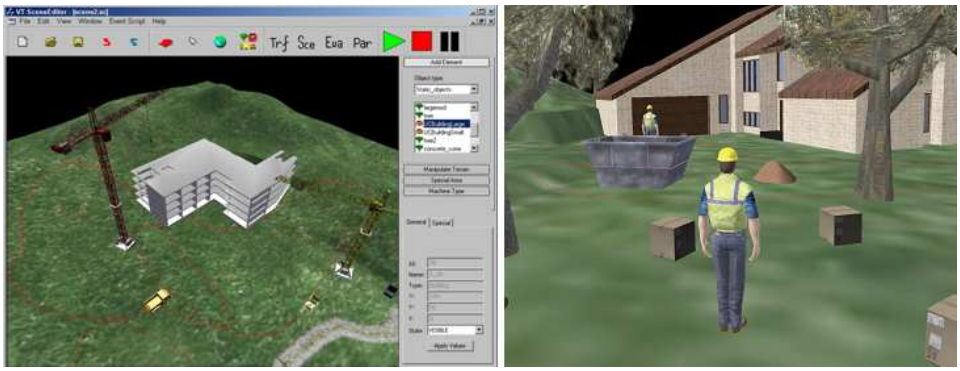

Figure 5. A screenshot of a scene being edited: Worker, objects and loads are placed on the terrain.

- Workers. They are represented by virtual characters. Workers are used to give a more realistic impression to the trainee (see Figure 5, right) and to present the trainee especially risky situations. Also, the avatars can be added to the different floors of an under-construction building.

- Connected objects. They combine a basic object and a path to obtain more complex objects such as roads, underground pipes and electric power lines.

- Special areas. They define special zones, like the Start and End locations. The Digging zone is a special area with special treatment during the simulation: the affected terrain zone can be excavated by the excavator.

- Under Construction Building. It represents a special building (see Figure 6), with a specific floor editor. It is used to create the scenes for the lift and platform simulations.

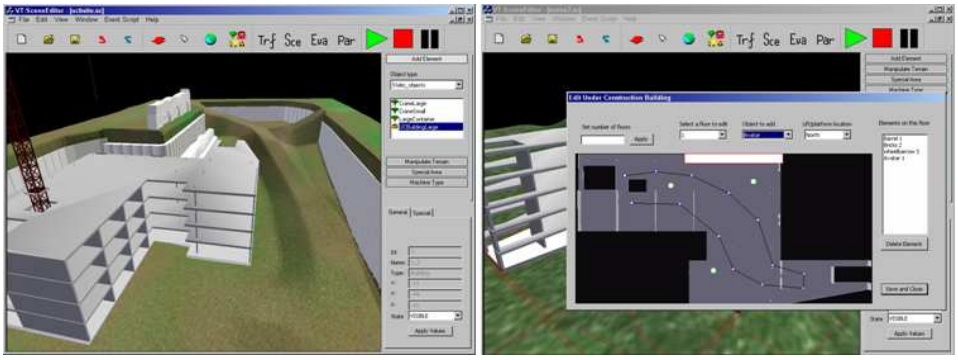

Figure 6. Building editing: Left: Creation of a new one (configurable number of floors). Right: Adding mobile objects (a worker in this case) to a given floor.

3.4 Exercise Editor

The instructor uses a separate module, the Exercise Editor, to define the behaviour of the elements in the scene and their reactions to the driver's actions. Using a scripting system, the instructor is able to configure specific tasks and events for the trainee.

For example, a common exercise for a dumper trainee is to move a certain amount of loads from one location to another. In this case, the trainee will need to know how much load the dumper can carry, in order to be within safety limits. Then, the trainee will drive the dumper following a safe path (without heavy slopes), taking into account the existing traffic (other trucks) and the walking workers. Finally, the load should be dropped at destination point. This procedure will be repeated by the trainee till the required amount is moved. During the simulation, the system will check for any error or warning condition, such as speeding, collisions, or exercise time limit that will result in bonus or penalty points in the final exercise evaluation.

The Exercise Editor has access to all the elements (properties and methods) defined in the Scene Editor. Using this information, a supervisor can define specific behaviour per object, for example, that a given mobile object must start moving when the trainee is close to it.

3.5 Exercise Editor in runtime

The simulator renders a virtual representation of the scene previously defined to the trainee. As the exercise goes by, the exercise editor monitors the state and the actions of the trainee in order to trigger the responses and events that the instructor configured at the design phase.

The Scene Editor can be used during the simulation process to retrieve the real-time state of the training exercise that is being run in the simulator. As the trainee is doing the task and goals, the Exercise Editor changes accordingly, highlighting the current task and subtask and the goal.

4 Conclusions

The Scene Editor was tested by some training instructors and they found a very intuitive and easy to use tool. The e-learning process can be enhanced using the editor, allowing them to design better and more precise exercises for the trainees. Both, simulator and editor are currently being evaluated by real users of construction machinery.

As future work, the Scene Editor tool can be extended with new capabilities that the simulator would require.

From the graphical point of view, it would be necessary in the future to add a preview or testing functionality, where a limited simulation would be launched within the scene editor. The supervisor would be able to detect the major problems with the current state of the edited scene, and therefore, the edition time would be lessened. At the current state of the project, the configured scenarios must be loaded and tested with the simulation tool, (normally, the PC-based setup).

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