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BIM-based virtual training environment for fire-fighters

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Abstract

Nearly every day fire disasters are reported in the news and show the importance of well-prepared action forces like fire-fighters. They have to train their operations regularly to be ready for emergency situations. The best way to do this is to re-enact an emergency-scene in reality. Buildings with a high potential risk for life and material are public buildings like airports or railway-stations and they have to be closed during the training sessions. Another problem is that hot fire cannot be simulated in these buildings. Due to this there are only limited possibilities to train under realistic conditions. Therefore, the use of game technology in terms of serious gaming could be a chance to train fire-fighters in virtual-reality to ensure that the forces are well-prepared in case of emergencies. The challenges here are, firstly, to create a virtual environment based on structural and material composition of the building, secondly, to simulate the potential impact of the emergency situation on the building (e.g., fire, smoke, explosion) in this virtual environment and, finally, to have a realistic visualisation and auralization of the emergency scenario and the ability for the gamer to interact with it. The key idea of the presented approach is to combine Building Information Modelling (BIM) and simulations (Fire, Smoke) with computer gaming and virtual reality methods and technology. With BIM all information is available to create the virtual environment where the emergency scenario takes place. Computer gaming technology can provide an interface for the interaction between the scene and the gamer. The virtual environment and virtual reality technology can be used for stimulating an immersive feeling by the gamer. In order to carry out these tasks, a new Virtual Training System has to be developed which can integrate all required information and technology.

Keywords: serious gaming, BIM, emergency management, fire safety, virtual reality

1 Introduction

Each fire-fighter experienced extreme situations in every mission. For these situations, they have to be physically and mentally fit, so they need a regular training under high realistic conditions. They must be able to handle their extensive equipment perfectly, to orient themselves within a short time on the site of operation to gain an overview of the situation and they must be able to act as a team and rely on each other. These skills are important because in an emergency their own lives and those of their comrades depend on these. The fire-brigade uses different methods and technologies for training their skills. Some of them are described in this paper. Beside this a new approach of a Virtual Training Environment based on BIM is presented in this paper.

2 Fire-fighter training methods

This chapter gives an overview about the current training methods of the fire fighters in Germany. After that some computer games will be discussed, which are already used for fire brigade training or have fire scenarios as game-content.

2.1 Hot training

The training face to face with the flames is an important part of the education of fire fighters. This is one of the significantly involved prerequisites to ensure that fire-fighters can complete their missions successfully. They must learn to get a feeling for the conditions in a burning building - roaring flames, temperatures of more than 700°C and toxic smoke can have serious consequences even if the smallest mistake occurs under the high stress for body and mind during an operation. To learn something about the effect of smoke, heat and fire extinguishing, evaporating water the fire-fighters can train in fire houses or mobile training units (Figure 1).

Figure 1. Fire house

A fire house is a real building with rooms differently equipped for simulating realistic scenarios for fire fighting. The computer-controlled burning unit is driven with gas. At the Fire House of the fire brigade academy of the state of Baden-Württemberg (LFS-BW, 2010) scenarios like a kitchen-, a workshopfire or a "flashover" can be simulated. A fire house is a good installation to train the basics of fire-fighting under conditions prevailing in a small to mid-sized building.

Not every fire department has a stationary fire house available. Another option is the use of mobile training units (e.g., Fire House, 2010). Mobile training units are mostly container equipped with a gas-fire system to regulate flame heights and temperatures selectively (Figure 2). The scenarios simulated in a Mobile Training Unit are more limited than in a fire house.

2.2 Virtual training

Real-life training in fire houses or mobile training units is the best way to develop competences in the hot part of the education of fire-fighters. To train tactic and strategic skills computer games are a common way. With these games emergency response teams can prepare themselves for incidents in a virtual environment. Many incidents can be virtually simulated in dynamic training sessions. Response teams can determine the best strategy, implement it and then observe the consequences of their decisions. A complete log of all actions, decisions and events allows detailed post-action reviews and performance evaluation. Additionally, an immersive training system (thereby avoiding the need to use real staff, vehicles, building and equipment) for fire commanders can replicate realistic incident behaviors and the roles of different personnel and resources at incidents. Examples for virtual training systems are RescueSim (VStep, 2010) or Tactical Command Trainer (Vectorcommand Ltd., 2010).

2.3 Conclusion

With the training methods described above the fire brigade is able to simulate a lot of incidents. But there are some limitations. The scenarios in fire houses or mobile training units are very static and the same variety of fire scenarios than in a training game cannot be simulated. Beyond that, the structural damage of the building is unaccounted. The training game at the other hand cannot simulate real hot conditions like roaring flames or smoke. Another thing that cannot be conducted in a fire house is the possibility to easily setup new and complete different scenarios. With a BIM interface a lot of scenarios based on real-world buildings with high-risk potential could be generated quickly.

However, the assumption is that it is possible to train fire-fighters in virtual reality training methods like it is known from the military sector (Morrison et al 2005). Virtual reality offers high training potential and complex situations can be modeled in an effective manner. Situations which are dangerous for humans can be realistically simulated in a virtual world without any risks.

3 Approach

The aim of the presented research is to improve disaster preparedness by providing a new kind of training environment for fire-fighters based on Building Information Modeling (BIM). Therefore, the development of a new virtual training system is of central interest.

3.1 Virtual training environment

A suitable hardware for the training system is a Virtual Reality Lab like the Darmstadt Civil, Environmental and Safety Engineering Lab (CES -Lab) which was established at the Institute of Numerical Methods and Informatics in Civil Engineering at Technische Universität Darmstadt (IIB). The Darmstadt CES-Lab comes with an efficient virtual environment in the sense of an immersive system. It is assumed that the immersion experience provided by this system, improve the presence of the gamer inside the computer game.

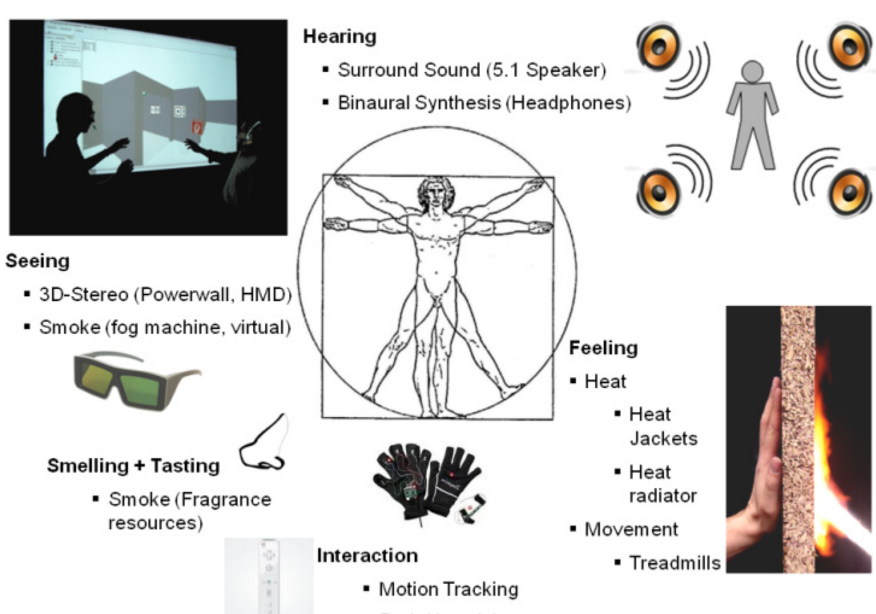

Figure 2. Features of the virtual training environment

Virtual environments vary greatly in detail of the represented conditions of the real world. It is plausible to assume that the more accurate and richly detailed the real-world is mapped in the virtual-world and the more senses can be stimulated; the training effect in a virtual environment will increase (Figure 2).

In order to approximate the visual stimulus conditions, a visualisation technique will be used, which allows the display of stereoscopic 3D-information. In order to minimize unrealistic behaviour in the virtual world, the gamer should have the feeling to be physically in the virtual world. Playing computer-games, gamer often take unrealistic decisions due to lack of physical pain and injury responses from the virtual world. This is known for military training, the "super-soldier syndrome" (Barlow and Morrison, 2005). The use of heating jackets and / or radiators, treadmills and other devices intended to ensure that no gamer feels himself to be a "super-fire-fighter". Beyond that, the realism of a virtual environment is also influenced by the design of the audio component (surround sound) and sound effects (noise from the roaring fire, collapsing structures).

3.2 *Virtual training engine*

The virtual training engine can be described as a game engine. A game engine is modular in general and consists of several components (Gregory, 2009). A Graphics-Engine is responsible for the graphical display on the screen and provides interfaces for loading, managing, displaying and animating textured 3D models. An example for a graphics-engine is Ogre3D presented in Figure 3 (Ogre3D, 2010). A Physics engine, like Nvidia-PhysX (Nvidia, 2010) can simulate the mechanics of rigid-bodies and soft-bodies (building elements) or particles (smoke, fluids). A sound system provides the ability to realistic (surround-) sound. Computer-controlled players are equipped with artificial intelligence (AI). To save and load savegames a game engine have to provide a data storage management. The interaction is usually done through input devices such as keyboard, mouse, joystick and motion or gesture tracking. More interactively components are network support for multiplayer mode and tools for programming and scripting at runtime without having to restart the game.

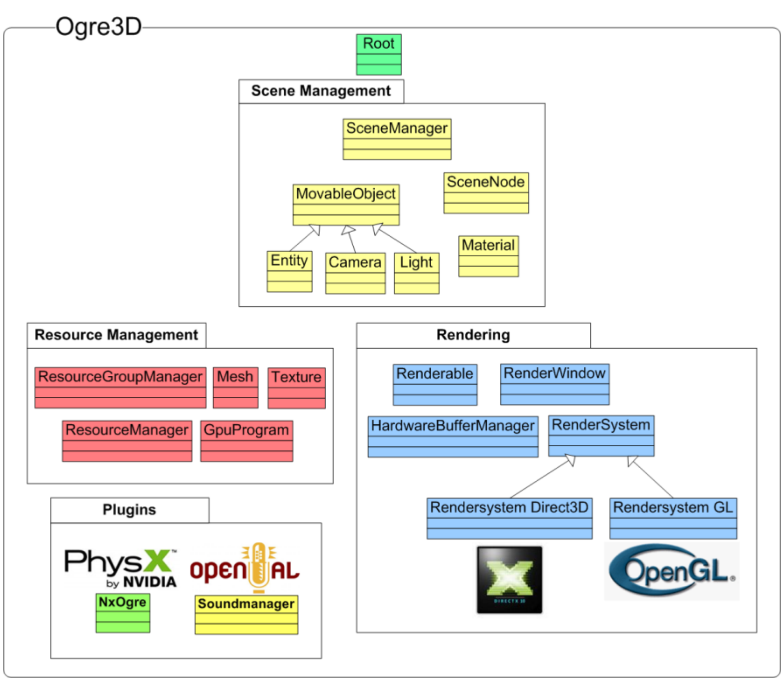

Figure 3. Ogre3D – graphic-engine with physics and sound plugins

3.3 BIM-integration

The core part of the virtual training engine is a simulation model which will include fire, smoke, explosions and structural damage based on the "Building Information Model-Fire Protection" (BIM.FIRE) developed at the IIB (Rüppel et. al., 2006, Theiss, 2005). This information needs to be in a format which can be used for generating the 3D-Objects used by the graphic-engine for visualization and to setup the fire and smoke simulations. Requirements here are, firstly, to support an international accepted data format, secondly, to have the semantic building information available and, finally, to have access on facility management data.

The presented Virtual Training Engine (VTE) implements two interfaces for BIM data. The first interface provides support for Industry Foundation Classes (IFC) (Liebig, 2009). IFC is an exchange format for building models. It has been specified by the IAI (International Alliance for Interoperability). It became an international standard and is supported by most CAD-software products of the leading CAD vendors, e.g., Autodesk, Graphisoft, and Bentley. It defines an exchange format and contains object classes for storeys, roofs, walls, stairs, etc. With IFC-Format all BIM-information is available to create the virtual environment where the emergency scenario takes place. Figure 4 shows the system of the virtual training engine. The second interface uses Autodesk Revit API (Autodesk, 2010) to process the BIM data.

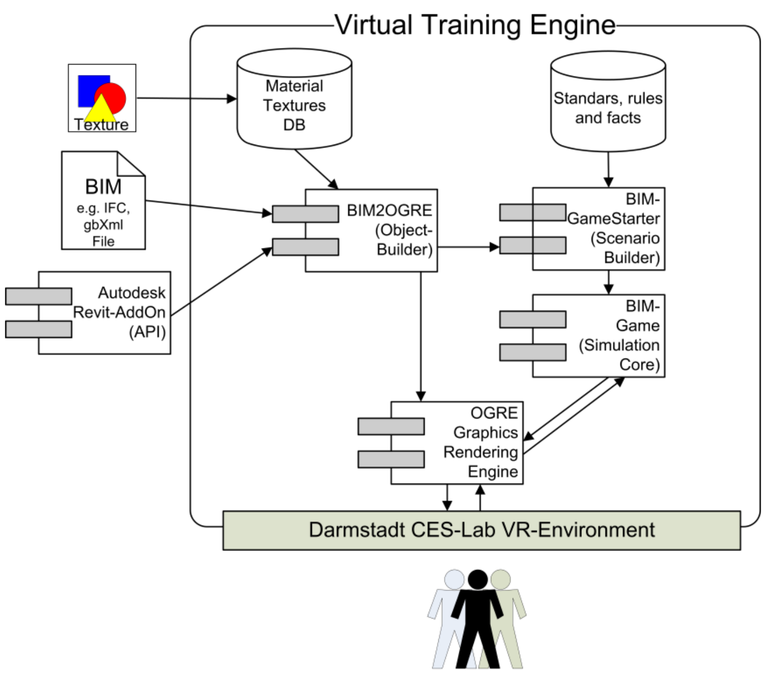

Figure 4. BIM based virtual training engine

The BIM2OGRE mesh builder reads the IFC file and links a texture-map depending on the material properties to each building element. After this the component can generate the 3D-Objects for Ogre3D (*.mesh) and PhysX (*.nxs). To re-create the building in the VTE the information of positions and constraints of the building parts are required. This information is stored in separate files (*.obim, *.opos, *.ojnt) (Figure 5).

The storyline for the game is created by the BIMGameStarter which combines the scenery (3D-Objects) with the screenplay. The screenplay can rely on facts and rules for creating scenarios. These facts and rules can be defined as specified fire scenarios or design fires from standards and guidelines (e.g., DIN, EC) or can be user-defined. The BIMGame represents the simulation-core of the VTE and is responsible for controlling the game flow and for the simulation of dynamic aspects of the scenario. This includes, inter alia, the simulation of fire and smoke, or the behaviour of virtual persons during the game process.

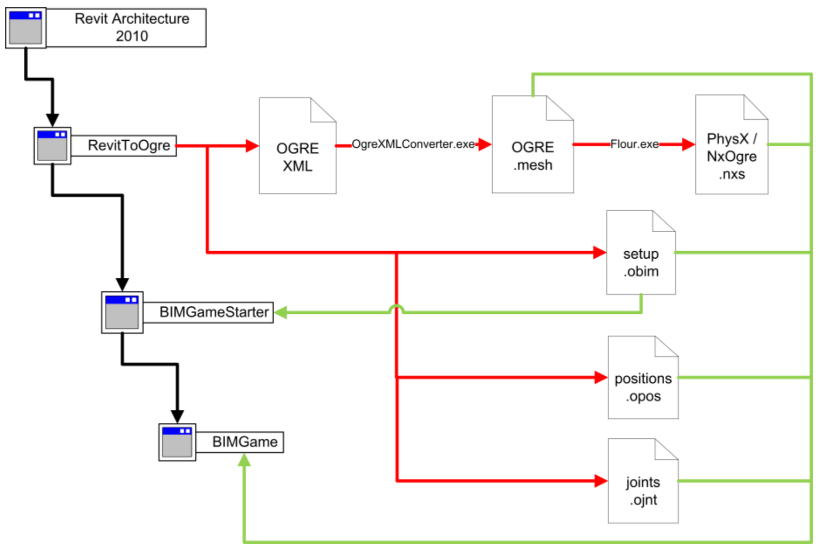

Figure 5. Creating 3D-objects

4 Conclusions and verification

The paper introduces a virtual training environment for fire-fighters to train their operations in a save, interactive and real-time simulation of the incident using game- and virtual reality technology. The base of the virtual world, generated by the virtual training engine, is a BIM-data model. This feature allows a quick setup of scenarios. The system described in this paper enables new training methods to approximate “hot”-training in a virtual environment.

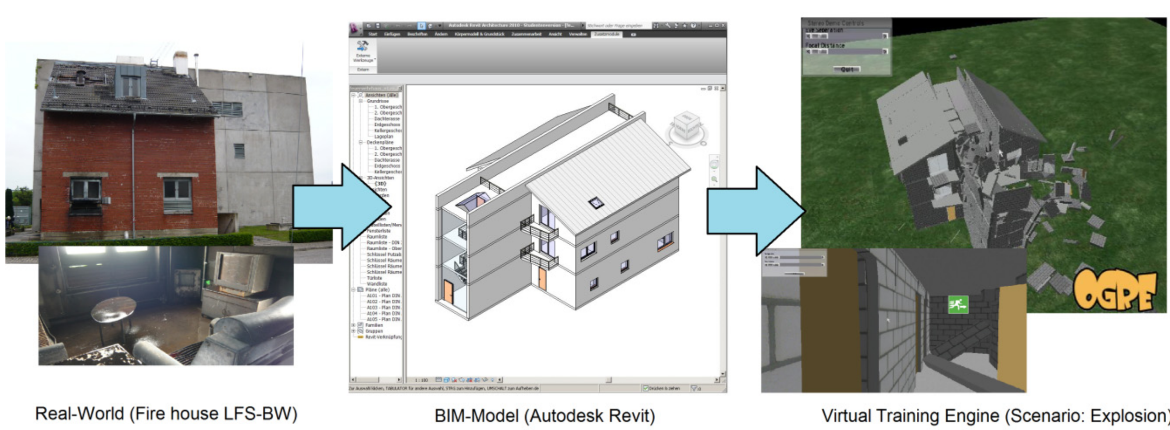

Figure 6. Verification of the virtual training engine

It is planned to evaluate the system by implementing the fire house of the fire brigade academy of the state of Baden-Württemberg (LFS-BW, 2010) in a prototype of the virtual training environment (Figure 6). With this fire-fighters are able to train the same scenarios both in a real and virtual environment. This helps to figure out how to adjust the virtual environment to stimulate the training effect.

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