VIRTUAL TUTORS IN VIRTUAL ENVIRONMENTS

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Abstract

Virtual human models are used in many areas such as planning of production processes, ergonomics studies, planning of maintenance tasks, etc. An Advantage of computer-based drafts of such tasks is the early availability of the virtual manufacturing plant. Before building the real plant, the virtual one can already be used for feasibility studies, solving Integration problems and also for the employee's training. In today's software solutions, it is noticeable that the real trainer is still required. Virtual scenarios are prepared, the trainer explains, illustrates and leads the training. E-Learning based approaches are rarely used, because on the one hand, the integration with the CAD datasets is difficult, on the other hand, the creation of contents with human models is very expensive. Therefore the project "Interactive Content System" (ICS) of Fachgebiet Technische Informatik at the University of Kassel aims to provide CAD-based virtual tutors for simulated scenarios. ICS is a system for the creation of interactive 3D-contents. Many ranges of application are covered, like teaching and training simulations or also visualizations in the "Digital Factory". The present paper gives an overview of the state of the art in the area of virtual people and introduces some usage areas of such digital humans, like for example digital factories, military training and road safety education for children. Afterwards, the ICS-System is presented, which offers some tools that can be used in several application areas, like e.g. teaching and training simulations or also visualizations in the "digital factory".

Keywords: virtual human, virtual tutoring, virtual training, avatar, CAVE

Presenting Author's Biography

Lars Holbein graduated as a Dipl.-Ing at the Universität Kassel, Germany, where he studied Telecommunication and Computer Engineering. Since 2007, he's a research associate at Fachgebiet Technische Informatik (Universität Kassel), where he's doing a Ph.D in the area of AI-methods in simulated environments.

1   Introduction

Virtual Human Modeling is a multidisciplinary scientific research area. Virtual people can be found today in many applications ranging from security, privacy, physical anthropology to space explorations, medical research, engineering, forensic sciences, film-making, augmented- and virtual reality and robotics. The creation process combines many technologies, such as computer graphics, digital simulation, motion capturing, shape reconstruction, cognitive and physiological modeling.

One of the first researchers was W.A. Fetter at Boeing in 1960. He used a pen plotter as a computer graphic device to create models of airplane pilots, as shown in fig. 1.
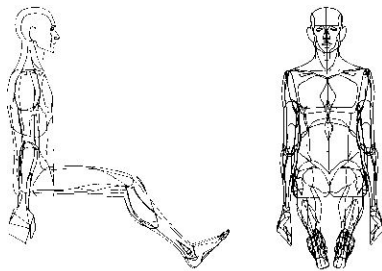

Fig. 1 Fetters first model [1]

With the appearance of powerful graphicscards for the PC the area boomed. One often cited model was the "virtual idol" Kyoko Date, created in 1996, shown in fig.2.

Fig. 2 Kyoko Date [2]

Today this area is driven by the film and game industry. It's self-evident that most actual computer games include very advanced virtual characters. Also computer generated (CG) films with virtual actors are common,

as shown in the example of the CG-film Final Fantasy (fig.3).

Fig. 3 Virtual actor Aki Ross in the film "Final Fantasy: The Spirits Within" [3]

1.1   Definitions

There exist a lot of terms, like avatar, virtual human, digital people, digital human, humanoid model, digital character, digital manikin, embodied human agents, synthesespian and others.

The famous pioneer in this area, Norman Badler, University of Pennsylvania, defines: "Virtual humans are computer models of people that can be used as substitutes for "the real thing" in ergonomic evaluations of computer-based designs for vehicles, work areas, machine tools, assembly lines, etc., prior to the actual construction of those spaces" [4].

Industry created the definition of "digital manikin" (ISO 15536) [5]. A digital manikin is a geometric model of the human body, including anthropometric correct proportions and the ability to control the body parts.

In this paper we define "virtual tutor" as a programmable digital manikin used for e-learning-purposes in virtual environments.

1.2   Usage areas for virtual tutors

Simulation using virtual tutors, in combination with 3D-graphics, is very well suited for training in areas:

- which are dangerous (nuclear power plants)
- difficult to train in extreme situations (airplanes)
- include high costs (factory, offshore platforms)
- difficult to reach (under water, space)
- impossible to practice in reality (explosions, fire in real buildings)

The areas for usage of virtual tutors spans from creation of videos, multimedia-presentations, e-learning courses to VR-based training.

2   State of the Art

The integration of virtual tutors in 3D-models is a complex task. In industrial solutions the modeling aspect is the dominant one. This leads to add-on solutions, where human models are made available in CAD packages. One area is the digital factory.

2.1 Virtual people in the industry and digital factories

A current hot topic in the planning processes for industrial production is the "digital factory".

It is a network of digital models and methods. One aspect is the graphical visualisation and simulation of technical components, machines, up to complete models of factories [6].

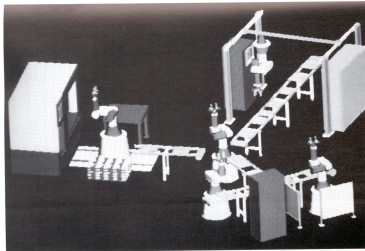Fig.4 shows a part of a factory created with ROBSIM [7] in 1986.

Fig. 4 Factory model created with ROBSIM [7]

Current approaches integrate virtual humans as part of the production chain or for questions of ergonomics in workplace design or cockpits (planes, cars, etc.).

Today, powerful CAD-packages exist, which include digital manikins, like CATIA Human Builder (see fig. 5) [8] of Dassault Systemes or eM-Human of UGS [9]. Common is the integration of models from third party, e.g. Human-Solutions [10] (RAMSIS) or UGS (JACK). Such Products allow users to place biomechanically accurate digital human models of different sizes in virtual Environments such as car cockpits (like in the example of fig. 5). Anthropometric Data of different world regions are here used to create digital reproductions of the customer groups.

Fig. 5 Usage of HumanBuilder [8]

2.2 Virtual 3D Training

2.2.1 Military Training

Military uses virtual humans in combat training simulations or in trainings of complex situations, which are in the real world too dangerous or too expensive. In [11], further pros and cons are discussed. According to this, one of the advantages is the goal oriented training of special situations with different degrees of difficulty.

Also repetitive practice is possible thank the exact reproduction of each training situation. Moreover, user actions can be recorded and used feed-back and reflection purposes. On the other side, deficient realism, the additional learning of handling the simulation and negative effects like Cybersickness are counted among the disadvantages of this approach.

There are some commercial systems, which allow to integrate virtual humans in training simulations or to build complete simulations. One example is the DI-Guy [12] System (see fig. 6) of the company Boston Dynamics. Their product DI-Guy scenario is a tool for creating interactive 3D training scenarios with lifelike human characters. It's composed of a collection of digital human models with a behavior library and an API for their control.

Fig. 6 Example created with Boston Dynamics Software[11]

Another leader in this area is the Virtual Soldier Research (VSR) Team of Iowa University. Their project "Virtual Soldier" [13] combines many modeling technologies to create a virtual soldier model named Santos. The VSR-Team conducts research in the following areas: Human Modeling and simulation, Dynamic Simulation, Virtual Reality, Biomechanics, Control, Multi-Objective Optimization, Clothing, Human Performance Measures, Electromyography, Artificial Intelligence, Human Kinematics and Dynamics, Physiology, Muscle Modeling, Hand modeling, Posture and Motion Prediction, Motion Capture, and Real-Time Visualization.

This impressive list shows the multidisciplinary approach necessary to create virtual humans.

Fig. 7 Virtual Soldier Santos [13]

2.2.2 Disaster Training

VSTEP (Virtual Safety Training and Education Platform), a specialist in serious games, supplies simulation modules, in which various situations can be ma-

nipulated [14], and simulators that allow people to train on-demand for real-life situations safely.

One simulator is "RescueSim". It's a training virtual emergency response training platform. It uses realistic representations for incident training at the Port of Rotterdam or in the petrochemical industry [15].

2.2.3   Language and Cultural Training

One company working in this area is Vcom3D [16]. They develop products and services that provide multilingual, multi-cultural, context sensitive, virtual characters that enhance learning and communication. The virtual humans are here used as online mentors. The goal is developing and evaluating a prototype of web-based instructional content for language training and cultural familiarization. One scenario is shown in fig. 8.

Fig. 8 Cultural familiarization of soldiers in a foreign operational area [16]

2.2.4   Project RMS

Technische Informatik, together with partners, has created a multimedia based learning environment, called RMS (Road Safety Education for Children) [17, 18]. Four children were developed as virtual tutors, which interact and perform with the learner, as shown in fig. 9. RMS was positively evaluated by german "TÜV". A product was created and is available for schools. More than 500 schools are currently using the RMS-Software.

Fig. 9 Children avatars in RMS

2.3   Virtual people as presenters of information

Virtual humans can also be used to present informations. In this context, they replace humans speakers. Systems like "BEAT", "Cyberella" and "Virtual Human" were developed.

The "BEAT" system [19] is specialized in play back of spoken text. This system creates, depending on the content of the text, an appropriate intonation for the speech output with sequences of mimic and gestures. Those can be then visualized with an animation system.

The "Cyberella" system [20] allows the presentation of informations and the interaction with users. A feminine virtual receptionist helps the visitors specific rooms or persons in a building. Through its emotional faculties and depending on the way, how the user communicates with the system, the "Cyberella" avatar behaves differently.

The company Charamel [21] offers commercial virtual human models for products or companies presentations. They can be used as "Web-Guides" and in "Living-Kiosks". As "Web-Guides", they help users to find the information wanted (e.g. a special product in an e-shop). A "Living-Kiosk" is a multimedia based information desk, which can be used for example in stores and malls. The Charamel avatars were also used in the project "Virtual Human" (see fig. 10).

The german BMBF-project "Virtual Human" created anthropomorphical agents for interactions in 3D-scenarios. The goal was to create virtual characters as personal dialogue partners.

Fig. 10 Charamel avatars in the project "Virtual Human" [21]

3   Virtual Tutors in the Project ICS

As already seen, virtual human models are used in computer games and computer generated films, in the industry (planning of production processes, ergonomics studies, planning of maintenance tasks, etc.), in training simulations and as presenters in virtual environments.

Animated pedagogic agents (virtual tutors) are a further development of virtual presenters. In combination with an Intelligent Tutors System (ITS), they assist actively learners inside simulation applications by supporting them in case of problems and by controlling continually the actions of the user and the didactic progress [22].

Only a few of such E-Learning based approaches are available, because on the one hand, the integration with the CAD datasets is difficult, on the other hand, the creation of contents with human models is very expensive.

The project "Interactive Content System" (ICS) of Fachgebiet Technische Informatik aims therefore to provide virtual tutors for simulated scenarios.

ICS is a system for the creation of interactive 3D-contents. Many ranges of application are covered, like teaching and training simulations or also visualizations in the "Digital Factory".

The ICS-System was designed under the following criteria:

- **Extension with other technologies:** For example, storytelling and artificial intelligence (AI). The main purpose is to support authors during the creation of contents and the realization of training simulations. To develop and integrate new technologies, it was important to have the source-code of the system.

- **Integration of avatars:** They are needed to bring life in the simulation and to interact with the users in a natural way, e.g. as tutors. The virtual humans are controlled by user action, script and AI-technologies.

- **Display on different graphical output devices:** It should be possible to display the contents without any adaptation on single monitors and in CAVEs.

- **Saving licenses fees:** From the available commercial applications like Game-Engines, only a few meet our requirements. And by the productive use of those applications incurred costs are not usually affordable in the area of teaching and research. The license costs of the "Unreal Game-Engine" come to $300.000.

3.1   Structure of the ICS-System

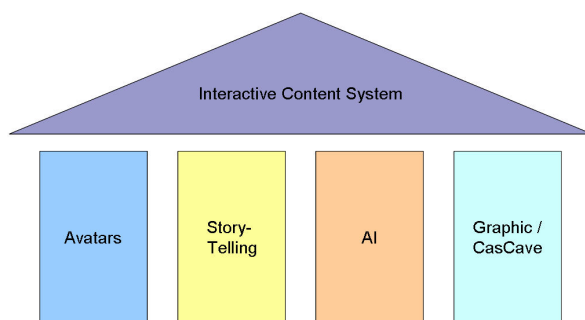Fig. 11 shows the structure of the Interactive Content System.

Fig. 11 Structure of the ICS-System

The ICS-System is composed of four main components:

- Avatars in ICS provide a basis-API with basic control of animation and speech.

- Storytelling offers new possibilities for the creation of interactive contents. It is also responsible for the high-level control of the avatars, the virtual world and the story lines.

- The third component contains AI technologies, for example for the creation of smart objects and the control of autonomous virtual humans.

- The last component is responsible for the graphical output e.g. on CAVEs and the display of complex models.

The ICS-System is based on several open source components, as shown in fig. 12. The first one is LibXML, which is used for reading and writing the XML configurations of the avatars.
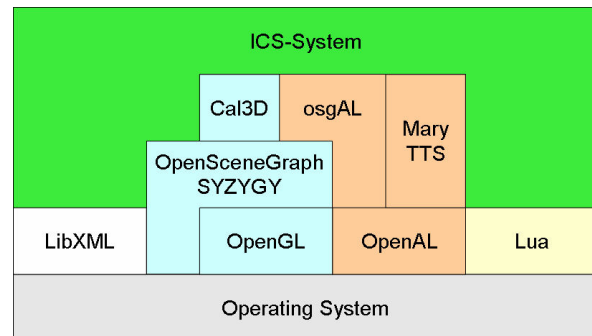

Fig. 12 Structure of the ICS-System

The ICS-System is based on several open source components. The first one is LibXML, which is used for reading and writing the XML configurations of the avatars.

Several components are used for the graphic output. The first component is Cal3D, a character animation library. Basic functionalities are here already implemented, like skeleton-based animation and morphing. This library supports however neither voice output, nor a direct graphic output.

For the graphical output, we followed the approach of scene-graphs. This choice occurred because the graphic output should not only cover the avatars, but also their environment. One advantage of scene-graphs is that, they make abstraction from the basic graphic operations (OpenGL-operations) and the scene is build on the basis of objects. Several import-plugins exist for OpenSceneGraph. This makes integrating models from 3D Studio Max or other modellers into the scene easy. OpenSceneGraph is based on OpenGL, a cross platform graphic-API.

For the sound output an audio extension for OpenSceneGraph called osgAL is used. It is based upon OpenAL. The speech synthesis is made by MaryTTS, a free text-to-speech system.

The scripting is undertaken by Lua. This script language is deliberately chosen, because we need scripts that does not only control the avatars, but also serve to control universally the whole scene with all animations inside.

In the following, we will show the workflow of the creation of tutoring and training simulations with the

ICS-System. So we will begin with creating the scene model. This is the virtual world, where the tutorial or the training will take place. Afterwards, we will prepare the virtual tutors and the rest of the avatars, that are implicated in the scene (like the virtual workers in a digital factory). After that, the tutors will be controlled by high-level commandos with one or more scripts. And finally the result of the simulation will be displayed.

3.2 Scene model

The modeling approach for the creation of scene-models consists of loading CAD-models with different formats in a scene-graph. Thus heterogeneous 3D scene models are build. Virtual tutors will be then inserted in those models.

The 3D scene model can be created with the ICS-Designer (see Fig. 15), which lays on OpenScene-Graph and uses the available model loaders. With the ICS-Designer, virtual landscapes, factory models including several machines and so on can be loaded in the scene.

Fig. 13 shows a city-model that was created during the project "RMS - Radfahrunterricht mit Multimedia-Software" (www.rms-fahrradwelt.de), fig. 14 shows a tutor during a training lesson.

Fig. 13 The virtual city "Burgstadt" from the RMS project

Fig. 14 Tutor demonstrates a learning sequence in the bike-training (RMS)

Fig. 15 shows the ICS-Designer with the example of a manufacturing plant with a virtual tutor.

3.3 Human model

The ICS-System allows the use of virtual tutors, which are used to interact with the user and to vivify the simulation. User inputs as well as script and planned AI-
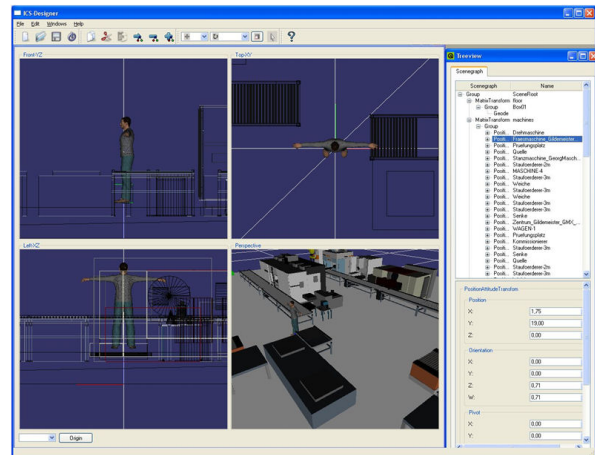

Fig. 15 Modeling a manufacturing plant with the ICS-Designer

technologies [23] make the control of the tutors possible. For the modeling and animation processes, we access partially the wide offer of available applications.

The ICS human models are created according to the following criteria:

- Script-based acting in real-time
- Representation possible also with moderate graphic capacity
- Easy and cost-efficient production of contents
- Credible and realistic acting: Movements and voice output.

The virtual tutors in ICS are equipped with a voice output (Text-to-speech and voice recording). Providing a realistic credible avatar with a faculty of speech is a very laborious process. ICS provides avatars using standard commercial programs (like Poser, 3D Studio Max and MotionBuilder) in a coupled workflow developed for this purpose.

After their creation, the tutors are configured in the ICS Avatar-Editor for their intended use.
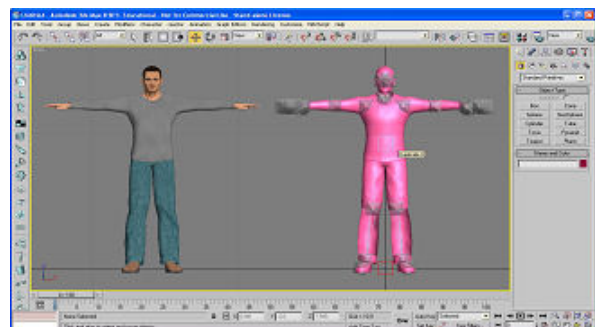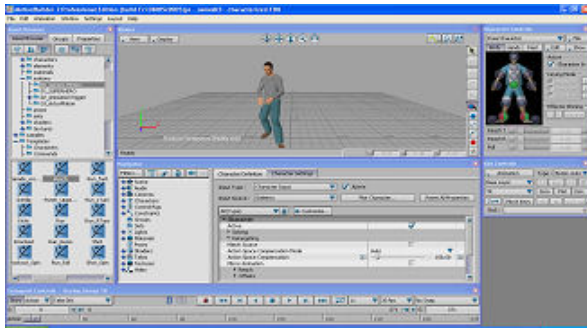

Fig. 16 Rigging the model in 3D Studio Max

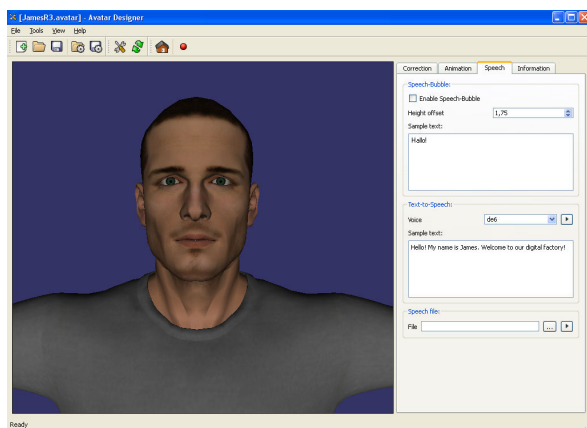Fig. 17 Model in MotionBuilder, Transmission of the movement sequences

Fig. 18 Tutor during a speech test in the ICS Avatar-Editor

3.4 Controlling the virtual tutors

After the preparation of the animations (among others by using BVH motion capture data) and the configuration of the virtual tutors in the ICS Avatar-Editor, scripts are used to control in real-time the virtual scene including model and avatars.

For this purpose was OpenSceneGraph extended by a self-developed Script-node. This node can be programmed in the scripting language Lua and allows the access to a part of the scene-graph API. In addition, routines to control the avatars by Lua-script were integrated. Also the real-time voice output, based on text or a WAV-file, is controlled by the script.

So the avatars in ICS provide a basis-API, where basic controls for animations and speech are implemented. With the script-node and basing on this API, high-level controls can be realized. Those high-level commandos simplify the creation of simulation contents. The following script show a very simple example:

```
function intro(avatar)
    avatar:move(1)
    avatar:turn(90,-1)
    avatar:stop()
    avatar:say("Welcome in the
        digital factory!",
```

```
        "greeting")
    avatar:say("On the right side,
        you can get informations
        about the project.",
        "point_left")
    avatar:say("With the buttons
        on my left side, you can
        choose a scenario and
        start the simulation.",
        "point_right")
    avatar:say("See you!","greeting")
    wait(1)
    avatar:start()
    avatar:turn(90,1)
end
```

In order to enable the creation and management of tutorial contents for scenarios and stories by script, a new ICS component was developed: the ICS Story-Editor (see Fig. 19).

The contents of the virtual world and the procedures (processes and events) taking place therein are introduced and configured through the ICS Story-Editor. Those procedures are controlled by a script and can therefore be altered and displayed in real-time.
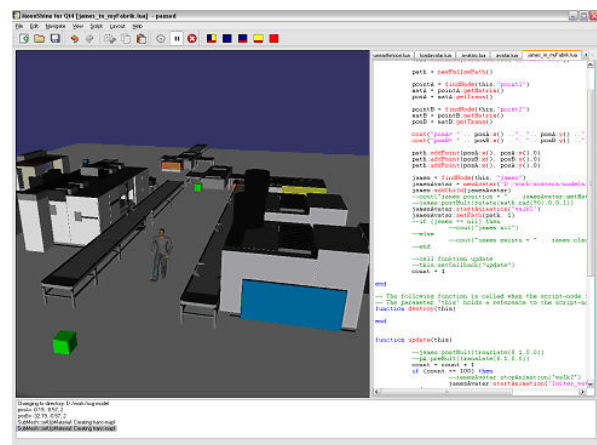

Fig. 19 Controlling tutorial contents by script in the ICS Story-Editor

4   Display / Graphical output

The display of the contents is without any adaptation scalable for the following configurations: a single PC-workstation (computation and display on the same PC), a cluster-based single PC-workstation (computation on a cluster, display on a single PC), a PowerWall (mono, stereo, active) up to immersive display on the CasCave [24].

CasCave, designed and build by Fachgebiet Technische Informatik, is a 3-sided immersive projection environment, that enables the viewer to immerse in a virtual 3D world.
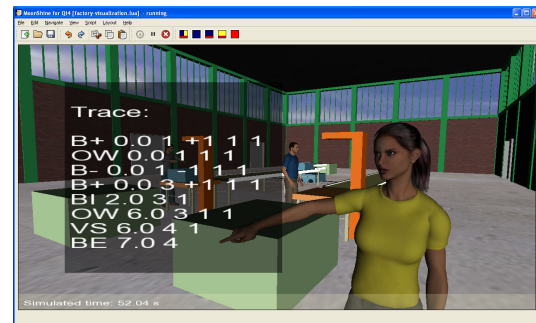
Fig. 20 CasCave: Navigation in the virtual city ”Burgstadt”

Fig. 22 Tutor Jessi explaining the simulation od ”traces” in the plant model

5 Applications

Within the framework of the funding program to enlarge the range of e-Learning offers at the Hessian universities, funded by the Hessian Ministry of Science and Art, an interactive simulation platform ”Ganzheitliche Fabrik” was developed.

The concept ”Ganzheitliche Fabrik” describes the integration of technical, economic, environmental, legal and social aspects in the planning as well as in the operational phase of a plant.

The web-enabled simulation platform [25] has interfaces for interdisciplinary extensions with contents from special fields like e.g. environment, economics, etc. It complements the theory with practice examples and allows learners to deal intensively with simulation technology. The simulation platform illustrates exemplarily a manufacturing plant with its entire process chain. Concrete tasks help the users (learners) to analyze the plant models of the platform. In their virtual learning tours through the plant, the learners are additionally accompanied by interactive employees (virtual tutors), who give them contextual assistance during their exploration of the machines and the production processes.

Fig. 21 shows the web-based solution of the simulation platform ”Ganzheitliche Fabrik”. Fig. 22 and fig. 23 illustrate the CasCave-based solution.
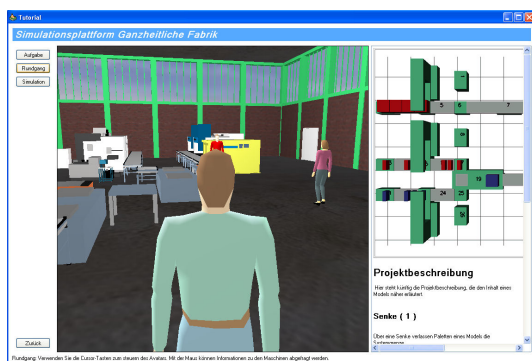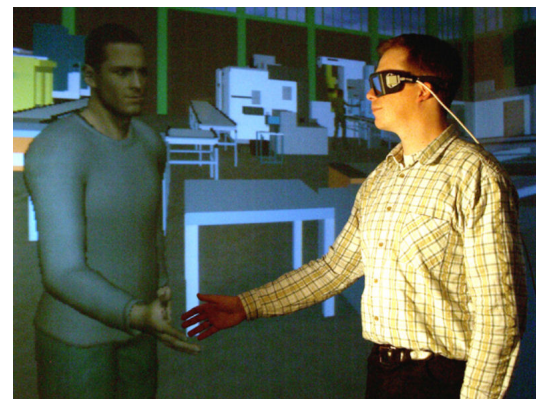

Fig. 23 Tutor James welcomes a visitor of the digital plant

6 Future work

New methods of Story-Telling and concepts of artificial intelligence (AI) are going to be developed and integrated in the ICS-System. A goal among others is to support authors in the best way possible during the creation of contents and to facilitate so the realization of training simulations.

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Fig. 21 The web-based simulation platform ”Ganzheitliche Fabrik”

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