iTeach: Ergonomic Evaluation Using Avatars in Immersive Environments

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Abstract. This paper describes an approach to use virtual reality technology and motion capturing for the immersive teaching of virtual humans. A combination of direct and indirect interaction as well as 2D list style menus and 3D dialogs has been realized to simplify the teaching process. In contrast to existing desktop solutions the presented concept allows even inexperienced users to reasonable work with the system. The interaction principles support an iterative work flow which speeds up the ergonomic evaluation and improvement of industrial work places remarkable.

Keywords: Virtual environments, virtual humans, avatars, virtual reality, ergonomics, production planning.

1 Introduction

Virtual humans and avatars are used in many fields of applications for the evaluation and improvement of ergonomic properties of products, technical systems, etc. Especially the automotive and aeronautic industry evaluates and improves new car interiors, aircraft cockpits and systems operation with virtual humans. The advantage is that the developers can simulate in early development stages easily and fast if the product is usable for different sized and proportionate humans. These evaluations support the engineers to plan sufficient adjustment ranges, to properly arrange important operation elements or to develop different sized product variants for different markets and groups of users.

A virtual human consists of a numerical description of the body and its physical behaviour and a visual representation, the avatar. Several virtual humans, e.g. Ramsis [5] [6] [7], virtual Anthropos [4], CharAT [8], Delmia V5 Human [3], Jack [13], are commercially available. They can be purchased as stand alone packages or fully integrated into CAD-, modelling and planning systems. The usage of virtual humans in the corresponding desktop applications can be considered as standard but the

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handling is complicated and the learning effort is very high. Fully integrated virtual humans in immersive virtual reality (VR) applications offer all advantages of the 3D stereo vision and the interaction with 6 degrees of freedom. The available systems are using very similar interaction concepts for the handling of the virtual humans like the desktop applications [8].

The goal for the herein described iTeach application is to develop an easy to learn, consistent interaction concept that makes the planning and ergonomic evaluation process more efficient and easier to learn.

2 Virtual Humans in Virtual Environments

At the beginning of an evaluation a virtual human is placed in a virtual environment, e.g. a virtual car interior, at the planned working or operation position.

If the purpose of an evaluation is an analysis of a working posture a **static virtual human** is sufficient. The virtual human is placed at the correct position and with the planned posture. Visual fields and reach envelopes [Fig. 1 are switch on to evaluate if all important elements are lying inside the volumes.

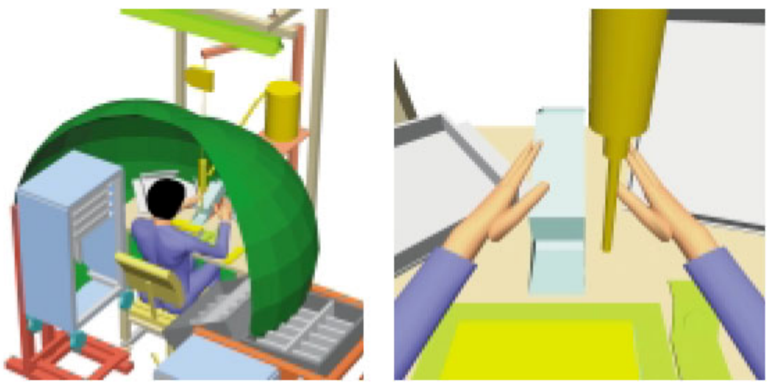

Fig. 1. Static avatar with reach envelope [2]

More complex is the analysis of movements a user must perform to operate a car, a work step, etc. In order to evaluate a sequence of movements a **dynamic virtual human** must "learn" these movements. The user picks control points, e.g. a hand, of the avatar with the interaction device and defines a sequence of key positions [Fig. 2. The positions in between are interpolated to a complete movement. A replay function allows the animation of the avatar and a control of the movements. The definition of the key positions is called "teaching" a virtual human. For complex or long movements many key positions are necessary. The exact positioning and the steady control regarding collisions make the teaching process complicated and very time consuming. The exact coordination of two movements at the same time makes the teaching even more difficult because for each key position the corresponding position of the other body part must be taken into account to end up with coordinated movements of all body parts.

Even a well trained user typically needs many mouse clicks, corrections and control steps from different view positions until an exact and natural looking movement has been defined. In a 2D desktop environment the typical effort for 1 minute simulation is 400 minutes teaching time [10].

In case of the integration of a dynamic virtual human into an immersive VR-applications the stereo vision and the interaction in 6 degrees of freedom supports the user to set the key positions in the three dimensional space and to identify collisions faster.

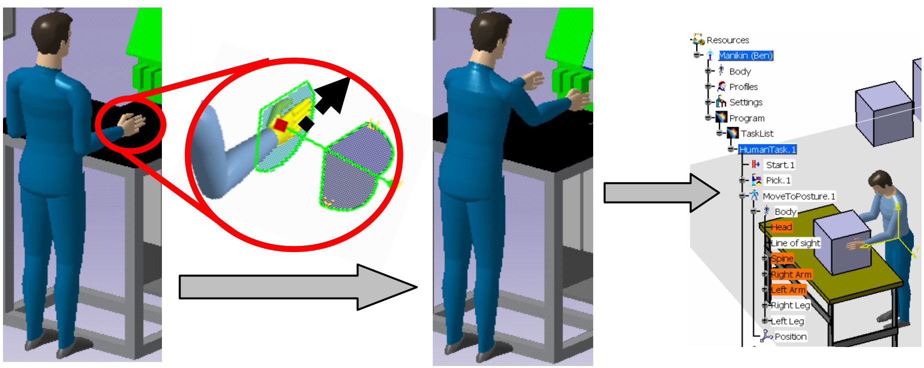

Fig. 2. Setup of a movement of a dynamic avatar (left and middle) and a sequence of movements (right) [3]

3 Application Handling in Virtual Environments

An interaction system for VR-applications consists of one or more hardware devices [Fig. 3 for interaction with 6 degrees of freedom (6 DOF), 2D and 3D user interfaces [Fig. 4 and appropriate interaction and navigation metaphors [11] [9]. Depending on the application's requirements and the user's preferences one or two handed interaction is possible. VR-installations are usually operated while users are standing in front of the projection screen. Object manipulations, navigation and 3D menu are handled with a 6 DOF device. Compared to a desktop environment with keyboard and mouse the user is forced to perform more hand and arm movements.

Complex VR-applications like the ergonomic evaluation with virtual humans need an interaction system that gives the users fast and comfortable access to the functions needed for the evaluation task. Otherwise the expected gain in efficiency due to the 3D stereo vision and the 6 DOF interaction will be lost because of slow and complicated application handling.

Fig. 3. Interaction devices “FHG-IAO Hornet” (left), ART hand target (middle) and ART finger tracking (right)

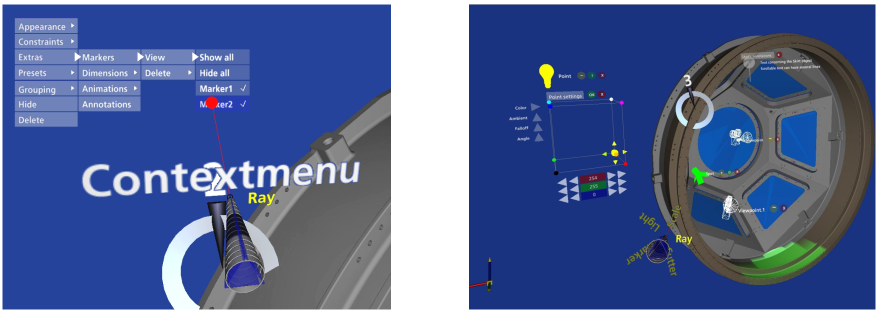

Fig. 4. Examples for list style 2D menu (left) and 3D dialogs (right)

4 Interaction Concepts

Depending on the application’s requirements, the tasks which should be performed with the application and the available interaction system different metaphors for the interaction with the avatar are possible.

- **Indirect interaction in a 2D desktop environment:** The avatar has control points for translation and rotation at the joints. The control points can be selected and moved with the mouse pointer [Fig. 2 left]. Translation and rotation are separate steps.
- **Indirect interaction in an immersive 3D environment:** As in a desktop environment the avatar has control points. The user selects and moves a control point with the 3D cursor connected to the 6 DOF interaction device. Translation and rotation can be performed in one step. Due to the stereo vision the user has a better control for collisions and the correct key positions. The 3D immersive display supports the whole evaluation process [4].
- **Direct interaction in an immersive 3D environment (motion capturing):** The user does not use an interaction device to select and move a control point. The control points of the avatar are directly coupled with the corresponding points on the user’s body. The tracking system records the user’s movements and sends the positions and orientations in real time to the control points of the avatar so that the avatar makes the same movements like the user [Fig. 5. The advantages are that the

user has the immediate and full control on the avatar and that the stereo vision helps to recognize and avoid collisions. Additionally the user gets a good feeling on how complex and stressful a certain movement is. In such a setup it is important that the size and proportions of the avatar are fitting to the user.

Fig. 5. Direct interaction with a virtual human [12]

5 Immersive Teaching

The application's name "iTeach" stands for "immersive Teaching". The purpose is the ergonomic evaluation of industrial working places. The target user groups are non VR-specialists, work place planners, physicians, constructing and design engineers and product developers, using the system for the planning and ergonomic evaluation of work places. The goal is to incorporate the relevant decision makers and discus the different economic, medical, ergonomic and functional aspects in very early planning stages. The system should be designed for its use in industrial work flows.

Accordingly the main requirement was an intuitive and easy to learn interaction concept. The system must support an iterative, communicative working style in heterogeneous working groups. Even novice users should be able to understand the relevant interaction concepts in a reasonable short time. The system must be fast ready to use so that time consuming setup procedures are not practicable.

5.1 System Setup

The target VR-installation is a 265 x 200 cm sized Powerwall. Such a wall is a good compromise between system costs and projection area. The installation is equipped with an ART optical infrared tracking system with 4 ARTrack 2 cameras. iTeach is based on the VR-runtime software Fraunhofer IAO "Lightning". For the ergonomic evaluation the virtual human and avatar Icido "CharAT" [8] has been integrated into Lightning. As hand tracking targets either two Fraunhofer IAO "Hornets" [Fig. 3 left] or two ART hand targets [Fig. 3 middle] are in use. Object manipulation, navigation and dialog and menu handling is performed with a Fraunhofer IAO Hornet.

5.2 Interaction Concepts

For the interaction with the virtual human iTeach combines direct interaction for the teaching of hand and arm movements with indirect interaction for object manipulation, navigation and the handling of 3D dialogs and menus. The direct interaction uses a simplified motion capturing, i.e. the user's head and hands are tracked only. Instead of wearing a special tracking suit [Fig. 5 equipped with many tracking targets users wear hand targets [Fig. 3 middle] at the wrists [Fig. 7. The hand targets are easy to draw and do not need a recalibration before an evaluation session can start. Due to the very high precision of the optical tracking system the user's movements are recorded and transmitted very exactly.

Object manipulation, navigation, dialog and menu handling are using indirect interaction with a virtual ray mounted at the Hornet. The user points on and selects the navigation direction or objects. If an object is selected it is connected to the Hornet and can be positioned by moving the Hornet.

The standard navigation metaphor is "point and fly". Viewpoints can be predefined and or be created during an evaluation session. The navigation to a viewpoint is either a hard "jump to" or a "fly to".

iTeach uses 2D list style menus [Fig. 6 for functions that are not often required during an evaluation session. The structure and logic of operation of these menus is very similar to desktop menus users are familiar with. The structure can be configured according to the applications needs and the user's preferences. The menu operation is completely tracking independent. The Hornet provides 3 buttons and a mini joy stick with the button function up, down, left and right which is used to scroll through and select menu items. The assignment of the Hornet buttons can be adjusted according to the user's preferences.

3D dialogs provide fast access to functions the user needs regularly during an evaluation session [Fig. 6. The dialog's buttons can be selected with the ray mounted at the Hornet. As any other 3D object the user can place a dialog freely in the virtual environment in order to find a comfortable position for interaction and to avoid disturbing occlusions of relevant parts of the displayed scenery. 3D dialogs offer "one click" access to the relevant functions of the virtual human such as record, play save and load teachings, pause, switch on and off inverse kinematics, switch on and off reach and envelopes, start and stop walking and the visual field.

Additionally iTeach can be operated from a remote console so that on demand an operator can take over the application handling and the planner can concentrate on the evaluation tasks.

A griping functionality has been built in. The user has either one Hornet or a finger tracking device [Fig. 3 in each hand. The avatar closes its hand either on a button click on the respective Hornet or by closing the thumb and index finger on the finger tracking device. If the finger tips of the avatar are touching an object while closing the hand, the object is connected to the avatar's hand and can be moved freely as long as the Hornet button is pressed or the fingers on the finger tracking device are closed.

Fig. 6. iTeach 2D menu (left) and 3D dialog (right)

5.3 The Teaching Process

For exact results the virtual human must be adjusted as exactly as possible to the gender, the proportions and the size of the user by adapting the CharAT at the gender and percentile the user belongs to. During the teaching process the user is supposed to stand at a defined point [Fig. 7 the axis of coordinates], the origin of the tracked space, in front of the screen so that the hand and arm posture of the user corresponds exactly to the posture of the avatar [Fig. 7. Each hand movement and rotation of the user is transmitted so that the avatar has the same posture like the user. The user gets

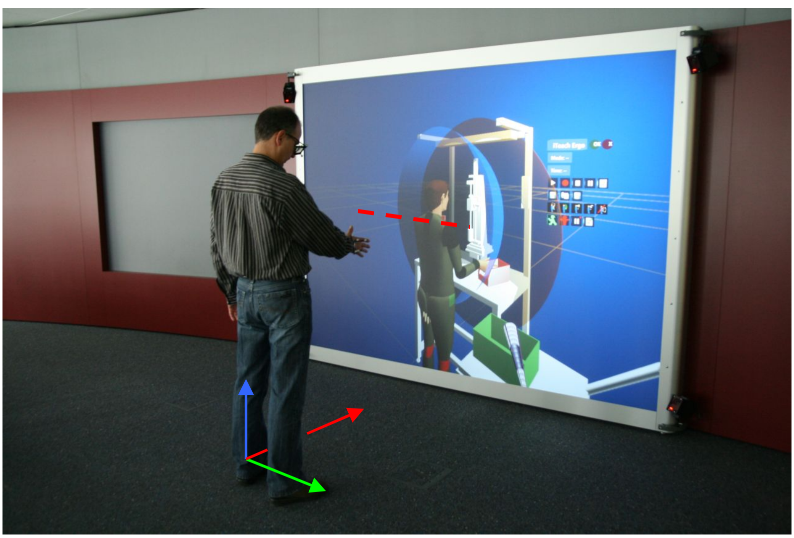

Fig. 7. Direct interaction: Coupling of the user's hand with the avatar (the red dashed line) and the origin of the tracked space (the axis of coordinates)

feedback on the stress level of a posture or movement in two ways. First he/she feels physically in the own hand and arm if a posture is comfortable or not. Second the virtual human indicates with different colours at the joints and the back how comfortable a posture is for the selected percentile of humans.

The avatar gives the necessary visual feedback on how exact the planner performs the movement and if collisions occur.

The head of the avatar can be switched of to allow a teaching position exactly at the planned worker's position. Other viewing positions are possible at any time but teaching gets harder the more the viewing position differs from the position of the avatar.

The user can iteratively reposition, add, replace or remove work place elements with the Hornet if the evaluation shows that the element's position is not optimal or an element is missing or wrong sized.

While replaying a recorded teaching the planner is allowed to navigate freely and analyze the movements and the avatar's postures from arbitrary viewing positions. Additionally the ergonomic stress values delivered by the virtual human can be saved in a file at any point in teaching time. Teachings can be saved to and loaded from files.

6 Summary

For the teaching of virtual humans the combination of direct and indirect interaction and the iterative work flow of evaluation and interactive reposition show promising results. Users are fast familiar with the system and give positive feedback. Compared to desktop solutions with a ratio of teaching time to simulated time of around 400:1 [10] the teaching process is much faster up to a ratio of 10:1.

The combination of 2D list style menus with 3D dialogs is a bridge from the well known desktop interaction to immersive interaction and application handling. Users easily understand how to operate iTeach. The biggest difficulty for untrained users is the free navigation through the virtual environment.

The herein presented approach allows the planner a realistic simulation of working situations at a planned work place. It is very easy to switch on and off and to compare different variants of a work place within one session. If the virtual workplace is scaled up or down the working situation of a smaller or larger human can be simulated in order to evaluate the resulting difficulties and stress values.

The immersive teaching and the, compared to desktop solutions, simple application handling supports the communication and the iterative planning in mixed groups.

The approach can not only be used for production planning but for evaluation of cockpits, machine operations, etc. also.

The next steps are formal user tests with productions planners to work out the user's acceptance and a benchmark between existing desktop solutions and the iTeach VR-application.

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