A framework for rapid evaluation of prototypes with Augmented Reality

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ABSTRACT

In this paper we present a new framework in Augmented Reality context for rapid evaluation of prototypes before manufacture. The design of such prototypes is a time consuming process, leading to the need of previous evaluation in realistic interactive environments. We have extended the definition of modelling object geometry with modelling object behaviour being able to evaluate them in a mixed environment. Such enhancements allow the development of tools and methods to test object behaviour, and perform interactions between real virtual humans and complex real and virtual objects.

We propose a framework for testing the design of objects in an augmented reality context, where a virtual human is able to perform evaluation tests with an object composed of real and virtual components. In this paper our framework is described and a case study is presented.

Keywords: Augmented Reality, Object Behaviour, Virtual Humans, Prototyping, Human Factors.

1. INTRODUCTION

With emerge of new technologies we have the possibility to design mixed interactive environments, containing real and virtual objects, and humans. Some companies have started using or testing virtual reality technology for specific aspects of manufacturing [1][12]. Boeing and Ford Motor Company have both used virtual reality within the product design phase. Boeing uses an Augmented Reality set-up where through a HMD computer generated images superimposed over real objects for manufacturing assistance. Feiner et al. [2] have developed a knowledge-based AR system for maintenance and repair instruction at Colombia University.

This paper focuses on creating mixed environments, where users can interactively evaluate synthetic prototypes in physical environments. Our objectives are: extending existing objects with new virtual components, evaluating such mixed prototypes within a real environment with a virtual human. The proposed framework incorporates Augmented Reality tools and methods to create a testbed meeting our objectives.

In Virtual Reality an object is represented by it's geometrical 3D model. Additionally some object behaviour attributed is attached to the object, if necessary. During a simulation users or autonomous virtual humans may interact with this object using the semantic information stored as object behaviour attributes. A similar approach is used in real world. For example for a drawer, we know where to pull or push by experience or thinking. As the latter method is out of scope of our research, we looked for an intuitive way to show virtual humans how to interact with real and virtual objects.

Object interaction in virtual environments is widely needed and many approaches are available in the literature. However, in most cases, the concerned topic is the interaction between the user of the system and the environment [3]. In our approach we make use of virtual human-object interactions, in order to be able to measure and extract ergonomic data (as field of view and reach ability aspects) with different kinds of virtual humans, with different skeletons sizes and situations.

Virtual human-object interaction techniques were first addressed in a simulator based on natural languages instructions using an object specific reasoning module [4] [5]. Also, virtual human-object interactions have successfully been used to train complex machines usage [6] in a virtual environment where the virtual human teaches the user how to correctly operate machines in many situations by demonstrating the operation with the machine in an interactive application.

Our augmented reality context presents a fast set-up of the environment to evaluate, as only part of the environment needs to be modelled, so that parts that don't offer interactivity to be tested are simply mixed with the real video input.

2. FRAMEWORK

Modifications and extensions to existing objects or creating a new object from scratch goes to the following work processes: Idea, Design, Test, Prototype and Manufacturing. This is an iterative workflow, where at each stage some improvements are made due to evaluation results. The design has to be changed and evaluated again. One goal of our framework is to decrease the time spent in this workflow.

Our framework is well suited to test modifications in existing objects without the need to construct a real prototype. In this way, we propose a methodology based on the following three steps:

1. An outline shape of the existing real object is roughly modelled using standard modeller CAD software, providing a geometric shape of the object to test. For large machines, only the parts of interest are needed to be modelled. We assume that in most of the cases a CAD model of the machinery is available. This geometric model is used then as a guide to place the new parts to modify and test the object.

2. The geometric model is then loaded in a specific feature modeller, where the behaviours of existing parts in the model, and the behaviours of the new parts to evaluate are defined. This modeller is called SOMOD, from Smart Object Modeller. A first version of this modeller is described in [7]. Possibly, for machines with complex functionality, more complex behaviours can be also included, and new graphic programming techniques were included in SOMOD to allow easy definition of behaviours based on graphic finite state machines.

3. Once the model with all behavioural features is defined (the smart model/object), it can be loaded in a simulator environment supporting mixed environment with virtual models and real input video. Now, only the smart model is kept as a virtual object, while the scenario, the ambient where the machine/object is being tested is completely put in the simulator with the real video input.

The smart object description contains all needed information to let a virtual human interact with the modified virtual object part. The model of the virtual human can be used to extract important ergonomics factors to evaluate the modified part of the object. We have developed an Augmented Reality (AR) system, which displays virtual objects in a real environment correctly. Our AR system enables to evaluate prototypes composed of virtual parts mixed with real objects and experiment ergonomics aspects through Virtual Human simulations. The Figure 1 presents the workflow of our framework.
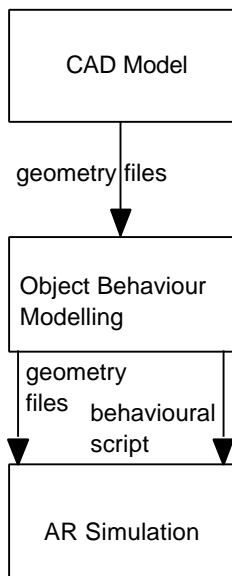

Figure 1: Framework components

3. GEOMETRICAL AND SEMATIC DESIGN

In our framework we may use several approaches to evaluate a prototype. One approach is to test a complete object from scratch and evaluate it in a real environment. Another one is to design one specific part or an extension to the object and test it on the real object with AR system. In both cases it is highly possible that the CAD model of the machinery is not adequate for an interactive real-time AR experience. The CAD model has to be simplified in order to get acceptable frame rates for our simulation.

Afterwards we add semantic properties to the object, using SOMOD[7]. This software tool enables us to design complex interactions with objects like grasping, pull, and push with virtual humans. We may describe object behaviours of a virtual object or a real object as well (translation of a drawer). All the behaviours are stored in a machine-readable interactive scripting language, Python [8] for later use for an Augmented Reality Simulation. The Figure 2 presents snapshots from an interactive object behaviour design.
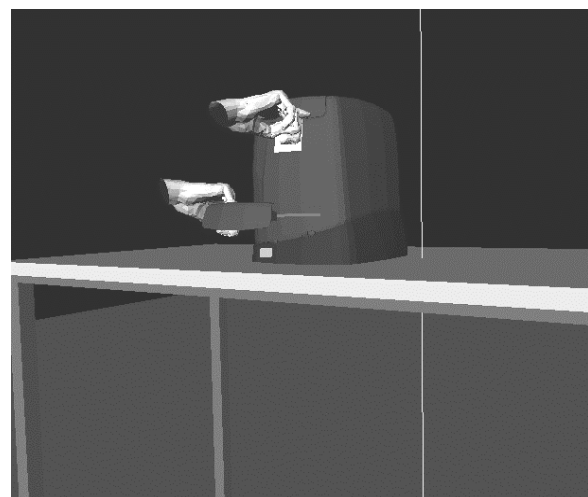

Figure 2: Snapshots of the Object Behaviour Design

4. AUGMENTED REALITY SIMULATION

Augmented Reality is an emerging technology, where virtual and real elements (objects, humans) interact in a mixed environment[13][14]. A lot of effort is put on HMD based or projective AR systems. Our AR concept is focusing on 3rd. party point of view, where we emphasize on creating photo-realistic illusion of a mixed environment for a large user group/audience. We developed an integrated AR system to perform our simulations.

Sannier [9] described an integrated animation system for virtual humans, Virtual Human Director (VHD). VHD incorporates fully integrated virtual humans with facial and body animation, and speech. It provides a range of animation, interaction, scripting and camera control capabilities integrated into one single virtual environment. Torre [10] extended VHD with a computer vision based tracker for AR research. The tracker gathers information from real world on objects of interest. It performs a model based optimisation algorithm over a gradient image. A standard camera calibration method is used to calibrate the real camera. The tracking information is transmitted to VHD over TCP/IP connection. Balcisoy[11] described the integrated AR system with additional tools for navigation and client-server. Our AR system does not require cumbersome sensors like magnetic trackers or specific targets to register or track objects in the real world. Such a non-invasive vision system has a large tracking space and produces photo-realistic illusion.

We defined and implemented a scripting language for Virtual Humans and Smart Objects in Python. This language provides necessary syntax to create complex scenarios for interaction. One important aspect is that such a script is readable for simulator and for the user. Multiple scenarios can be written before an evaluation, executed in one single simulation process. The SmartObject behaviours are accessible in this scripting environment. The Python interpreter is connected with VHD over TCP/IP.

VHD serves as core platform for real-time animation and simulation. The tracker gathers information from real world on objects of interest. The Python interpreter translates user input and prepared scripts into internal animation calls. VHD performs the simulation and renders the synthetic scene.

The output image is send to an off the shelf chroma-key mixer, where the filmed image and rendered image is mixed. In chroma-keying technique an intermediate colour, acts as a "keyhole" and determines where a video layer shows through another. Compositing is performed by Sony DFS 300P mixer. We set blue as keying colour. Some real objects of interest, like table are presented in virtual environment with 3D models in keying colour. This ensures correct clipping of real and virtual elements. The Figure 3a has the O2 workstation all in virtual. The Figure 3b is a snap shot from live output from video mixer, where only the CD-ROM drawer is rendered. The mixed image is then displayed on a large monitor to the user/audience.
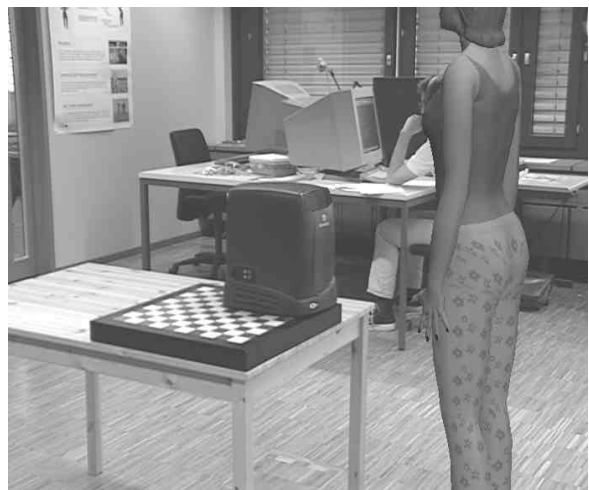

Figure 3a,b: Real (up) and Virtual (down) O2 workstations.
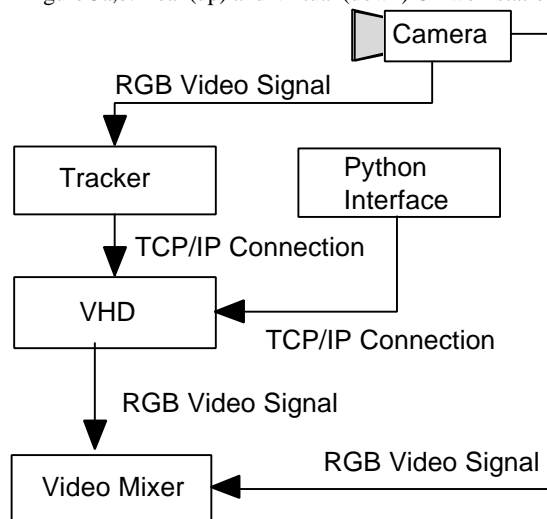

Figure 4: Components of AR system

The Figure 4 depicts our AR components in detail. One major advantage of such distributed components is that we can use one workstation for computationally heavy tracking algorithm and another workstation for rendering. We use an Onyx2 Workstation for rendering and an Octane for grabbing

the video and performing the tracking algorithm. Our system performs with such a set-up 15 frames per second.

5. CASE STUDY: DESIGN AND PLACEMENT OF A CD-ROM DERIVER

To present our idea we worked on an example case: Placing a CD-ROM driver in a workstation. We want to experiment with the placement of the CD-ROM driver and figure out which position is most suitable. We assume that the Silicon Graphics workstation O2 has no CD-Rom driver. The 3D model of the CD-ROM is available and we know that it has to be placed in the front of the workstation.

The model of a complete Silicon Graphics O2 workstation is available from a Silicon Graphics demonstration in VRML format. We developed the necessary object behaviours for the CD-ROM driver with SOMOD. In this case study we designed:

where the virtual human should stand to interact with the O2.

where to push the button on CD-ROM drawer,

where to place a CD inside the drawer, the same position is also used to take it out,

translation of the CD-ROM drawer, when it opens and when it closes.

We stored this information as Python script. The script contains short commands for users. Some example Python commands are:

vhdpushbutton(actor1, o2cddrawer)

vhdgraspobject(actor1, o2cd)

vhdpositionobject(o2chdrawer,positionx, positiony, positionz)

The underlying Python language for Virtual Humans enables users to type simple commands for complex interactions. An inverse kinematics module lets a virtual human reach a target with left or right hand including knee flexion and leaning. We defined some keyframes for hand finger movements to get a correct hand posture for pushing a button or grasping a CD. These keyframes are included into the SmartObject data, so the virtual human knows how to handle an object correctly autonomously.

To test and evaluate different locations on a real O2, we register and track a real workstation within our AR system. We also made the model of the table to have a correct occlusion between the real table and virtual human. A semi-autonomous Virtual Human walks to the pre-designed position in front of the real workstation and relocates the CD-ROM driver. An operator types in Python commands to guide the virtual human or to relocate the CD-ROM drawer. Participants can observe the virtual human performing different postures and grasping movements, and decide which location for a CD-ROM driver is most user-friendly or how the distance between the virtual human and O2 effects on the virtual humans body posture.

The Figure 5 depicts a virtual human testing a CD-ROM driver in a mixed environment at different distances. In the Figure 5a the virtual human is 80 cm away from the O2, and in the Figure 5b this distance is 60 cm. The left hand of the virtual human goes to the same place, but the upper body posture is different. Our inverse kinematics module is capable to give visually acceptable body postures. However we cannot guarantee obtaining valid human factors data from the performed postures. In this case study we concentrated only in the design of our evaluation framework.

The Figure 6 presents some snapshots from an interactive experiment, where a virtual human tries to operate the CD-ROM drawer. There is a significant change in the body posture between the Figure 5 and 6, which is due to the position of the CD-ROM drawer.

All the images are taken from a live experiment. We replaced the CD-ROM drawer from its original location, and we also changed the position of the virtual human. This allowed us to generate a large set of data of visual evaluation purposes.

Figure 5 a, b: A Virtual Human testing a virtual CD-ROM driver from different distances. The driver is placed lower. In these images a virtual model of the CD-ROM is placed in a lower position in the O2, like in the Figure 2.

Figure 6 a, b: The images show two snapshots of the simulation of a virtual human operating the CD-ROM driver in an upper position. Note that all the components of the O2 are real, but the CD-ROM driver is virtual.

6. DISCUSSION AND CONCLUSION

Extending 3D geometry with semantic information allows users to experiment with a large set of possibilities without having extensive knowledge on the underlying simulation system. Using real machinery and surroundings as part of the interactive simulation increases realism. This approach also decreases time for building complex virtual environments and heavy computations to render them.

Virtual humans are proving large range of animation capabilities. In our case study we made use of an inverse kinematics module for animation of the virtual human body. For some specific animations keyframed animations can be used also.

The movements of the virtual human can then to be interpreted by ergonomics experts to study human factors issues. However we do not provide ergonomics data on comfort, injuries etc. This is a possible future work to be investigated. On the other side we provide a flexible interactive tool for generating photo-realistic experiments in a mixed environment.

In this paper we presented a new framework for evaluation of prototypes with Augmented Reality. We have shown that using our approach users can decrease the time spent on prototype evaluation and have a realistic testing environment.

7. REFERENCES

[1]   Chuter, C., S. R. Jernigan, and K. S. Barber. "A Virtual Environment Simulator for Reactive Manufacturing Schedules." Symposium on Virtual Reality in Manufacturing Research and Education, pg. 197-209. October 7-8, 1996, Chicago, Illinois.

[2]   S. Feiner, B. Macintyre, and D. Seligmann. Knowledge-based augmented reality. Communications of the ACM, 36(7):53-62, July 1993.

[3]   C. Hand, "A Survey of 3D Interaction Techniques", Computer Graphics Forum, 16(5), 269-281, 1997.

[4]   L. Levinson, "Connecting Planning and Acting: Towards an Architecture for Object-Specific Reasoning", PhD thesis, University of Pennsylvania, 1994.

[5]   B. Webber, N. N. Badler, B. Di Eugenio, C. Geib, L. Levison, and M. Moore, "Instructions, Intentions and Expectations", Artificial Intelligence Journal, 73, 253-269, 1995.

[6]   W. L. Johnson, and J. Rickel, "Steve: An Animated Pedagogical Agent for Procedural Training in Virtual Environments", Sigart Bulletin, ACM Press, vol. 8, number 1-4, 16-21, 1997.

[7]   M. Kallmann and D. Thalmann, "Modeling Objects for Interaction Tasks", EGCAS'98 - 9th Eurographics Workshop on Animation and Simulation, Lisbon, Portugal, 73-86, 1998.

[8]   Python http://www.python.org

[9]   G. Sannier, S. Balcisoy, N. Magnenat-Thalmann, D. Thalmann, VHD: A System for Directing Real-Time Virtual Actors, The Visual Computer, Springer, Vol.15, No 7/8, 1999, pp.320-329

[10]   R. Torre, S. Balcisoy, P. Fua, D. Thalmann, Interaction Between Real and Virtual Humans: Playing Checkers, Proc. Eurographics Workshop On Virtual Environments 2000

[11]   S. Balcisoy, R. Torre, M. Ponder, P. Fua, D. Thalmann, Augmented Reality for Real and Virtual Humans, Proc. CGI 2000, IEEE Computer Society Press

[12]   R.T. Azuma. A Survey of Augmented Reality. Presence, Teleoperators and Virtual Environments, 6(4):355–385, August 1997.

[13]   G. Klinker, K. Ahlers, D. Breen, P.-Y. Chevalier, C. Crampton, D. Greer, D. Koller, A. Kramer, E. Rose, M. Tuceryan, and R. Whitaker. Confluence of Computer Vision and Interactive Graphics for Augmented Reality. Presence: Teleoperations and Virtual Environments, 6(4):433–451, 1997.

[14]   Z. Szalavari, E. Eckstein, and M. Gervautz. Collaborative Gaming in Augmented Reality. In ACM Symposium on Virtual Reality Software and Technology, pages 195–204, Taipei, Taiwan, November 1998.