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Virtual Reality technology in Civil Engineering: the wall's construction model

A. Z. Sampaio[1], P. G. Henriques[2], P. S. Ferreira

Summary

This communication describes a Virtual Reality technology application in the construction-training domain. A prototype was developed that serves as a didactic tool for civil engineering students of disciplines concerned with building construction. Geometric Modeling and Virtual Reality techniques are used on the visual simulation of construction processes and to define user-friendly interfaces in order to access construction information, which could prove useful to civil engineering professionals.

The construction of a double brick wall is the case studied. The wall is defined as a three-dimensional geometric model formed with the several components needed to construct it. Using the wall's virtual model it is possible to show, in an interactive way, the sequence of the construction process and observe, from any point of view, the configurations in detail of the building components. This is a didactic application in the construction processes domain of great interest to civil engineering students.

Introduction

Normally, academic and commercial applications of computer-aided design in construction, provide a visual presentation of the final state of the project, that is, the three-dimensional (3D) representation of the building with an animated walk-through, allowing observation of both its interior and exterior. The current computer tools and models are unable to follow changes in the geometry of the building or structure during the construction process.

The visual simulation of the construction process needs to be able to produce changes to the geometry of the project dynamically. It is then important to extend the usefulness of design information to the construction planning and construction phases [1]. The integration of geometrical representations of the building together with scheduling data is the basis of 4D (3D + time) models in construction domain. 4D models combine 3D models with the project timeline. VTT Building Technology has been developing and implementing applications based on Virtual Reality (VR) technology and 4D to improve construction management practice [2].

[1] Technical University of Lisbon, IST/ICIST, Dep. of Civil Engineering and Architecture, Lisbon, Portugal

[2] Technical University of Lisbon, IST/ICIST, Dep. of Civil Engineering and Architecture, Lisbon, Portugal

The virtual model presented here was developed within the activities of a research work: Virtual Reality in optimization of construction project planning – POCTI/1999/ECM/36300, ICIST/FCT [3] now in progress at the Department of Civil Engineering and Architecture of the Technical University of Lisbon. The main aim of the research project is to develop interactive 3D models where students can learn about planning construction activities by means of the visual simulation of its development. The innovative contribution lies in the application of VR techniques to the representation of information concerning construction, of practical use to civil construction professionals [4].

As a first step, a prototype was developed that serves as a didactic tool for civil engineering students of disciplines concerned with building construction. The study case is a common external wall composed with two brick panels. The wall's virtual model, developed along this work, allows the user to visualize the construction progression, in particular, the following actions: the interaction with the construction sequence by means of the production of 3D models of the building in parallel with the phases of construction; the accessing of qualitative and quantitative information on the status of the evolution of the construction; the visualization of any geometric aspect presented by the several components of the wall and the way they connect together to form the complete wall. Using the developed virtual model, allows students to learn about construction planning of a specific situation in the space provided by the virtual environment.

This communication is then oriented to teaching construction techniques by means of virtual environments. It is expected that the implementation of the prototype will be able to contribute to support teaching disciplines concerned with civil engineering. Another objective in creating this kind of virtual applications is to show in which way new technologies afford fresh perspectives for the development of new tools in the training of construction processes. The virtual models can be very useful both in face-to-face classes and in distance learning using *e-learning* technology.

The wall's virtual model

As a study case in the building construction field a common part of a building was selected, an external wall with double brick panels. The developed virtual model allows the student to learn about the construction evolution concerning an important part of a typical building. The selected construction component focuses on a different aspect of the construction process: the structural part; the vertical panels and the opening elements.

The 3D model of the wall was defined using the AutoCAD system, a computer-aided drawing system common in civil engineering offices. Next, the wall model was transposed to a Virtual Reality system based on a programming language oriented to objects, the EON system [5]. Virtual Reality can be described as a set of technologies, which, based on the use of computers, simulates an existing reality or a projected reality [6]. This tool allows computer-users to be placed in three-dimensional worlds, making it possible for them to interact with virtual objects. First, all building elements of the wall must be identified and defined as 3D models. Structural elements (demarking the brick panels), vertical panels of the wall and two standard opening elements, were modeled. In order to provide, later in a virtual space, the simulation of the geometric evolution of a wall in construction, the 3D model must be defined as a set of individual objects, each one representing a wall component.

Foundations, columns and beams, were considered as structural elements. The concrete blocks are defined as *box* graphic elements (available in the AutoCAD system) and the steel reinforcements as *cylinder* and *torus* graphic elements (Figure 1). In the image, it is possible to observe how to accommodate the steel reinforcements inside the structural elements. This is a real problem that is solved for each case in the work on site. These elements were modeled taking into account this kind of difficulty. So, it is an illustrative example.

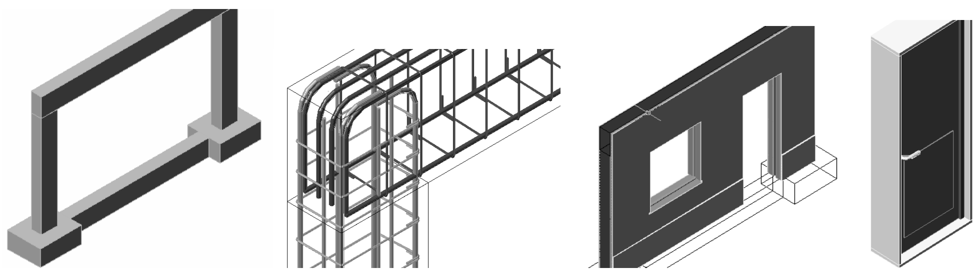

Figure 1: Details of the structural, vertical and opening elements of the wall's 3D model

Confined by the structural elements are the **vertical elements**: two brick panels, a heating proof layer, two rendering coats and two painted surfaces. Initially, all these elements were modeled as boxes with different thickness. The selection of thickness values for each panel is made according to the usual practice in similar real cases. Next, there were defined openings in the panels to place the window and the door elements, as shown in Figure 1. Finally, the components of two common opening elements, **a window and a door** (Figure 1), were modeled. The pieces of the window's and the door's frames were created as individual blocks.

Application of Virtual Reality capacities to the model

One by one every part of each element considered as a building component of the wall was modeled. They was modeled taking into consideration the real configuration that such elements must present in real situations. By this approach in the virtual animation of the wall's construction, it is possible to observe each one separately and analyze conveniently the configuration details of those frames. Figure 2 shows the complete wall model. Next, the 3D model was exported as a 3DStudio-drawing file (with the file extension .3DS) to the Virtual Reality system used, EON Studio [5]. The Virtual Reality system should allow the manipulation of the elements of the wall model according to the plane prescribed for carrying out the construction. Supporting that, a range of nodes or functions is available in the system to build up convenient virtual animations.

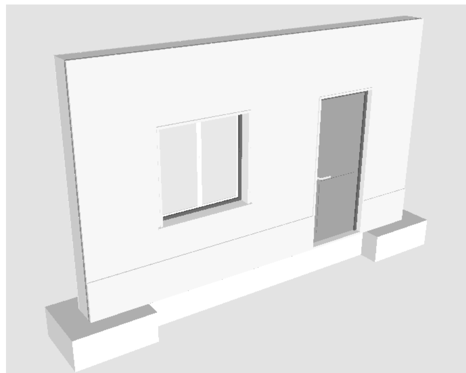

Figure 2: Projection of the developed 3D models of the wall.

To define the animation of the construction process it was decomposed into 23 phases following the real execution of this kind of element in the work on site. The first element to become visible, in the virtual scenario, is the steel reinforcement of the foundation (Figure 3) and the last is the door pull. The programmed animation simulates the progression of the wall construction. For each construction step the correspondent geometric model is shown (Figure 3). In this way, the virtual model simulates the changes that really occur while the wall is in construction in a real work place.

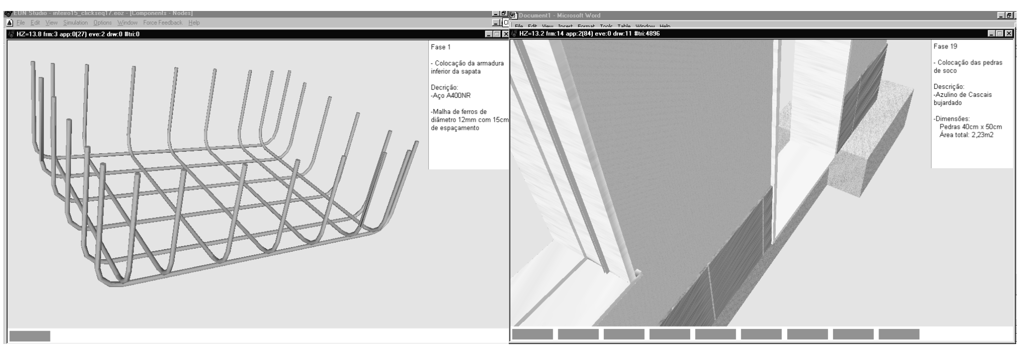

Figure 3: Presentations of two steps of the virtual construction progress.

By manipulating the camera with zooms over the model, all configuration details that the components of a real wall must present can be observed and analyzed (Figure 3). For each new wall component becoming visible in a construction phase, the virtual model allows the user to pick the element and to manipulate the camera around it (Figure 4). The student can then observe the element (displaced from the global model of the wall) from any point of view.

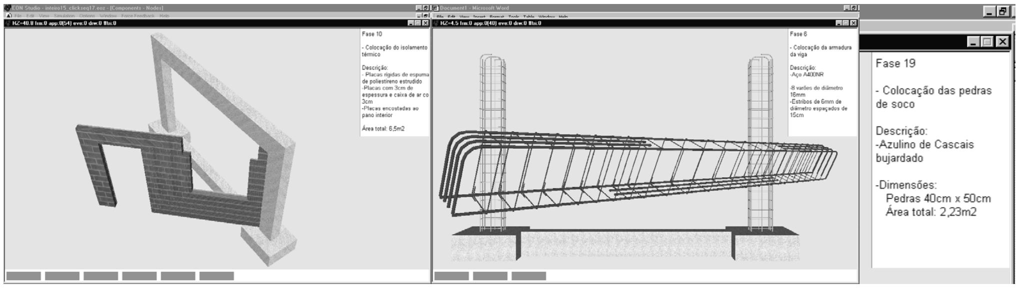

Figure 4: Pictures presenting elements displaced from the global model of the wall and the box text with construction information.

While the animation is in progress, a box text is presented, fixed at the upper right corner of the display (Figure 4). It contains construction information about the step showing. The text includes the order in the construction sequence, the activity description and the material specification and quantification concerned to each phase. The visualization of this type of data following the virtual construction evolution is useful to students. The virtual animation presents, below the visualization area, a toolbar (Figure 4). The set of small rectangles included in it shows the percentage of construction up to the step visualized. To exhibit the next phase the user must click in any part of the model. To go back to an anterior step the user must click over the corresponding rectangle in that progression toolbar. Finally, the animation allows the user to visualize the pieces of wall elements in an exploded view. The images included in Figure 5 show two elements presented in explosion. This type of presentation allows the student to know how the different parts connect to form wall components and can observe the configuration of those parts with detail. This capacity provided by the virtual model is also of great interest in construction domain instruction.

Figure 5: Images presenting components of the wall in explosion.

Future perspectives

Other types of building components can be modeled and manipulated in a virtual scenario for construction learning proposes. Two other applications, also in the construction area, are now in progress. One concerns the construction of a bridge by the segmental free cantilever method and the other to the construction of different types of roofs. With this type of virtual model students can learn about construction technologies and analyze the sequence of construction, the steps required along the correspondent planned execution process and the configuration detail of each element.

Conclusions

The Virtual Reality technology applied to the construction field makes it possible to represent a three-dimensional space realistically. The visual simulation of the construction evolution of a common case was achieved. The user can interact with the virtual model of the wall and impose any sequence in the construction process, select from the wall model any component or parts of an element and manipulate the camera as desired in order to observe conveniently any detail of the component's configuration. While the animation is in process, the construction information associated with each step is listed. The use of these capacities, allowed by the developed virtual model, is beneficial to the civil engineering student in construction process subjects. This type of didactic material can be used in face-to-face classes and in distance learning.

Acknowledgements

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