

Interactive project planning in construction based on virtual reality technology

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Abstract

This paper describes a didactic application that is part of a research project whose main aim is to develop a computer-aided system which will assist design and construction processes. It is based on the visual simulation of construction activities. Geometric modelling and virtual reality techniques are used in the visualization of the design process and to define user-friendly interfaces in order to access construction information, which could prove useful to Civil Engineering professionals. As a first step, was developed a prototype that serves as a didactic tool for Civil Engineering students of disciplines concerned with building construction. The construction of a double brick wall is the case studied. The wall is defined as a three-dimensional model formed with the several components needed to edify 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 then a didactic tool application in construction processes domain of great interest to Civil Engineering students.

Key words: Development of visual tools, optimisation in construction design, visual simulation in construction process, computer-aided design.

1 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. However, the tools of construction planning (scheduling, monitoring of progress and so on) work with the whole construction process, from its conception to its final phase. Not only are current computer tools and models unable to follow changes in the geometry of the building or structure during the construction process but also the representation of construction activities is not always compatible with, or even possible to be modelled by, these project aids. The visual simulation of the construction process needs to be able to produce changes to the geometry of the project dynamically.

The main aim of the research project: *Virtual reality in optimisation of construction project planning* – POCTI/1999/ECM/36300, ICIST/FCT [1] now in progress at the Technical University of Lisbon, within the program of activities of the Department of Civil Engineering and Architecture, is to develop a system for the planning and monitoring of construction activities by means of the visual simulation of its development [2]. The innovative

contribution lies in the application of 3D modelling techniques and virtual reality to the representation of information concerning construction, of practical use to civil construction professionals. As a first step it was developed a prototype 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 control 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.

This communication is oriented to teaching construction techniques by means of virtual environments. The objective of this application is to show in which way new technologies afford fresh perspectives for the development of new tools in the training of construction process of edifices. It is then expected that the implementation of the prototype will be able to contribute to support teaching disciplines concerned with civil construction.

Using the developed virtual model, it permits students to study and to experiment alternative strategies for construction planning in the space provided by the virtual environment.

2 Virtual reality technology

2.1 Concept and historical background

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 [3]. This new tool allows computer-users to be placed in three-dimensional worlds, making it possible for them to interact with virtual objects at levels until now unknown in information technology: turning handles to open doors; switching lights on and off; driving a prototype car or moving objects in a house. To achieve this, elements of video, audio and three-dimensional modelling are integrated in order to generate reality, initially through specific peripheral devices (handles, helmets and gloves) and at present, through the Internet.

Its origin is attributed to flight simulators developed about fifty years ago by the American Army. The beginning of virtual reality is attributed to Ivan Sutherland, with the introduction in 1965 of the first three-dimensional immersion helmet, which was later divulged to the peripheral device industry with the designation, head mounted display. A precursor, Nicholas Negroponte (and collaborators), in the seventies, produced a virtual map of guided walks using a model of the city of Aspen, Colorado. In 1989, Jaron Lamier, an important driving force behind this new technology, designated it virtual reality [4]. In the 90s, with the upsurge of the Internet, a specific programming language was defined, the virtual reality modelling language. It is a three-dimensional interactive language devised for the purpose of modelling and visually representing objects, situations and virtual worlds on the Internet, which makes use of mathematical co-ordinates to create objects in space [3]. This constitutes a new means of communication that allows the construction of, and experimentation with, new computer-

modelled realities. The virtual reality modelling language was the first standardized definition of three-dimensional space on the Internet.

2.2 Principal technological characteristics of virtual reality systems

Interaction and immersion can be considered the most important characteristics of virtual reality [4]: the immersion sensation is obtained by means of special physical devices, that allows the user to have the sensation of finding himself physically present in a world imagined and modeled by the system; the interactive characteristic is assumed because the virtual reality technology is not limited to passive visual representation of this world but enables the user to interact with it (touching or moving objects, for example). What is more, the virtual world responds to such actions in real time. In the developed application only the interactive propriety was explored. Technically, the active participation of the user in a virtual environment, or, in other words, the sensation of immersion or presence in that environment, is achieved on the basis of two factors: the integration of information technology techniques (algorithms) used to obtain images of the highest degree of visual realism (ray-tracing, luminosity, application of textures etc.); the integration of a series of physical devices resulting from specific technologies like visual technology, sensorial technology (sensors of force and positioning) and mechanical technology (for transmitting movement such as a 3D mouse or gloves).

One of the areas in which the incorporation of virtual reality technology as a means of geometric modelling and visual presentation of three-dimensional animated models is most often applied is Architecture. The range of potential applications extends from buildings on a small scale to the development of town plans. However, virtual reality technology does not merely constitute a good interface but presents applications that provide the possibility of finding solutions to real problems in such diverse fields as Engineering, Medicine or Psychology.

3 Developing the wall 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 to an important part of a typical building. The selected construction component focuses 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 [5], 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 [6].

3.1 Creating the wall 3D model

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. The Figure 1 shows some details of these components. In the image, it is possible to observe how to accommodate the steel reinforcements inside the concrete blocks. This is a real problem that is solved for each case in the work *in loco*. These elements were modelled taking account this kind of difficulty. So, it is an illustrative example.

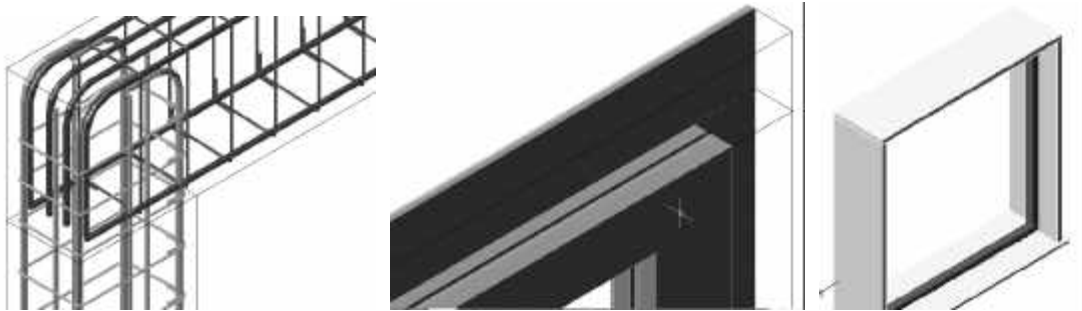


Figure 1: Details of the structural elements, the vertical elements and of the window.

Limited by the structural elements are two brick panels, a heating proof layer, two rendering coats and two painted surfaces. Initially, all these elements were modelled as boxes with different thickness as shown in Figure 1. The selection of thickness values for each panel is made according to the usual practice in similar real cases.

Finally, the components of two common opening elements, a window and a door, were modelled (Figure 1). First, there were defined holes in the vertical panels to place these elements. The pieces of the square stones of the window and the door were created as individual blocks. Each element was modelled taking in consideration the real configuration that such type of elements must present in real situations. By this, at the virtual animation of the wall construction, it is possible to observe each one separately and analyse conveniently the configuration details of those stones.

3.2 Creating the virtual environment of the construction process

One by one every part of each element considered as a building component of the wall was modelled. The Figure 2 *a* 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 [6]. The virtual reality system should allow the manipulation of the elements of the wall model according to the planning prescribed for the carrying out of the construction. Supporting that, a range of nodes or function is available in the system to build up convenient virtual animations.

The Figure 2 *b* presents the work ambience of the EON system. In the left side of the image, is the nodes window (containing the virtual functions available in the system), in the central zone is the simulation tree (is the place where the drawing blocks hierarchy is defined and the actions are imposed to blocks) and, in the right side, the routes simulation window (the local where the nodes are linked). Essentially, the simulation is programmed using the last two windows.

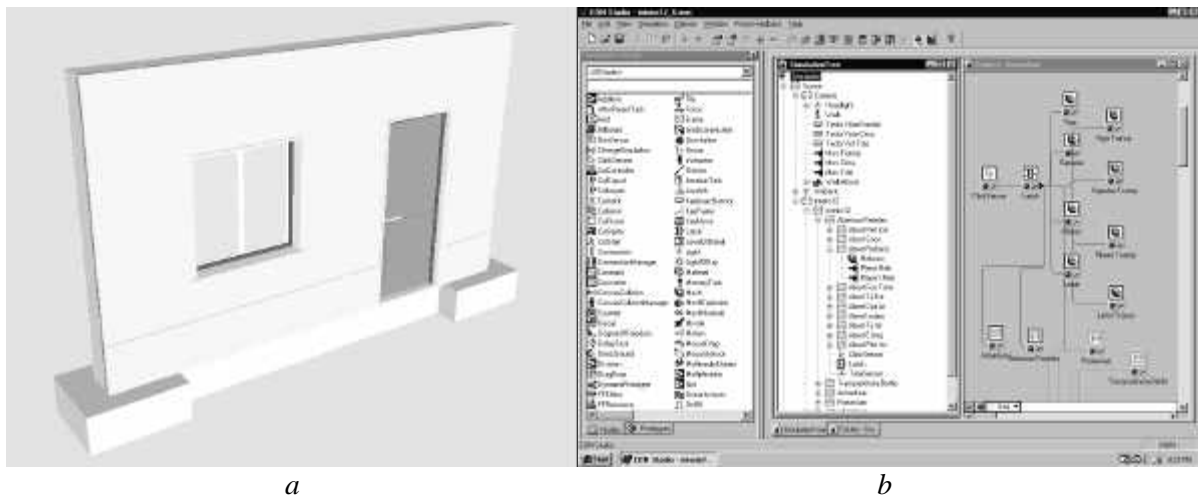


Figure 2: The developed 3D models of the wall and The work ambience of the EON system.

The construction process was decomposed in 23 phases following the real execution of this kind of element in the work *in loco*. The first element to become visible, at the virtual scenario, is the steel reinforcement of the foundation (Figure 3) and the last is the door pull.

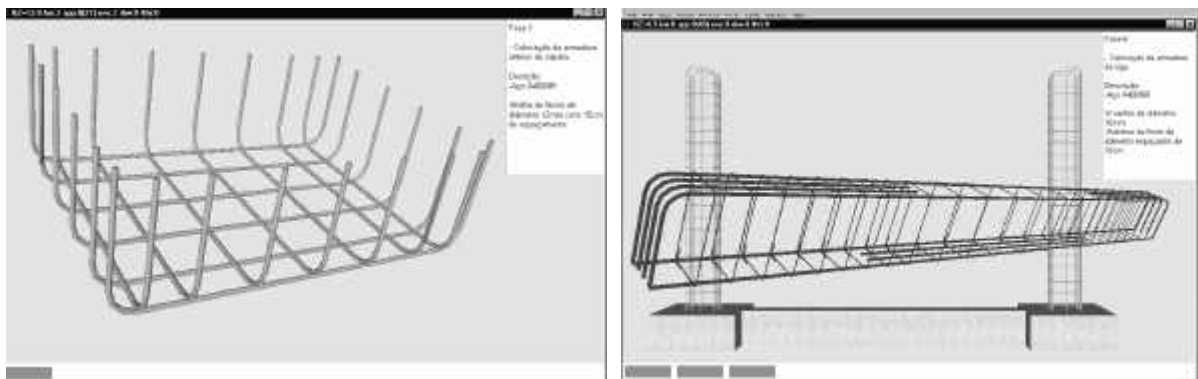


Figure 3: Presentations of two steps of the virtual construction progress.

The programmed animation simulates the progression of the wall edification. For each construction step the correspondent geometric model is shown. In this way, the virtual model simulates the changes that really occur while the wall is in construction in a real work place. 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 3). The user can then observe the element (displaced from the global model of the wall) from any point of view. Then all configuration details that the components of a real wall must present can be observed and analysed. This capacity is important in construction process training. While the animation is in progress, a box text is presented, fixed at the upper right corner of the display (Figure 3). It contains construction information about the step in exhibition. The text includes the number, 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, in relation to the wall fully constructed, 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 pretended rectangle in that progression toolbar. Finally, the animation allows the user to visualize the peaces of wall elements in an exploded exhibition. The images included in Figure 8 shows two elements presented in explosion. This type of presentation allows the student to know how the different peaces connect each other to form wall components and can observe the configuration of those peaces with detail. This capacity provided by the virtual model is also of great interest in construction domain instruction.

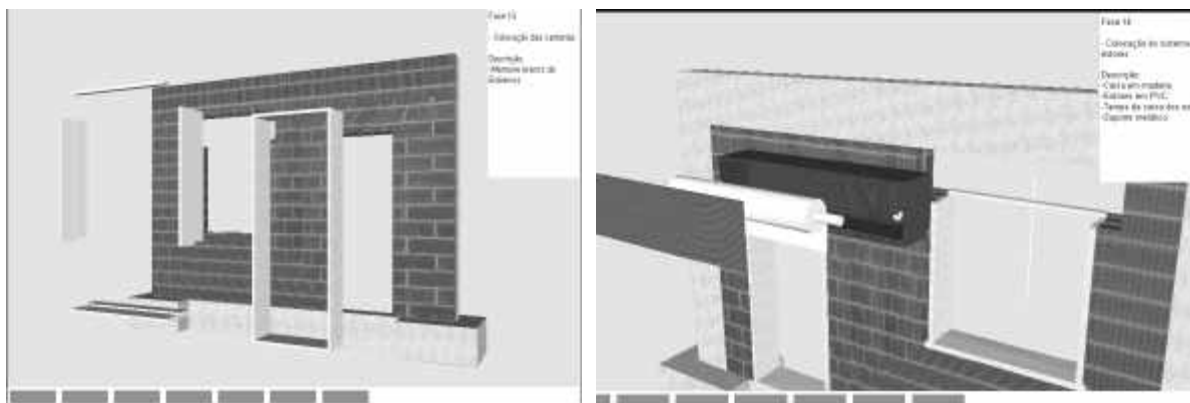


Figure 4: Images presenting wall components in explosion

4 Conclusions

The virtual reality technology applied to construction field made 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 peace of element and manipulate the camera as desire in order to observe conveniently any detail of the components configuration. While the animation is in process, the construction information associated to each step is listed. The use of these capacities, allowed by the developed virtual model, is beneficial to Civil Engineering student in construction process subjects. This type of didactic material can be used in presencial classes and in long distance learning.

5 References

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