USER-ORIENTED INTERACTIVE BUILDING DESIGN*

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Abstract: The objective of the paper is to presents the 3D VR-based environment for basic design of the apartment buildings. The key issue of the system is the user-in-the-loop philosophy which permits the interactive modification of the building design. The user is able to choose the preferences in order to select their best apartment design: number of bedrooms, bathrooms, distribution, sizes, sun-orientation, etc. And all with a simple click of the mouse. This user-oriented design need to have in account (in automatic way) numerous restrictions during the design, with the overall objective of obtaining, at the end of the design process, the feasible and realisable result. The friendly-user interface and internet-based facility of the system make them extremely easy to use.

Keywords: User oriented, building, architectural design, virtual reality.

1. INTRODUCTION

Within the actual building market the user is out of important stages of the construction process and he cannot decide about a lot of aspects of his future dwelling. This implies that the degree of satisfaction of the final user of a dwelling is determined by the joining between the user desires and the market offer.

The goal of this investigation is to introduce the end user of a dwelling into the whole construction process, from the first phase of design to the end of the cycle of life of the building. In that way, the final user would be the centre of the process and his level of final satisfaction would be increased.

In this first stage of the work the end user will be introduced into the architectural design of a multi storey building, more specifically, in the personalization of his own dwelling.

In order to achieve this goal, a virtual reality environment will be designed where the end user will see his dwelling and will be able to modify some aspects of the architectural design, as can be number of bedrooms, bathrooms, distribution, sizes, sun-orientation, etc. according with his preferences. This interactive design will maximize the user final satisfaction.

2. SCOPE OF THE WORK

2.1. Building Design

The actual building construction process in Spain is very complex and has no participation of the final user in early stages [1]. It can be seen that in a traditional process of a private developer the end user is only involved in the final part of the process, where no decision from his side will be taken into account (figure 1).

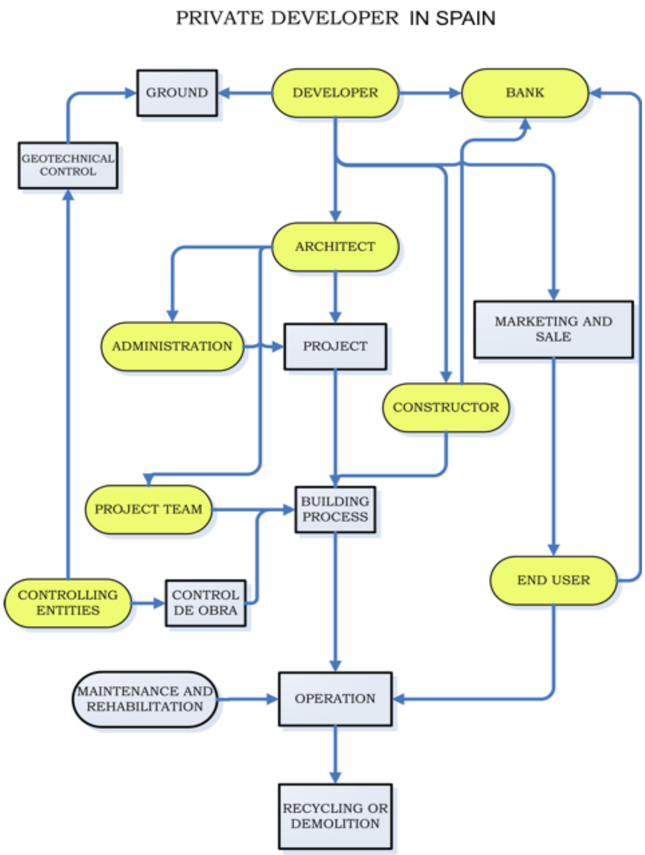


Fig. 1 Private Developer Building Process

* This Works is part of the EU ManuBuild Project.

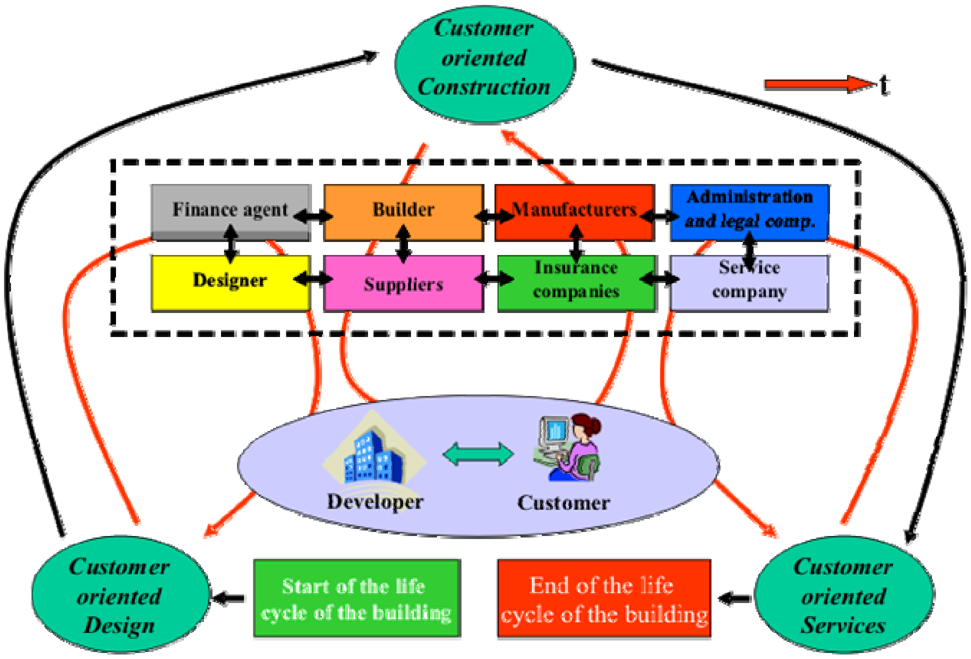


Fig. 2 User-in-the-loop Process Model

The significant change that the project wants to introduce is the user-in-the-loop philosophy in building construction, from design to the final cycle of life of the building. In this way, the user can participate in all the stages of the process to get a final product according to his preferences [2].

At the first stage, the architectural design, the user will be involved in the process by making modifications on a previous design modelled in 3D. This architectural model will be introduced into a virtual environment in which the user will make modifications according to his preferences and with the limitations of predefined designing constraints. An approach of the model with the customer in the centre of the process can be viewed on the figure 2.

2.2. Virtual Reality Environment

The virtual reality environment can be taken into consideration according two points of view. The first is from the side of the hardware systems and the other point of view is from the user interaction type with the system.

The hardware systems can be classified depending of the sense of immersion, or degree of presence it provides [3]. There are three different levels of immersion that the systems can provide:

- Non immersive systems

These systems are so called ‘desktop systems’ because the virtual environment is viewed through a virtual reality browser by utilising a standard high resolution monitor. Interaction with the virtual environment can occur by conventional means such as keyboards, mice and trackballs or may be enhanced by using 3D interaction devices such as a SpaceBall™ or DataGlove™.

The non immersive system has several advantages as for the designer as for the end user. The main advantages are that they do not require the highest level of graphics performance, no special hardware and can be implemented on a domestic PC system. This means a low cost virtual reality solution which can be used for many applications.

The main disadvantage issue is the 2D interaction devices, not designed specifically for 3D applications, which limit the perception of the user.

- Semi immersive systems

A semi immersive system is composed mainly by a wide field projection system. They can be, for instance, large screen monitors, large screen projector systems or multiple television projection systems. These systems increase the feeling of immersion or presence experienced by the user. However, the quality of the projected image is an important consideration. It is important to calibrate the geometry of the projected image to the shape of the screen to prevent distortions and the resolution will determine the quality of textures, colours, the ability of define shapes and the ability of the user to read text on-screen.

These systems are more complex and much more expensive than desktop systems. For these two reasons, it is difficult to use these virtual reality devices out of determinate environments, as they can be professional simulators or entertainment areas, where the most important thing is the sense of immersion.

- Fully immersive systems

A fully immersive virtual reality system tries to replace a real environment by a computer generated environment and some of the user senses only have perceptions from this virtual world. To achieve full immersion the user has to employ a head-coupled display which is either head mounted or arranged to move with the head. A sense of full immersion is achieved because the display provides a visual image wherever the user is looking. Consequently, a head coupled display provides a 360° field of regard. The field of view of a head coupled display is also very important and it is essential to note that the sense of immersion will be a function of the quality of the display provided in terms of resolution, field of view, update rate and image lags etc [4].

The main advantage of these systems is the degree of perception achieved by the end user but, for this reason, the computational cost is higher than in other systems because the necessity of achieve a real perception of the virtual environment.

The other possible classification of the virtual reality systems is depending on the level of the user's participation and interaction with the virtual environment. Virtual reality applications are also subdivided into passive, explorative or interactive environments:

- Passive environments.

The passive environment is only a projection that the user can see. The user cannot interact with the virtual reality world so, the perception is limited to the sense of the sight.

- Explorative environment.

The basis of the system is the same as the passive systems but, in this case, the user can navigate through the virtual reality environment.

- Interactive environment.

The last type of systems and virtual worlds is the interactive one. In these systems, the user as well as navigate also can interact with the environment. There are objects into the world with interaction properties as can be displacement by the user, etc.

3. USER ORIENTED 3D BUILDING DESIGN

The user dwelling design starts from an architectural building design made by and architect's office. In order to accomplish with the user-in-the-loop philosophy, this basic architectural design must be made following several rules that will be fixed during the ManuBuild project development. Mainly, the design should be carried out following the Open Building philosophy.

With this architectural design and with input data about the environment of the building, the 3D user oriented model will be built.

3.1. 3D Model Construction.

The first step is the construction of the virtual reality environment where the designed building model will be placed. The environment model has two main parts [5]:

- The terrain information.

In order to make a realistic 3D model it is necessary to do a terrain model. The building models will be placed on it taking in account the geospatial orientation and the terrain profile. The basic process is shown in the figure 3.

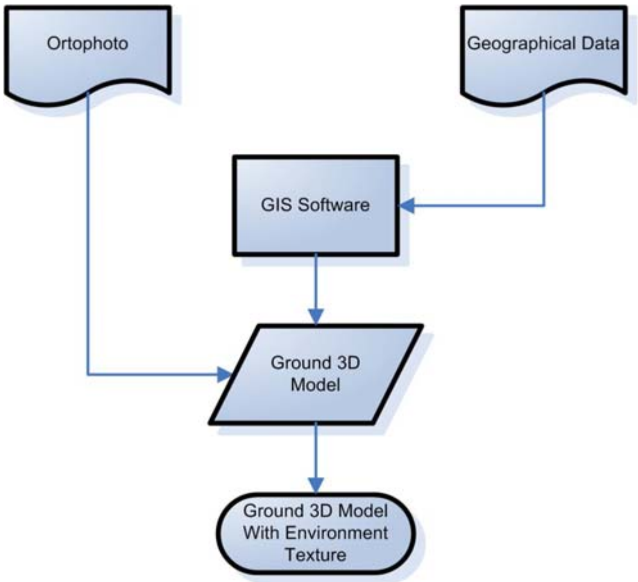
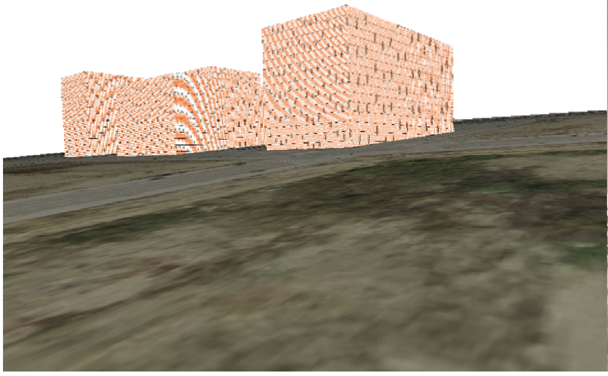


Fig. 3 Basic 3D Terrain Model Generation Process

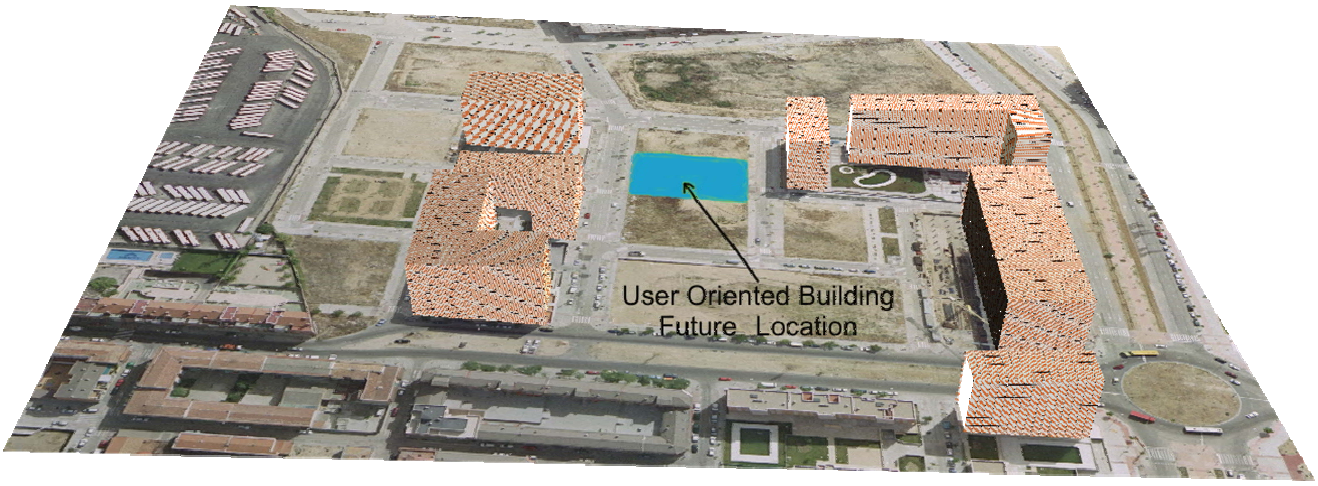
The input data for constructing the terrain model is an orthophoto of the work area and geospatial data (topographic map and a contour map).

In this step GIS (Graphic Information System) software is used. A DEM (Digital Elevation Model) will be created with the contour map. This DEM file contents the elevation points of the terrain corresponding with each pixel of the photograph map. With these elevation points a 3D model of the terrain profile will be generated.

The orthophoto will be use as texture of the 3D terrain model. It will also provide information of the situation of the different objects surrounding the user oriented building location (other buildings, streets, trees, etc.)




(a) (b)



(c)

Fig. 4 (a) 3D Approached Model from (b) Real Photograph and (c) Whole 3D Model.

- The surroundings object models.

Once the 3D terrain model is obtained, the following step is reconstructing the environment. In order to do this, it is necessary to have 2D photographs of the objects and apply photogrametric technics. This procedure consists on matching common points from different 2D views of a 3D object. The photographs must be taken with a calibrated camera or with a camera with known characteristics in order to make a correct geometric reconstruction.

With software like PhotoModeller™ it is possible to make 3D models of objects from their 2D photographs. The models of the buildings of the neighbourhood will be modelled in this way. Other objects, like trees or streetlamps, will be modelled with object obtained from a 3D objects library.

The figure 4 (a) shows an approach to a 3D model produced from several 2D photographs like (b). The final result is the whole 3D environment model (c). All of them are located in the Carabanchel district, in the city of Madrid.

3.2. Interactive Modification of the Building Design

The following action is integrate the architectural design of the user oriented building into the 3D model. In this stage starts the participation of the final user who can achieve the first actions to configure his dwelling.

The process of configuration starts selecting the area desired within the city and then the specific building. The final user can navigate trough the 3D environment and can see the building where his dwelling will be situated. The user will be able to see all the surroundings of the building and, with this information, he will be able to select some general aspects like orientation, floor, etc. This process is showed in figure 5.

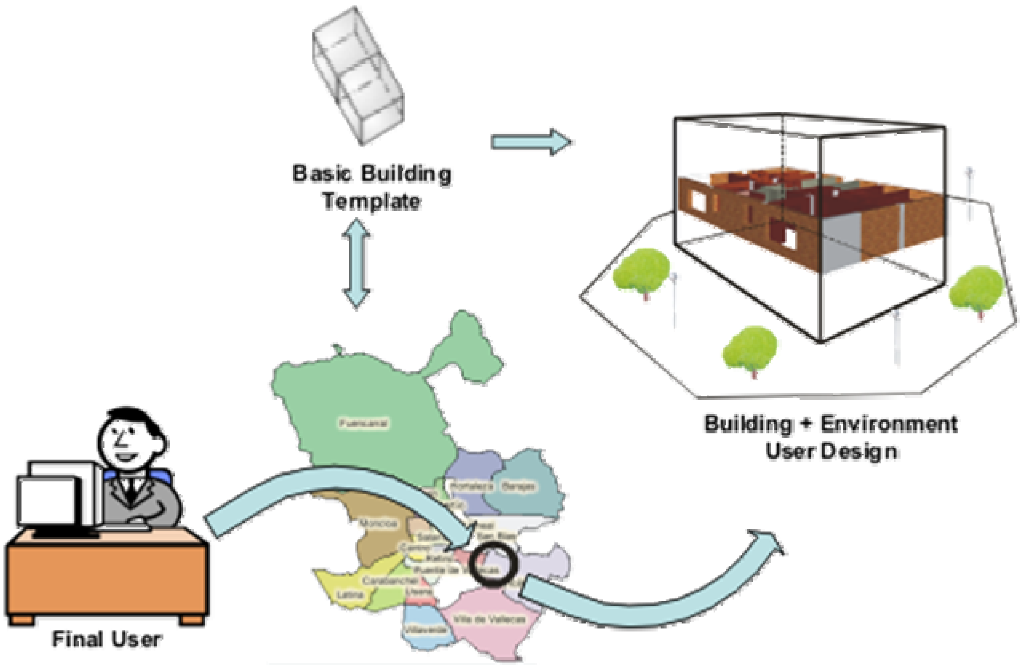


Fig. 5 Area Selection and Environment Configuration

Once a particular location of his dwelling is selected the user starts the configuration of the interior side.

The user will have a list with the possible modifications permitted and will be able to do them according to constraints that the designer of the 3D building model will put on it. For example, the user can move a wall but it cannot be situated a position where there is a window.

Another step to obtain the fully configured by the user dwelling is selecting the elements of the dwelling such as doors, windows and the qualities of them. This will be possible due to the connection of the system with a data base containing the different constructive elements and their suppliers. This data base is called 'intelligent component catalogue'. All these configurations will modify the final price of the dwelling, very important information to the user that can decide to maintain or change the configuration and his desires. This process can be viewed in the figure 6.

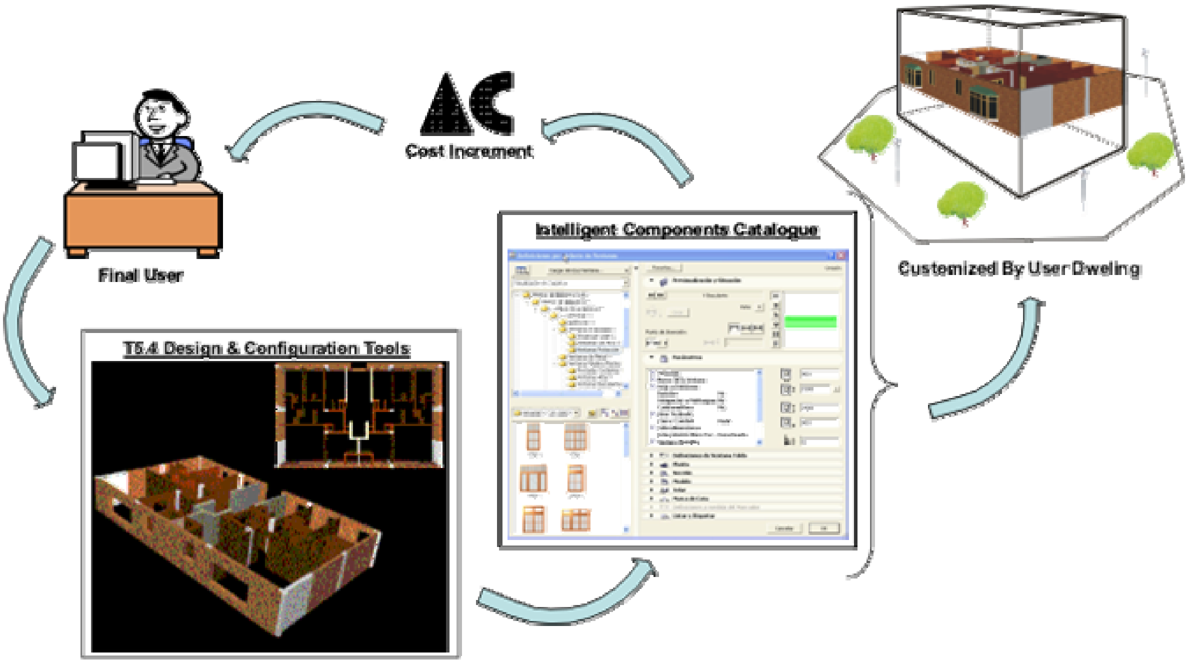


Fig. 6 Dwelling Configuration Loop

4. VIRTUAL REALITY INTERFACES

It is necessary to develop two different kinds of virtual reality interfaces, one for designers and another for the final user.

The two main differences between them are the complexity and the functionality. While the designers interface must allow total control of the virtual world, the end user interface only allows to navigate and to modify the list of objects determined.

For designers, it is possible to select an immersive and interactive system. This system is more powerful providing more capacities to the designer.

By the other hand, it is more difficult for the user to have access to an immersive system. Due to this, the end user interface will be an interactive desktop system. The user can interact with the virtual world in order to configure his dwelling according to his preferences. At last, this interface must be web based in order to be accessed from any user location.

5. CONCLUSIONS AND FUTURE WORKS

One of the most important changes introduced by the project and by this work is to take into consideration the user, from the beginning of the construction process to the end of the cycle of life of his dwelling.

Using virtual reality technologies and web based applications it is possible to make a visual design, more suitable for every kind of end user. The usability of the system is not depending on the user skills or his location.

The development of the system is in an early stage. The first work to do is to develop an interface for designers that it allows to create fully virtual environments from a limited number of data sources in a simple and automatic way.

The second step is the development of program that translates the 3D model from the designers' environment to the final user model. This software must apply the constraints to the model in such a way that all kind of building designs can be used.

The following logical phase is the web based virtual reality interface development for the end user. The interface must be designed to be used on a domestic PC and by end users with different skills. This interface should be connected with the components data base.

6. REFERENCES

[1] C.Balaguer. *"EU FutureHome project results"*. 20th International Symposium on Robotics and Automation in Construction (ISARC'2003). Eindhoven. The Netherlands. Sep, 2003.

[2] C.Balaguer. *"Open issues and future possibilities in the EU construction"*. 17th International Symposium on Automation and Robotics in Construction (ISARC'00). Taipei. Taiwan. Sep, 2000.

[3] F. Biocca. *"Virtual Reality Technology: A Tutorial"*. Journal of Communication, 42(4), 23-73. 1992

[4] RS Kalawsky. *"Exploiting Virtual Reality Techniques in Education and Training: Technological Issues"* - SIMA Report Series ISSN, 1996 - agocg.ac.uk

[5] Eran Sadek Said B. Md Sadek, Sayed Jamaludin B. S. Ali & Mohd. Rosdi B. Md. Kadzim. *"The Design and Development of a Virtual 3D City Model"*. Available on line at www.malaysiagis.com/gis_in_malaysia/ articles/article47.pdf