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BUILDING FACILITIES MANAGEMENT SUPPORT ON VIRTUAL INTERACTIVE MODEL: THE LIGHTING COMPONENT

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Abstract. *The main aim of the research project, which is in progress at the TUL, is to develop a virtual interactive model as a tool to support decision-making in the planning of construction maintenance and facilities management. The virtual model gives the capacity to allow the user to transmit, visually and interactively, information related to the components of a building, defined as a function of the time variable. In addition, the analysis of solutions for repair work/substitution and inherent cost are predicted, the results being obtained interactively and visualized in the virtual environment itself. The first component of the virtual prototype concerns the management of lamps in a lighting system. It was applied in a study case. The interactive application allows the examination of the physical model, visualizing, for each element modeled in 3D and linked to a database, the corresponding technical information concerned with the wear and tear aspects of the material, calculated for different points in time during their life. The control of a lamp stock, the constant updating of lifetime information and the planning of periodical local inspections are attended on the prototype.*

1 INTRODUCTION

Along the **lifecycle** of a building a great amount of data must be generated, analyzed, transformed or replaced. The information technology (IT) becomes an important support on the management of computer-based information, namely to convert, store, protect, process, transmit, and securely retrieve datasets. With the emergence of the relevant computer technology, method based drawing and the visualization capabilities were combined into one process, the three-dimensional (3D) models. The further enhancement of the computers resulted in the development of **3D visualization tools**, which facilitates a more real appreciation of the end product. At present, the management building planning could be presented in a 3D form and various materials can be assigned to the fixtures and furnishing enabling the user to be virtually placed in the building and view it from inside as well as outside.

Visualization technologies empower users to perceive important data, identify areas of information and make decisions. However, without interactivity, visualization is often considered as an end point of the workflow or as a way of communicating observations. Users need to manipulate and explore the data. The way people perceive and interact with visualizations can strongly influence their understanding of the data as well as the usefulness of a visualization system. In order to increase the users' ability to explore the data and better understand the results, **interaction** and **visualization** capabilities need to be optimized. Effective integration of advanced visualization is incorporated to inter active simulation systems. The integration of several specific applications has been established on domains such as virtual reality (VR) and augmented reality (AR) environments, computer aided design (CAD) systems, and visualization systems [1]. This paper describes integration between a VR system and a computer application implemented in Visual Basic (VB) programming language.

The improvements in computational performance have created needs for new systems that enable users to explore computation datasets in an intuitive and flexible manner. Interactive systems must incorporate the interactive techniques and input devices to perform visual exploration tasks. Furthermore, the models must attend information visualization, human-computer interaction, and **interactive interface** design. It requires effort for users to understand the structure, characteristics and interdependency of data. In the present case, a bibliographic research support had to be made regarding the lighting systems usually applied in a building and the characteristics of different types of lamps. Also programming skills had to be enhanced to establish the integration needed on the creation of a lighting virtual prototype. In addition, the structure of different kind of databases had to be study and implemented, integrating diverse type of information, needed to develop the virtual model.

In an interactive system, in order to produce an **effective visualization**, human perception must be understood otherwise the end result may not lead to a visualization that can be interpreted by the users. Accordingly, the virtual environments used in the present prototype lead, in a natural way, with 3D geometric models. The human perceptual and cognitive capability transmitted by this type of multimedia is great. The developed prototype shows, in a 3D space, the simulation of a lighting system along the time in a common building, allowing interactively information concerning lamps changing with the parameter time.

In addition, the 3D model linked to a data base concerning the lighting system management characterizes a **collaborative virtual environment**. It means that it can be manipulated by partners interested in creating, transforming and analyzing data in order to obtain results and to make decisions. The process of developing the prototype interface considers this proposes. Then, the model is easy to use and not require sophisticated computer skills by users, as many are not computer experts. The human perceptual and cognitive capabilities were taken into account when designing this visualization tool. It uses an interactive 3D visualization system based on the selection of element directly within the virtual 3D world. Further more, associated with each component there are integrated databases, allowing the consult of the require data in any point in time.

2 MAINTENANCE AND VR

The performance of the maintenance of a building has been increased through the application of new modelling concepts, particularly the incorporation of **VR techniques** and the addition of time as a factor to be considered in the strategy of building conception. In the same vein, 3D models have been developed, related to the time parameter (designated 4D models, [2]), focused in the beginning, basically, on planning the construction process. The geometric model of **construction** is presented as a progression of steps in its physical evolution following planning. The University of Stanford [3], and the Finnish Centre of Investigation VTT [4], have presented concrete applications in the design phase with considerable befits relevant to communication between specialists, constructors and promoters. In the construction domain, the VR models are used to show the physical evolution of the building, through 4D models, in different phases of its construction following specific planning [5] and the simulation of the operational evolution of the associated construction processes [6]. In the area of **architecture**, VR models are generally applied to the visualization of static physical models in the definition of itineraries of walk-through, as a means of transmitting the functional and geometric aspect of the building.

2.1 4D models

This paper contemplates incorporation of the 4^{th} dimension, the time, into the concept of visualization. The focus of the work is on travelling through time: the ability to view a product or its components at different points in time during their life. It is envisaged that the incorporation of the time dimension into 3D visualization will enable the designer/user to make more objective decisions about the choice of the constituent components of the building.

One of the more recent targets of investigation is in fact, research into the **sharing of data** between applications, which can be manipulated by means of a common interface, as a way of rendering 4D tools efficacious and of wide use. Virtual reality is seen today as an integrating technology, with great potential for communication between project participants, and most recently, as a tool for the support of decision-making, made possible by the integration of distinct computer applications in the virtual model. In this context, the present work presents the development of a system based on VR technology, involving knowledge of the physical aspects of materials, in particular, those which refer to wear and tear (a function of time, use and environmental factors), integrating them in digital spatial representations. In this way, the indisputable advantage of the ease interpretation and perception of space provided by the visualization of 3D models, and the technical content underlying the real characteristics of the observed elements are brought together.

2.2 Lifecycle

An important aspect that ought to be considered in the lifecycle works is preventive **maintenance**. In the construction industry continuous necessary maintenance is frequently substituted by sporadic remedial actions involving repair, restoration or reconstruction which target deteriorations threatening the structure or its services. The management of the data building in a lifecycle could be then performed in a visual interactive platform. It enables the visual information captures of building knowledge in a direct and informational rich format that is easy to understand and follow. The accumulation of visual information in this format and the definition of databases concerning components of the building are adequate to be reused in future projects.

In the maintenance domain some researches have been including visual interaction: Anna-Liisa Linholm describes the creation process of an interactive model for identifying the added value of corporate real estate management and implement it in a case organization, testing whether it works in practice [7]; Visualization of building maintenance through time is the topic of the researching activity of Rad [8]; Khosrowshahi focus the research VR application on lighting and paintings of interior wall maintenance [9]; Alain describes a model which quantifies maintenance and repair actions based on the relationship between the quantity of damages observed and the time between the geneses of alterations [10].

Maintenance is defined as "all actions necessary for retaining a component in or restoring it to specific condition" [9]. Clearly the scope of the building element identifies what should be included in or excluded from maintenance in any specific case. Basically, there are two kinds of components, which are differentiated on the basis of their lifestyle:

- **Continuous** lifestyle. The elements, which have no death-time or break-time (e.g. paint and carpet);
- **Discrete** lifestyle. The component, which have a discrete death-time after which they are rendered as being useless (e.g. bulbs and lamps).

2.3 The research project

The interactive lighting system, described here, was developed within the research project in progress, *Virtual Reality technology applied as a support tool to the planning of construction maintenance*, PTDC/ECM/67748/ 2006, ICIST/FCT. In this first stage, just the lamps elements of a common building were implemented in the virtual prototype. It allows the examination of the physical model, visualizing, for each element modelled in 3D and linked to a database, the corresponding technical information concerned with the degree of use of each lamp, calculated for that period of time. The practical usage of this model is directed, then, towards supporting decision-making in the planning of maintenance of light systems. In further work other components will be analyzed and incorporated into the interactive system, namely, walls, floors, doors and windows. The ability to view a product or its components at different points in time during their life is a target to be achieved, related to the maintenance of a building, with the present work.

The modelling of the lifecycle of infrastructures has, thus, in the VR technology a strong basis for development. The present project aims to bring important contributions to this domain, with the implementation of virtual models with capacities of calculation related to the behaviour of materials, variable throughout the construction's lifecycle. During this investigation the basic knowledge of the topics involved (aspects related to the materials, the techniques of rehabilitation and conservation and the planning and costs of maintenance) has been studied and methods of interconnecting this knowledge with the virtual model were explored. The first prototype, implemented with the light system, was trailed in a concrete project. This kind of building element has a discrete lifestyle, so its maintenance requires the control of a lamp stock, the constant updating of lifetime information and the planning of periodical local inspections. In the future it is going to be applied in others situations of buildings, news or for rehabilitation.

3 THE LIGHTING INTERACTIVE SYSTEM

The paper describes the implementation process of the lighting component. First, the 3D geometric models of building case and the some light equipment were created (Figure 1). The building consists of a ground-floor, a 1st floor and an attic waters with allocation of housing.

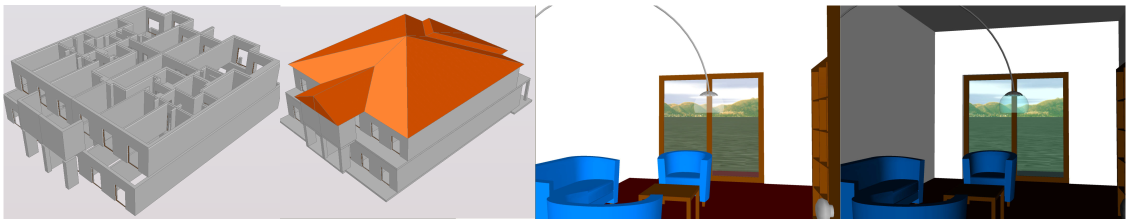

Figure 1: Sequences of the 3D modelling process of the case study.

The visualization of the lighting system in a building and the impact of time on its performance, require an understanding about the characteristics of lights, bulbs and lamps:

- The bulb type and its wattage are important parameters, which determine the amount of light produced by a particular bulb. The correspondent compatibility characteristics is also a significant management data in case of replacement of elements in a building;
- The life of the bulb is an essential factor in a maintenance analyses. By using the bulb lifetime and the related break-time distribution, it will be possible to represent the prediction of lifetime in a statistical form, that is, the time after which the bulb is likely to break;
- Bulb and lamps have discrete lifestyle. So the maintenance plan must include the control of bulb stock established for each type of element in a building, and a permanent updating of the lighting database.

These characteristics were included in a database concerning lighting elements, which was created and linked to the 3D model of the building. So, the virtual model gives the capacity to transmit, visually and interactively, information related to the compatibility of bulbs, in case of substitution, the expectation of break time and the number of items for each type of bulb. In any point of time is possible to analyze the state of the management of the light system. In addition, the model includes alert to periodic local inspections of observation of the real state of each bulb in the building. After inspection, automatically, the compatibility of each broken bulb is checked in the database, the element is replaced, the installation date is actualized, and the lighting stock is updated.

The interface of the lighting prototype was defined to be used in a very intuitive way. The model is organized in order to:

- Create an **identity** to each new lamp inserted in the 3D model of the building;
- Search in a general **data base** an adequate/compatible bulb to that lamp;
- Insert the **installation date** of the new bulb and the **average number of hours** of the predict functionality;

- Calculate the **predicted break-time** for the bulb based on the installation data and the statistic period of lifetime for that type of bulb;
- Planning a visual **inspection periodicity** to the real place;
- Consult and update the correspondent **bulb stock** established for the building;
- **Walk-through** the interior of the house model and observe the location and the information concerning each installed lamp.

3.1 Identification of elements

To test the prototype, the 3D models of several types of lamps were created. The new elements were imported by the virtual system, EON studio [11] and the identification process is initialized. The identification of each new component of the building must be done to enable the monitoring of the maintenance control. For this propose, a database concerning bulbs usually used in a building was defined. The database is composed with the specifications techniques of some commercial light elements. The identification process is based on the following steps:

- Choose, in the virtual model, a not yet identified element (one lamp, Figure 2);
- Select the type of element for classification (lighting, wall, floor, or other);

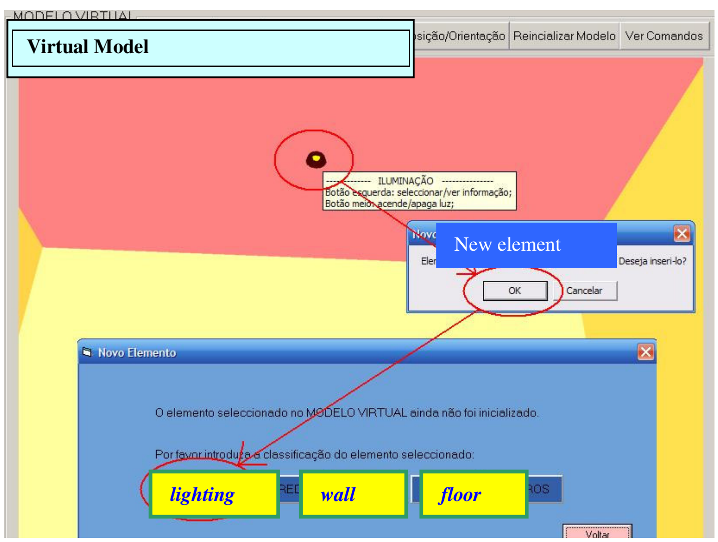

Figure 2: Identification of a new element.

- Pick a bulb in a list of elements included in the database. The information associated to each light element is composed by an image and the correspondent technical characteristics (commercial identification, wattage, power, compatibility, average lifetime, … Figure 3);
- Identify the place in the building where the element is installed (room, kitchen, …);
- Insert the installation date and the average number of hours of the predict usage (low, average or high, Figure 4).

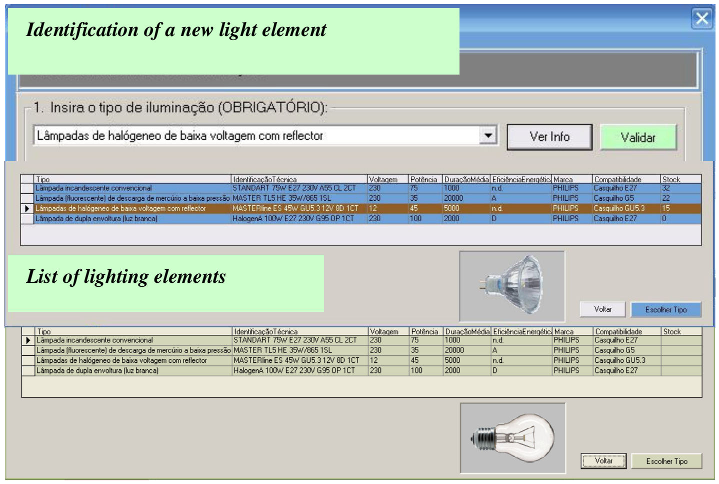

Figure 3: Bulb type selection.

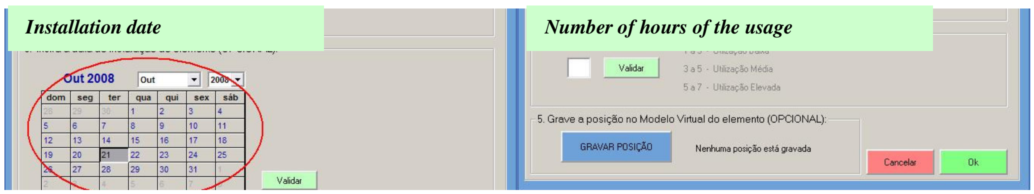

Figure 4: Installation date and the average number of hours of the predict usage.

Thus, the relationship between the new light element and the individual database of the virtual model of the building is established. The virtual model includes a top menu that allows the user to access both data bases. Figure 5 shows the data base of the identified element and the list of lamp types included in a general data base.

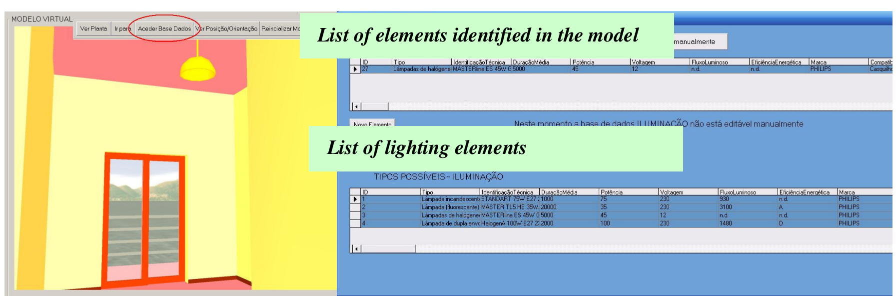

Figure 5: Access to the data bases associated to the virtual model.

Now, the lamp is properly identified as a monitored element and the corresponding information can be visualized. By just clicking over the component in the virtual model, the element is selected and the associated information is presented (Figure 6). In addition, the researcher platform allows the user to select a parameter (localization, compatibility, wattage, …) and a list of the elements is then presented. They correspond to the indicated specification.

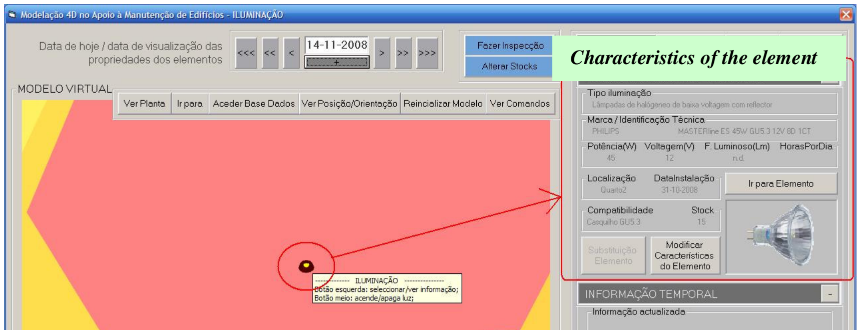

Figure 6: Element identified in the virtual model.

3.2 Monitoring the facilities maintenance

The database contains the information necessary for the interaction with the model in function of the parameter time (installation date, period of average lifetime, next periodic inspection date and the actual date of interaction with virtual model). The result of the research and the adjustments/actualizations necessary to carry out are allowed through the interface of the characteristics of the each identified element. Figure 7 presents the interface with several characteristics of the map that can be modified.

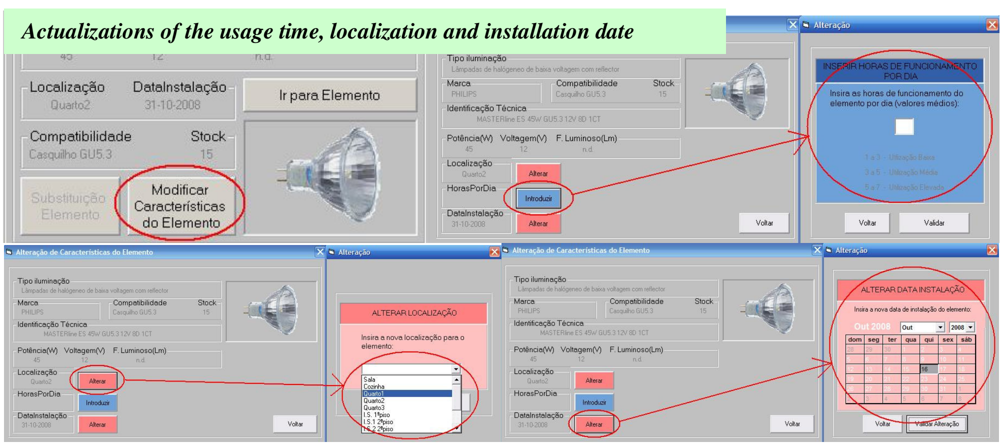

Figure 7: Adjustments/actualizations of technical information.

The virtual model allows the access to all the information of the selected element (Figure 8). So, the comparative information of dates of inspection/installation/re-placement and the average lifetime is controlled and visualized in the interface.

As, this type of building component, for maintenance proposes, has a discrete lifestyle, the elements have to be substituted when the real bulb is broken. The interactive model alerts when the predicted broken date is achieved. The calculation is based on the installation data and the statistic period of bulb lifetime. This verification could be occasionally (by the observation of the state of the bulb in the real place) or by periodic visits (this period was established and incorporated in the virtual model in order to alert of the necessity of inspection to the place). The model allows the definition of a report for each observed element. Figure 9 presents an aspect of the report were it is possible to visualize the inspection date and the options, bulb active and bulb broken.

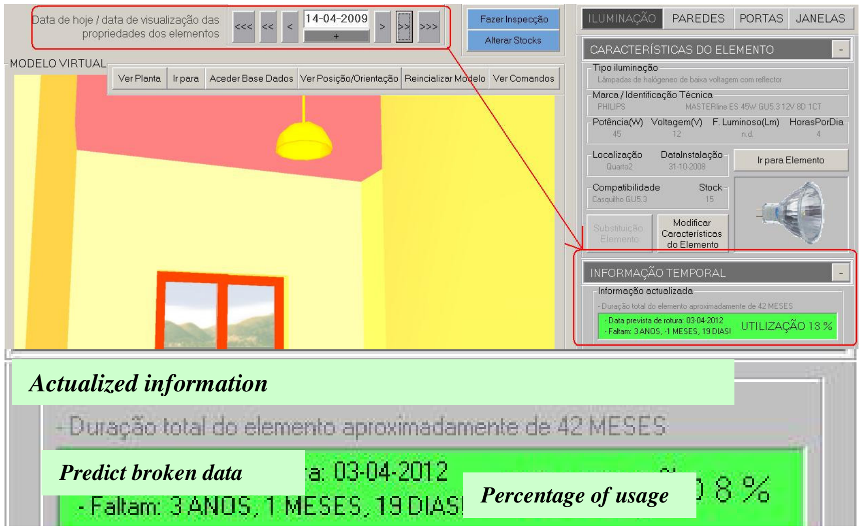

Figure 8: Actualized information of an element.

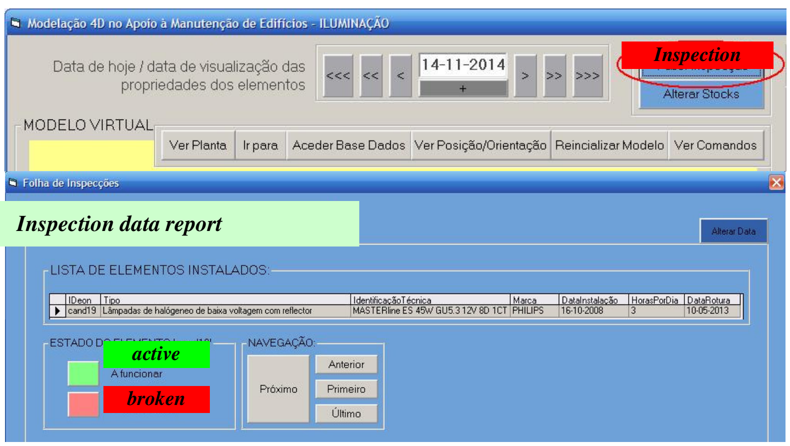

Figure 9: Periodic inspection of each element.

To allow the substitution of an element the compatibility between the old bulb and the bulb to be installed must be verified. The virtual model alerts to this kind of problems. For instances, if the user chooses a wrong bulb the interface displays a message indicating that the selection made was incorrect (Figure 10).

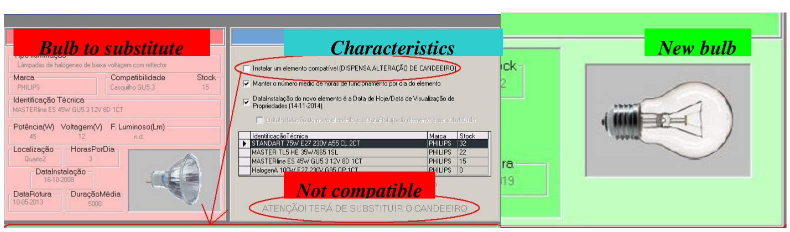

Figure 10: Replacement of a bulb.

The database of each type of bulb must contain the number of elements that is admitted to be used in the building (management of stocks). After each replacement the number of light elements must be updated as well as the installation date concerning the new bulb (Figure 11).

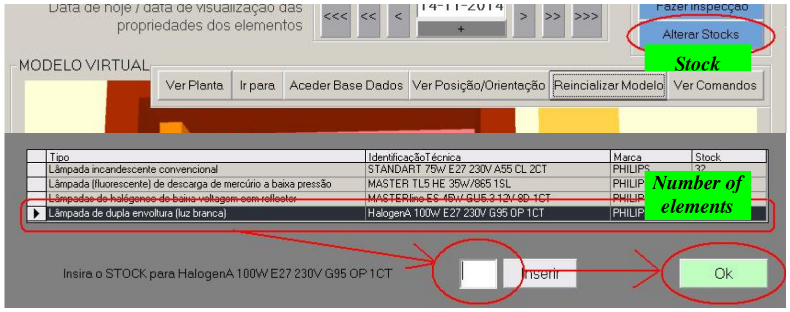

Figure 11: Management of stocks.

3.3 Walkthrough and orientation inside the model

In order to help the user to manage the model, detect the identified element and, in general, walk inside the house, a top projection of each floor was included located at the bottom left corner of the visualization window. A point focus was included in it indicating the position of the user and the direction of visualization (Figure 12). It helps to go to any part of the house.

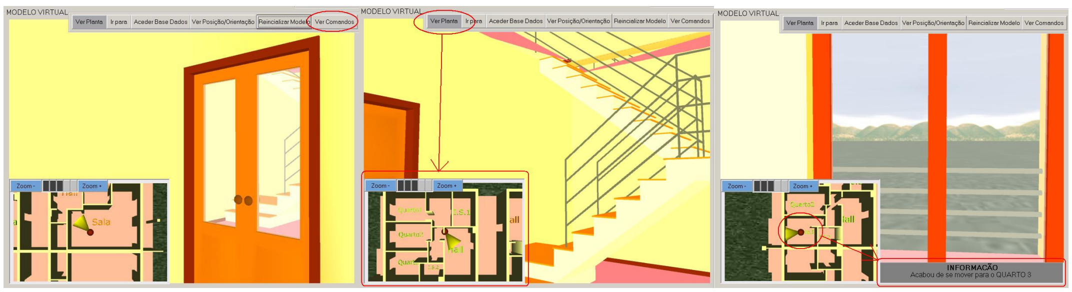

Figure 12: Help orientation inside the model.

This aspect is important in a collaborative virtual environment. In this prototype, when all the lamp elements were identified, any user can interact with it in order to obtain any information concerning each lamp, related to its lifetime or stock management. This developed capacity associated to the model was essential to make it more users friendly and in consequence, even more efficient.

4 FUTURE DEVELOPMENTS AND CONCLUSIONS

In this first phase, a lighting prototype on academic scale was defined and it served as a test. The study model include two elements and diversity of types of bulbs to be able to evaluate the degree of correction of the technical results obtained and the efficacy relating to interactivity and to the properties of visualization provided by the virtual model. The next step in to increment the model with others building components, namely, closures of interior and exterior walls, surfaces of floors, and doors and windows elements.

Further more the prototype will be put to work on another concrete case of infrastructure. The study model will be trailed and the problems caused by an increase in scale (volume, new materials, and other interconnections) will naturally lead to the optimization of the initial model. A method of action will be established with a view to the generalization of the process of generating virtual models from 3D models. It will be promulgated in education, in related disciplines and training courses and on a professional level, to those offices concerned with lifecycle facilities management.

This paper introduces the concepts of VR and interactive visualization on the reflection of the state of a building through time, by focusing just one aspect of building maintenance, the lighting system. Here the simulation and implementation of time-related events, on the building components, has been highlighted. To this end, a model has been proposed to simulate visualization, and interaction with a database concerning the lighting component.

The future work over this prototype must be based on: Systematization of concepts of planning of maintenance; Inclusion of new elements concerning other building components in database; Analysis the methodology to attend the application of the virtual system over other situations. In this way, it is promoted the application the system to any model 3D of buildings. Each concrete situation to be monitored, the virtual model will allow the day-by-day control of the maintenance activity.

The presented example concerns only a type of element, the illumination devices, but it was verified to be efficient in the identification of elements, in the promotion of alerts of inspection and in the management of stocks, all activities related with the maintenance and management of a building.

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