Buildings maintenance supported on virtual environments

Prof. A. Zita Sampaio, PhD, CEng.
Department of Civil Engineering and Architecture, University of Lisbon, Lisbon, Portugal
https://fenix.ist.utl.pt/homepage/ist12448
e-mail: zita.sampaio@tecnico.ulisboa.pt

Prof. A. M. Gomes, PhD, CEng.
Department of Civil Engineering and Architecture, University of Lisbon, Lisbon, Portugal

Abstract

The text presents the description of a research work that has as its main objective the development of a technological tool to support the maintenance activity of buildings, with resort to new information and visualization technologies. There were analysed three main components of the building: roofs, facades and interior walls. A building's roof covering of ceramic tiles constitutes a component of its surrounding and possesses an important function in the performance of an edifice, namely in its protection against the permeation of moisture and rain water; Facade coatings play a significant role in the durability of buildings, since they constitute the exterior layer that ensures the protection of the wall against the aggressive actions of physical, chemical or biological nature; The paint coating applied to interior walls conveys their aesthetic character, performs an important function of protection, and is exposed to agents of deterioration related to the building use. A survey of the main anomalies that occur in these components, the respective causes and the adequate interventions, in order to plan maintenance strategies was conducted. The information collected serves as a basis in the implementation of applications using interactive visualization technologies, to support the planning of building maintenance. During this work the basic knowledge related to the materials, the techniques of rehabilitation and conservation and the planning of maintenance is outlined and discussed in addition, methods of interconnecting this knowledge with the virtual applications were explored. The implemented prototypes were trialled in real cases. This research work brings an innovative contribution to the field of maintenance supported by emergent technology.

1. Introduction

The main aim of a research project PTDC/ECM/ 67748/2006 [1], was to develop virtual models as tools to support decision-making in the planning of construction management and maintenance. Virtual Reality (VR) technology can support the management of data throughout the lifecycle of a building, allowing interaction and data visualization. Factors such as the constant exposure of the coating materials, like ceramic tiles in roofs and facades, stones and painted surfaces in facades and interior walls, to the weather, pollutants and the normal actions of housing use, linked to its natural ageing and, in some cases to the unsuitable application of construction materials or systems of painting give rise to its deterioration and to the appearance of irregularities, which can negatively affect its performance as both an aesthetic and a protective element. According to Lopes [2], in normal conditions of habitation use and when correctly applied, a paint coating can remain unaltered for about five years. To perform maintenance activities a survey of failures in the building must be conducted in order to arrive at the best solution for repair and maintenance.

The Virtual Reality (VR) technology is actually used in areas like education as a teaching support tool or in planning processes concerning industry as a collaborative tool. In architectural design studio, Abdelhameed [3] applies micro-simulation function, inside a virtual reality environment, using the VR Studio program, in order to provide the students with an effective tool to select and visualize a structural system and its construction process. Sampaio and Martins [4] present didactic VR models applied to the construction of bridge field, and developed a set of learning activities for students, in the Engineering Graphics subjects, in order to acquire, develop and improve their levels of spatial skill and, for that purpose; they have structured training with VR, Augmented Reality (AR) and PDF3D technologies. Fillatreau et al. [5] develop a framework for immersive industry checklist-based project reviews, combining immersive navigation in the checklist, virtual experiments and multimedia update of the checklist, relied on the integration of various VR tools and concepts, in a modular way, and Menck et al. [6] uses VR as a tool for collaboration to exchange information and data has increased significantly over time in production-related areas.

2. Interactive Applications

The developed VR models can be considered as useful computer tool with advanced visualization capacities in the maintenance field. The kind of building material that composes the roofs, façades and the interior wall has a continuous lifestyle, so requires the study of preventive maintenance (the planning of periodical local inspections) and of corrective maintenance with repair activity analysis. The models of maintenance facilitate the visual and interactive access to results, supporting the definition of inspection reports, whether in new constructions or those needing rehabilitation. These applications can be easily transported to any building place in order to obtain adequate anomaly surveillance and a consequent methodology of rehabilitation, supported on the data base. The interaction and the data visualization allowed by the models turn these applications simple and direct to work with.

The implemented prototypes, concerning three building components, roofs [7], facades [8] and interior walls [9], incorporate interactive techniques and input devices to perform visual exploration tasks. The following computational systems were used in there development and the scheme of links between software is presented in Figure 1:

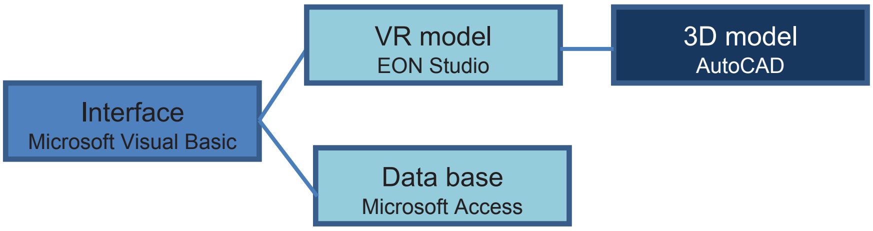

Figure 1: Scheme of links between software.

2.1 The VR model of roofs

The roof covering is the most effective element of a building's surrounding in its edification performance, and, as such, must be efficient in the face of mechanical, thermal, solar radiation and water action [10]. Although several covering materials can be applied in the execution of pitched roofs, the most frequently applied covering in Portugal is the ceramic tile [11]. As the covering performs a predominant role in the protection of buildings, namely against moisture permeation, it requires a greater attention in regards to the analysis of its deterioration process. The developed VR application supports the inspection activity [7].

An in-depth study on the anomalies that might occur, and the most likely causes associated with the different elements of the roof, are contained within the database. To maintain the ease in structuring the database, the causes and the intervention are both linked to the anomaly. Table 1 illustrates two examples of anomalies associated to the type of element (current surface and singular covering points), respective provable causes and recommended interventions.

Table 1. Anomalies, respective causes and recommended interventions.

Element type	Anomalie	Causes	Intervention
Current surface	Cracking of coating elements 	1. Laying the supporting structure 2. Lack of walkways on roofs 3. Placing heavy equipment on the roof 4. Excessive amount of fixations of tiles to support 5. Effect of temperature and moisture	Replacement of damaged elements.
Singular covering points	Insufficient size of the trim 	1. Deficient execution	Element removal and placement of new trim with higher heights.

The implemented interface allows the user to perform, intuitively, an inspection to an inclined roof (Figure 2). The first step in using the application is, naturally, to identify the building to be analysed and the respective roofing characteristics. The filling out of a new anomaly chart or the viewing of existing charts' data is made available through the interface anomaly chart accessed by the main interface. In the anomaly chart the scroll-down menu referring to the anomaly field shows the anomalies that have been registered in the database in association with each of the types of elements. The causes and intervention modes were equally associated to the anomalies, and, therefore, by selecting the respective control buttons, the probable causes and recommended "Intervention" fields are filled-out with the database records connected to the selected anomaly.

The severity of the anomaly can be characterized according to three parameters (low, medium and high), reflecting the previously realized study. The inspection chart interface also comprises a photo insertion zone, thus it is possible to add photographs taken in the inspection location or other images related to the element being analyzed, forming a considerably relevant complementary information for the subsequent study of repair/maintenance relative to the observed severity.

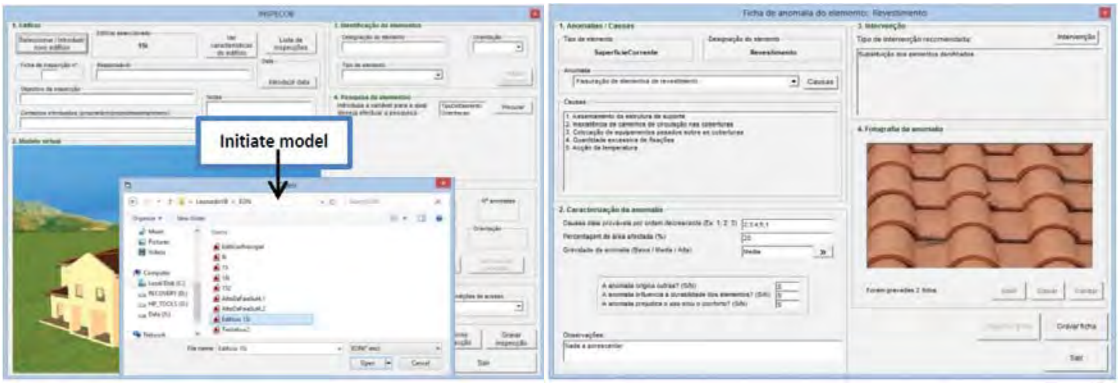

Figure 2: The VR model of roofs interface.

2.2 The VR model of façades

The façades VR model allows interaction with the 3D geometric model of a building, visualizing components for each construction [8]. It is linked to a database (Table 2) of the corresponding technical information concerned with the maintenance of the materials used as exterior closures [12].

Table 2. Anomalies in facades, repair solutions and methodologies.

Anomaly	Specification of the anomaly	Repair solution	Repair methodology
Detachment 	Fall in areas with deterioration of support	Replacement of the coat (with use of a repair stand as necessary)	1º Removal of the tiles by cutting grinder with the aid of a hammer and chisel; 2º Timely repair of the support in areas where the detachment includes material constituent with it; 3º Digitizing layer of settlement; 4º Re-settlement layer and the tiles.

The VR model interface is composed of a display window allowing users to interact with the virtual model, and a set of buttons for inputting data and displaying results (Figure 3). For each new building to be monitored the characteristics of the environment (exposure to rain and sea) and the identification of each element of the façades must be defined (façade orientation, double or single exterior wall, and area and type of coating). Once each monitored element has been characterized, several inspection reports can be defined and recorded and thereafter consulted when needed. An inspection sheet (Figure 3) is accessed by the main interface. Using the drop-down menus of the interface, the user can associate the characteristics of the observed anomaly to a façade element; the type of anomaly, the specification, details and the probable cause of the anomaly, an adequate repair solution and pictures taken in the building. After completing all fields relating to an anomaly, the user can present the report as a pdf file. With this application the user may fully interact with the program referring to the virtual model at any stage of the maintenance process and analyze the best solution for repair work.

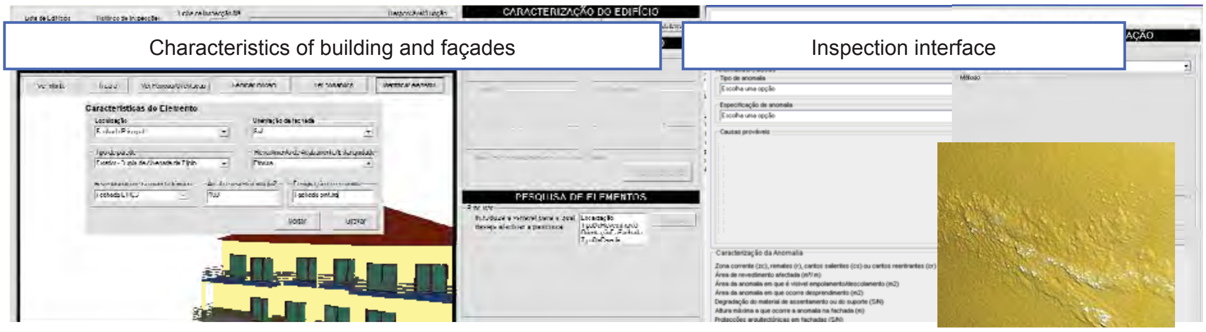

Figure 3: The main and inspection interfaces of the VR application.

2.3 The VR model of painted walls

The material most frequently used in the coating of ordinary interior walls of buildings is paint. Irregularities manifest themselves in various ways and in different degrees of severity. According to Coias [13], in normal conditions of exposure and when correctly applied a paint coating can remain unaltered for about five years. The developed VR application supports on-site inspections and the on-going analysis of the evolution of the degree of deterioration of the coating [9]. The VR model identifies each interior wall surface, in each of the rooms of the house, as independent elements. The application is supported by a database (Table 3), composed by the most common irregularities, their probable causes and suitable repair processes, which facilitate the inspection process.

Table 3. Anomalies and associated repair methodology.

Classification	Anomalies	Repair methodology
Alteration in colour	Yellowing	- Cleaning the surface and repainting with a finish both compatible with the existing coat and resistant to the prevailing conditions of exposure in its environment
	Bronzing	
	Fading	
	Spotting	
	Loss of gloss	
	Loss of hiding power	
Deposits	Dirt pick-up and retention	- Cleaning the surface.
	Viscosity	

The main interface of the application gives access to the inspection module. On an on-site inspection visit, the element to be analysed it selected interactively on the virtual model and using the inspection interface, the specialist can select the irregularity included in the list of the database, which corresponds to the observed defect, and can select also the probable cause and the prescribed repair methodology.

Conclusions

The presented VR applications support the inspection activity of roofs, facades and painted interior walls and promote the use of IT tools with advanced graphic and interactive capabilities in order to facilitate and expedite the maintenance process. The VR capacity of chromatic alteration was applied in two of the models allowing users to see, in the virtual environment, the state of gravity of anomalies or conservation of the coating materials. The information about pathologies, causes and repair methods, collected from a specialised bibliography, has been organised in such a way as to establish each model database to be used as a base for the drawing up of a tool to support building maintenance. The main aim of the applications is to facilitate maintenance enabling the rapid and easy identification of irregularities, as well as the possible prediction of their occurrence through the available inspection record. This analysis has been shown as playing an important role in conservation and in the reduction of costs related to the wear and tear of buildings and contributes to the better management of buildings where maintenance is concerned.

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