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Presentación

Con esta publicación se culmina el trabajo del congreso APEGA (Asociación de Profesores de Expresión Gráfica Aplicada a la Edificación), cita bienal que reúne a los expertos y profesores del área que imparten docencia e investigan en las distintas Universidades y Escuelas de Europa y América, fundamentalmente. Sirve de vehículo para el intercambio de conocimiento y experiencias con el objetivo de fomentar, potenciar, orientar, desarrollar y promover la enseñanza de la EXPRESIÓN GRÁFICA en las titulaciones universitarias de Arquitectura Técnica, Ingeniería de Edificación y demás titulaciones del ámbito de la edificación.

En las quince anteriores publicaciones de APEGA se establecieron las bases con las que pretendemos la realización de proyectos conjuntos que permitan obtener resultados relevantes en el ámbito de la Expresión Gráfica en la Edificación, proyectos que contribuyan y conduzcan hacia una producción científica de calidad e interés internacional. La continuidad de estas publicaciones de resultados científicos durante tantos años atestigua el éxito de la iniciativa que no se vio interrumpida ni siquiera en años de pandemia y crisis.

En tiempos de inteligencia artificial y reuniones virtuales, la presencia física en los congresos, con oportunidad de discutir y defender propuestas en vivo y en directo, ofrece un nuevo valor a la investigación del que carecen los actualmente reinantes artículos de revistas. De ahí el interés de esta publicación que combina la evaluación del comité científico con la presentación y discusión de las propuestas entre congresistas y ponentes.

PENSAR DIBUJANDO es el lema elegido para la presente edición y propone una estructura transversal de las líneas temáticas de las comunicaciones. Se parte, como premisa, de que la imagen final, el dibujo, es para la expresión gráfica aplicada a la edificación, no tanto un fin en sí misma, sino un vehículo útil para el exhaustivo análisis y/o producción de lo representado; infiriéndose de ella que precisa, para alcanzar dicho objetivo, extraer la esencia de la realidad de forma previa a su dibujo o modelización.

Esta es la secuencia necesaria que pretende reflejar la publicación: desde la síntesis a la realidad, que es la que inspira tanto el lema del Congreso, PENSAR DIBUJANDO, como la estructura transversal establecida en la publicación.

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INTERACTIVE VIRTUAL ENVIRONMENTS: FROM MODELLING TO ARCHITECTURAL EXPLORATION

ENTORNOS VIRTUALES INTERACTIVOS: DEL MODELADO A LA EXPLORACIÓN ARQUITECTÓNICA

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Abstract

To attract students' attention and communicate cultural content, computer applications are increasingly being used. The pedagogical potential of new technologies and their trend towards graphical representation and advanced visualisation techniques are clearly evident.

Within the scope of an interdisciplinary master's degree project in building engineering and architecture, new didactic techniques based on the integration of virtual reconstructions in spatial infographic systems have been explored, using graphic representation as a transversal approach to inspect, analyse and explore different architectural objects.

With the aim of generating inspectable models, emblematic examples of the Modern movement architecture by Le Corbusier have been selected: the Curutchet House and Villa Savoye.

The applied methodology was developed following well-defined stages, starting with the analysis of the architectural style, going through a process of simplification and object-oriented modelling, then the visualisation process, assigning textures and materials to the elements and, finally, the diffusion and exploration of the architecture.

Digitisation and the design of new tools for exploring architecture not only increase the user's sense of presence in the virtual environment but also make it possible to perceive it from different perspectives. Students will feel as if they are physically present in the virtual world, an extraordinarily enriching experience, and an almost unique recreation of extended visualisation technologies.

The digital model allows practical cases to be examined in a way that would not be possible with the actual physical object. This will allow a wide academic audience, from anywhere and at any time, to experience and investigate architecture.

Keywords: 3D Reconstruction, Visualisation, Modern Architecture, Teaching.

Para atraer la atención de los alumnos y comunicar contenidos culturales, se recurre cada vez más a aplicaciones informáticas. El potencial pedagógico de las nuevas tecnologías y su tendencia hacia la representación gráfica, explorando las técnicas avanzadas de visualización es, claramente, evidente.

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En el ámbito de un proyecto interdisciplinar, han sido exploradas técnicas didácticas basadas en la integración de reconstrucciones virtuales en sistemas infográficos espaciales, utilizando la representación gráfica como enfoque transversal para inspeccionar, analizar y explorar diferentes objetos arquitectónicos.

Con el objetivo de generar modelos inspeccionables, han sido seleccionados ejemplos emblemáticos de la arquitectura del movimiento Moderno de Le Corbusier: Casa Curutchet y Villa Savoye.

La metodología aplicada ha sido desarrollada siguiendo etapas bien definidas, comenzando por el análisis del estilo arquitectónico, pasando por un proceso de simplificación y modelización object-oriented, asignación de texturas y materiales a los elementos y, por último, la difusión y exploración de la arquitectura.

La digitalización y el diseño de nuevas herramientas para explorar la arquitectura no sólo aumentan la sensación de presencia del usuario en el entorno virtual, sino que permiten percibirlo desde distintas perspectivas. Los estudiantes se sentirán como si estuvieran físicamente presentes en el mundo virtual, una experiencia extraordinariamente enriquecedora y una recreación casi única de las tecnologías de visualización ampliadas.

El modelo digital permite examinar casos prácticos de una forma que no sería posible con el objeto físico real. Esto permitirá a un amplio público académico, desde cualquier lugar y en cualquier momento, experimentar e investigar la arquitectura.

Palabras clave: Reconstrucción 3D, Visualización, Arquitectura Moderna, Educación.

1. Introduction

With the development of digital technologies, graphic expression in the field of AEC, has for several years been giving rise to edutainment models that promote the dissemination and study of architecture. In fact, experimentation in the field of digitalisation has promoted the development of virtual spaces and interactive applications. In this context, immersive virtual reality technologies, including the "serious games" sector, are growing rapidly [1].

Within the scope of an interdisciplinary project of the subjects Architectural Drawing II and Computer Graphics of the Master's Degree programme in Building Engineering-Architecture of the University of Salerno, new didactic techniques based on virtual reconstruction in spatial infographic systems have been explored, using graphical representation as a transversal approach to inspect, analyse and explore different architectural objects. The aim of this work is to propose good practices and guidelines on "experience design" prompting an innovative, participative, and integrative approach to architecture, its representation and communication, thus fostering the digital transition in the academic field.

The idea of the experience is to provide students with the tools to understand and analyse the world of architecture in depth. Two case studies were chosen for the experience, both "machines for living in" by Le Corbusier: Villa Savoye, considered the paradigm of international architecture, and the house of Doctor Pedro Curutchet in La Plata, Argentina. It was necessary to create a new architecture, and Le Corbusier founded it around his five basic points, concepts that were used by the students for modelling. Seeking to simplify their work, the students realised that, although initially time-consuming, the most effective way to approach the task was to break down the architecture into elementary units, the so-called architectural generators. This resulted in an ideal strategic learning experience in which students have the opportunity to walk through iconic architectures, without the need to physically be into them.

1.1 State of the Art

Previous generations of architects travelled around Europe documenting the antiquities with a sketchbook in their hands. The "Grand Tour" was a required formation period on the path to achieving the "Architect" status. Particularly, Le Corbusier was among those designers capable of understanding the worth of history and the cultural value of tradition tying cultural heritage and modern architecture. Still today, the act of drawing represents the preferential mean to read a built asset or an urban space, getting to discretise it to its elemental generative components, i.e., its very lemmas, via schematisation and geometrical representation [2,3].

On the other hand, the "digital natives", i.e., the generation currently attending universities, are both somehow experts when it comes to advanced digital representations and unaware of how the mechanisms of architecture construction work in a world where the lines between images of "invented truths" and reality are increasingly blurred. Therefore, educators play a crucial role in providing naïve audiences with the tools for understanding and analysing the physical world and becoming able to semantise it. How best to understand architecture is to be able to read the flow and balance of the space it creates [2], which is why recreating digital spaces that can be intuitively investigated becomes an effective way to understand even what seems far away. If drawing – and later modelling – and design started as synonyms became antonyms over time, opposing the concept of analysis architecture to the act of creating it. It is then mandatory to reconcile this dichotomy by leading the students through a process of awareness in rediscovering the past so as to build a solid foundation for their future work life. Unfortunately, not all students have the opportunity to walk the buildings they study in books; therefore, it is necessary to rethink the pedagogical strategies to improve current learning experiences.

Fig. 1. Picture of Casa Curutchet (left) [4] and Ville Savoye (right).

In the last three years, physical access to cultural heritage has become even more challenging, so it was necessary to experiment with innovative solutions regarding digital surveying [5,6] and remote reconstruction techniques [7,8], involving the academic community in such a multidisciplinary topic. In other words, the process of democratising the dissemination of cultural heritage is moving in the direction of reconciling the detachment between the scientific community and average stakeholders through integrated digital storytelling strategies [9].

1.1. Objective

Involving the students in shared modelling procedures is nowadays a consolidated approach in the field of architectural representation [10,11] to educate them on the benefits and drawbacks of teamwork while learning the structural functioning of buildings breaking them down into their components to be modelled separately to reassemble them later [12–14].

From a systemic perspective, art and heritage should be analysed as complexity and not as isolated entities where the information architecture is defined precisely in relation to the heritage itself. The tangible and intangible heritage merge into the virtual, which allows the end-user to get closer through the so-called learning by interacting, where amusement and edutainment merge [15]. This prompted the idea of guiding students new to architectural representation in an object-oriented approach to 3D modelling validated through real-time rendering applications, which are additionally optimised for posterior virtualisation of the asset under investigation.

2. Method and Research Process

Whereas every architect or just architecture enthusiast is familiar with such an iconic work of modern architecture as the Ville Savoye by Swiss architects Le Corbusier and Pierre Jeanneret – a private residence located in Poissy – not so well known to most is the Curutchet House, Le Corbusier's only work in South America, commissioned by surgeon Pedro Domingo Curutchet in 1948, listed in 2016 as UNESCO World Heritage, and whose construction was directed by local architect Amancio Williams (Fig. 1).

Ville Savoye, built as an isolated villa, is the manifesto of rationalist building poetics featuring three levels organised as a continuous flow of spaces around a large central ramp and further connected vertically by spiral staircases (Fig. 2). In it, the renowned five principles of architecture are represented in an almost didactic manner: (1) the ground level supported by "Pilotis", to elevate the building from the ground and allow the garden to blend with the inner space; (2) the garden/terrace roof, as an insulating element partially restoring the natural space occupied by the building; (3) the floor plan with no load-bearing walls, owing to the introduction of the reinforced concrete frame structure, which allows the interior space to be freely composed; (4) the neat-cut in the perimetral walls by means of long horizontal windows for illumination and ventilation purposes; (5) the freely designed facades that merely provide the skin of the building.

On the other hand, whilst the Curutchet house incorporates all the elements of rationalist architecture, Amancio Williams had the challenging task of adapting Le Corbusier's design to a modestly sized lot, less than 200 square meters [16], located in the middle of the city with an axis inclined at about 45 degrees to the municipal line. The house extends outwards, blending with a beautiful sunny square and the forest of La Plata [17].

The outside space seems to be channelled from the inside forming a harmonious façade encapsulated among neoclassic buildings. The skin of the building stems from the rooms beneath, but at the same time feels as if it were constructed from modular elements arranged in an irregular grid to balance openness and closure. Through the columns-framed entrance and the almost hidden blue door, the visitor can access the ramp connecting the inner spaces located at different intermediate heights. Like a ribbon, the ramp floats over the courtyard garden, revolving around a central tree. On the first floor, there are the consulting spaces of the private medical office of the owner of the house; even though one could think that the cubicles would cut the fluidity of the space, in reality, their masterful interplay of light and shadows further exalts the internal-external relationship [18].

Planes and volumes are perfectly equilibrated in a sensitive continuity and, by climbing up around the tree in the middle, the ramp finally leads to the terrace garden, whose lawn looked like a leap from the house's park before being replaced with arid tiles. The horizontal screen hanging over the terrace like a canopy strongly remarks the continuity with the park [18].

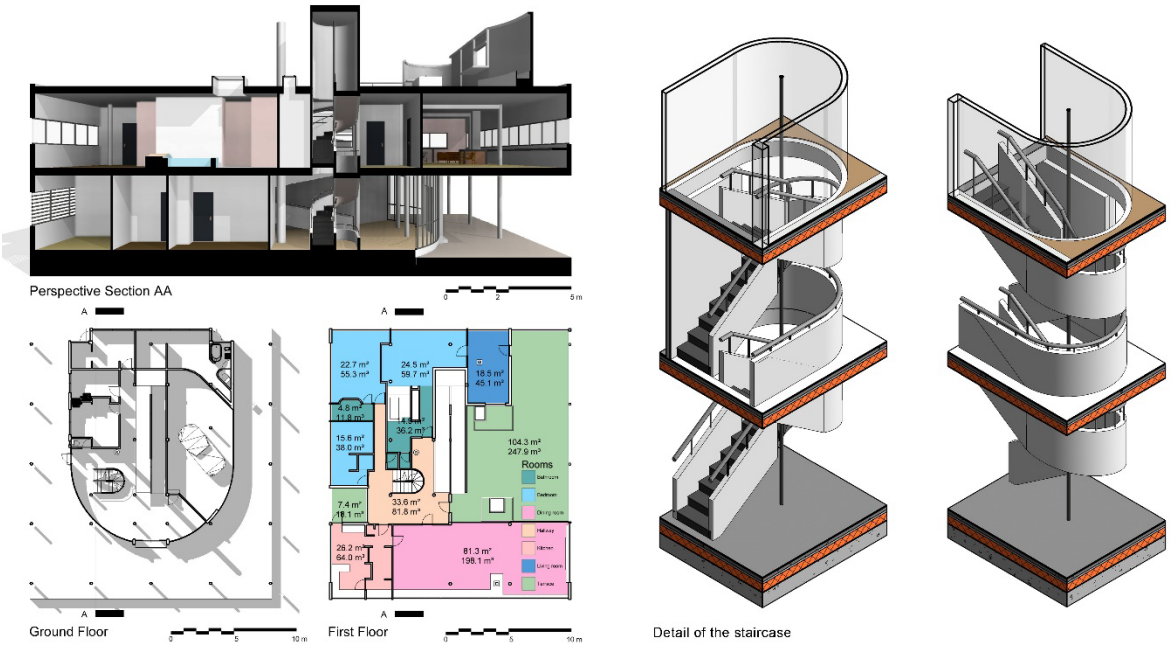

Fig. 2. Technical Drawings of Ville Savoye. Authors' Elaboration based on the work of "Computer Graphics" Students: Andrea de Luca, Andrea Matrone, Ilenia Mauro, Carlotta Mellone, Giuseppe Pecoraro Scanio, and Angela Pierri.

Namely, the strength of Le Corbusier's design is the flowing spatiality resulting from a sincere dialogue between opposites that manage to coexist peacefully: mathematics and perception, objective and subjective experience, geometric rules and plasticity, unity and breakage, fullness and emptiness, structural order, and visual variety [16]. Therefore, these artworks are best suited to the interactive teaching of modelling techniques, starting with the static discretisation of their elementary components and culminating in the dynamic experience of the virtually reconstructed architectural assets through real-time rendering tools.

2.1. An Object-Oriented approach

The collaborative approach involving second-year students of the "Architectural Drawing II" course and the third years of the "Computer Graphics" course – degree programme in "Building Engineering-Architecture" held at the University of Salerno, academic years 2020/21 and 2021/22 – concerned the introduction to three-dimensional modelling techniques with an eye to the HBIM (Historic Building Information Modelling) methodology [19,20]. Particularly, the second years focused on the object-oriented aspect of BIM modelling working in the Trimble SketchUp environment, decomposing the Curutchet house into its constructive generative components to set the environment for optimised visualisation; on the other hand, the third years developed a few models of Ville Savoye within the Autodesk Revit software environment, enriched with both constructive information and PBR (Physically Based Rendering)[21] materials to fulfil the BIM paradigm.

Indeed, upon setting up an informative system of a built asset, a few propaedeutic choices have to be undertaken regarding the rate of replicability, standardisation, and interoperability we want to achieve [22]. The particular 3D objects that characterise the built heritage can be designed as fully parametric, totally "in-place", or as somewhat in-between, e.g., they can be generated with a non-BIM authoring tool and only afterwards imported into such software to be enriched with non-geometric information [9]. Additionally, non-native software environments, such as SketchUp, blender, freeCAD, and so on [23], support BIM

plug-ins that allow assigning IFC categories and additional textual properties to the constructive components provided they have been accurately broken down.

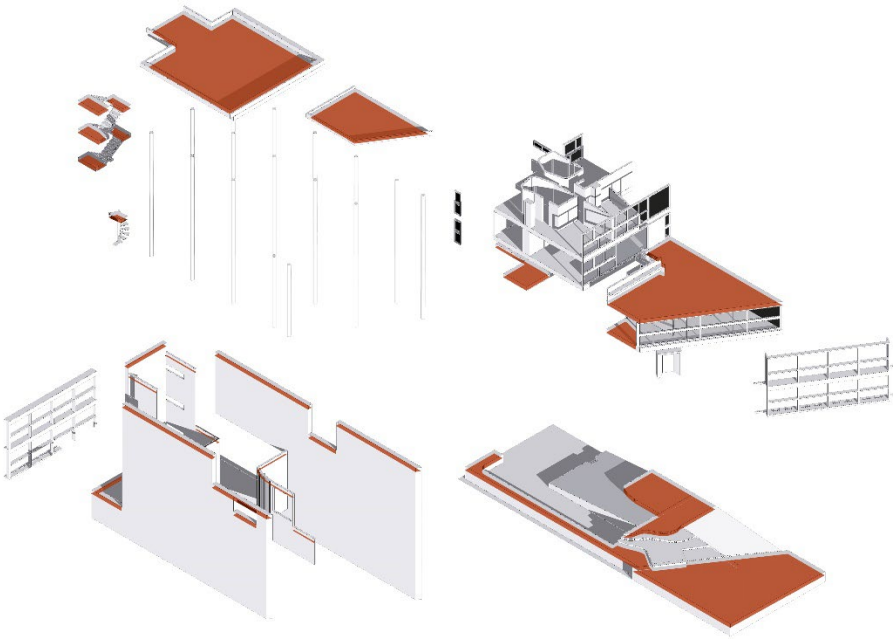

Fig. 3. Exploded axonometric of Casa Curutchet. Authors' Elaboration based on the work of "Architectural Drawing II" Student: Sara Mattia.

For this purpose, in both cases, we first encouraged the student to analyse the architecture under study in-depth to look for the elemental generators. Thus, the Casa Curutchet was ensembled via "Solid Components" in SketchUp. Albeit hollow, once created, these elements can be placed multiple times by just recalling their "name" from the dedicated panel; moreover, upon modifying one of them, all the other instances will be adjusted accordingly. Furthermore, working with elements identified as "Solids" also allows for boolean operations between them in order to simulate the real joint among physical parts (Fig. 3).

As far as Ville Savoye is concerned, the third-year students of the "Computer Graphics" proceeded to model the elements representative of the five principles of modern architecture mostly as "loadable" parametrised families, fitting them to the original design. Peculiar structures, such as the central ramp and the peculiar staircases, were modelled as a combination of "system families", "in-place" models and also "loadable" elements. Furthermore, additional constructive information was provided.

Realistic 3D environments offer the possibility of immersive and realistic reconstructions of events and context, thus facilitating learning and heritage awareness [1]. To this mean, in both modelling experiences, the students employed downloadable PBR materials to more accurately reproduce the specific ambience of the houses – photorealistic renderings were generated for Ville Savoye (Fig. 6) – and went even further by experimenting with, to some extent, surreal settings in the case of the Casa Curutchet (Figs. 4 and 5).

"[…] But all of a sudden, you touch my heart, you make me feel good, I am happy, I say: this is beautiful. This is the architecture. The art is here...", Le Corbusier [24].

Thus, alongside directly assessing the adequacy of their work, they also had the chance to experiment with virtual exploring distant architectures via the real-time rendering plug-in Chaos Enscape, both in SketchUp and Revit. Namely, Enscape also provided the possibility of georeferencing the models and downloading the urban context from Open Street map, i.e., it was instrumental in framing the Curutchet house within its environment, making it possible to

better understand some design choices undertaken by Amancio Williams in adapting the Le Corbusier original project to the La Plata city context (Fig. 7).

Fig. 4. Rendered views of Casa Curutchet exteriors. Authors' Elaboration based on the work of "Architectural Drawing II" Students: Gaia Agovino, Barbara Ferraro, Annapia Potolicchio, and Francesca Stanzione.

Fig. 5. Rendered views of Casa Curutchet interiors. Authors' Elaboration based on the work of "Architectural Drawing II" Students: Gaia Agovino, Alessia Curcio, Palmira Montella, and Nella Pagano.

Fig. 6. Rendered views of Ville Savoye. Authors' Elaboration based on the work of "Computer Graphics" Students: Andrea de Luca, Andrea Matrone, Ilenia Mauro, Carlotta Mellone, Giuseppe Pecoraro Scanio, and Angela Pierri.

3. Results

"Then we have computer science. It is true that software cannot exercise its powers of lightness except through the weight of hardware. But it is the software that gives the orders, acting on the outside world and on machines that exist only as functions of software and evolve so that they can work out ever more complex programs.", Italo Calvino [25].

The experimented teaching techniques mixed with interactive virtual environments fostered the so-called "learning while playing" [26,27] approach, which led to optimal results for each student group involved. All of them managed to successfully pass the exams going, in most cases, far beyond the minimum requirements.

The main advantages of using this type of virtualisation technique lie in the possibility of querying, modifying, and updating intelligent objects within a single software environment. In addition, the use of advanced textures/materials makes it possible to simulate in an increasingly realistic fashion – in line with the advancing development of integrated rendering technologies – scenarios that make it easier for both specialists and less experienced users to understand and dialogue with architectures that would otherwise be inaccessible, especially for distance-related issues.

The resulting products are also already optimised for virtual reality applications, real-time virtual walks, and exporting standalone models, as well as for the generation of 360° panoramas ready to be implemented in virtual tour applications (Fig. 8).

The versatility of the developed work methodology appears evident, i.e., it enables the elaboration of a plethora of outputs, most accessible online without having to download any proprietary software, by operating just a few small modifications, with informative and interactive features that can be adjusted according to the specific requirements and the intended stakeholders.

4. Conclusions

Digitisation and the development of new tools for exploring architecture not only increase the user's sense of presence in the virtual environment, but also make it possible to perceive it from different perspectives. With the exposed activity, students will feel as if they are physically present in the virtual world: an extraordinarily enriching experience and an almost unique recreation of extended visualisation technologies.

Fig. 7. Rendering of Casa Curutchet framed in its urban context visualised within the Chaos Enscape software environment. Authors' Elaboration.

The digital model allows practical cases to be examined in a way that would not be possible with the real physical object. They allow remote analysis of objects from all possible angles, improve surface visibility, enable the generation of technical drawings, and even automate measurements. This will allow a wide academic audience, from anywhere and at any time, to experience and research architecture.

Applied research avenues include the development of data and AI-based services, advanced design thinking methodologies, interaction design, user experience and user engagement for the use and dissemination of architecture, and educational design models that ensure engagement and inclusion in museums and cultural services, for research, innovation, training and technology transfer in the strategic area of building.

The usefulness of 3D models is not only academic, as these new technologies allow for different forms of interaction with the public. Students will be able to take a virtual tour of a given architecture in their classroom. This change in the way information relates to the public can bring the past to life for people and make the field of architecture more accessible to a wider audience.

This experience was part of a series of workshops and exchanges between the universities and once again opened up new possibilities for research and teamwork. The interaction between professors and students and the cultural exchange became the basis for the construction of shared knowledge and further strengthened the collaboration and understanding between the different countries involved in this experience.

The graphical user interfaces allow easy direct input of data and simplify the use also for non-experts in AEC and enable collaboration between the many figures involved in the construction process, such as architects, engineers, and others. Therefore, the possibilities offered by digital practice, from virtual reconstruction to three-dimensional environments and interaction with digitised architecture, constitute new frontiers for digital design. Through simulated experience, the human experience of a situation through computer technology will potentially be like a walk through the real situation.

Fig. 8. Panoramic images of Ville Savoye ground floor – with highlighted the equirectangular diagram used to build 360° images – produced via Chaos Enscape. Authors' Elaboration.

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