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Communicating Architecture. An AR Application in Scan–to–BIM Processes

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Abstract
The paper presents the first results of an ongoing research on the benefits of implementing computational modeling in Scan–to–BIM processes for the representation of historic architecture in AR and VR application with education and communication purposes. The 3D laser scanner survey of a complex vaulted system was the starting point for the development of the research. The design of an App that optimizes the effectiveness of computational modeling concludes the workflow exporting the FBX file from Revit and then importing it directly onto the Unity real–time development platform. The study shows the feasibility of the computational approach in the application of AR and VR systems demonstrating its effectiveness thanks to the segmentation and hierarchization of the different components of the ribbed cross vault.

Keywords
interactive AR, scan–to–BIM, algorithmic modeling, 3D visualization, mobile applications.

doi.org/10.3280/oa-686.52

3D Digital Representation as Effective Communicating Framework for Cultural Heritage

Information and communication technologies (ICT) have expanded the dimensions of survey and representation models in architecture. Representation systems and graphic schematization have always been a crucial step in architecture learning process. Only due to a correct coding of the visual message, the abstract conventional 2D models of architectural drawing convey information in an immediate, rich and effective way. A successful graphic representation needs to assume a certain distance between the reality and its visual exemplification: communication acquires immediacy and quality as the degree of schematization and coding increases. In some cases, especially when there is no sharing of the codes of representation, only limited information and knowledge are available about traditional 2D graphic models. It's now widely proven as ICT can favorably impact student learning and communication of Cultural Heritage (CH), as for example in teaching–learning interaction, museum installations or virtual and augmented visits [Mortara, Catalano 2018].

New technologies such as 3D laser scanning (LiDAR) or Structure from Motion (SfM) systems constitutes a valid support to cultural heritage visual presentation and documentation in different fields of scientific research and professions. Despite the interpretation and critical representation of the massive amount of 3D data of these two systems sometimes becomes a limit, these technologies can certainly express strong potential also for communication and educational purposes. A consolidated application in architecture is certainly that of the so–called Scan–to–BIM processes aimed at generating semantically rich as–built BIMs of complex objects from 3D point clouds datasets. In our research, computational modeling allows an approach that registers BIM components with semantic information driving the design process from both 3D point clouds data and rules from historical architectural treatises. By parameterizing the modeling process, the algorithms prove to be particularly effective in the analysis and representation of object categories normally non–native in BIM libraries. The algorithm also presents the advantage of recording information on the segmentation and hierarchization of the different architectural components, with interesting and useful repercussions in AR applications. In addition to the methodological contributions, computational approach allows us to interact in the visualization of the different individual components and

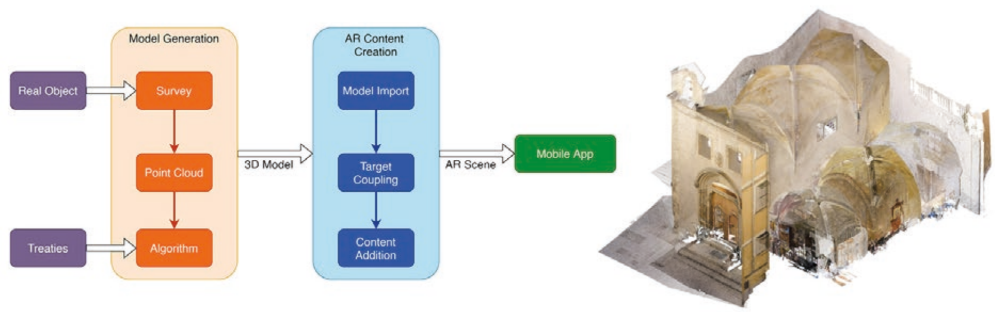

Fig. 1. Workflow from the survey to the mobile AR app (left); Point Cloud from the Laser Scanner surveys (right).

to have a range of possible relations already stored in the algorithm. The workflow was prototyped in parametric design with Visual Programming in Dynamo with Autodesk Revit and tested on a 3D point cloud of the XVI century church of Nostra Signora della Speranza in Cagliari (Italy), scanned via Leica Laser Scanner HDS 7000 (fig. 1). Starting from the 3D laser scanner survey of the entire monument, the workflow was tested by focusing attention on the main components of its complex vaulted systems, consisting of some ribbed cross vaults with pointed arches. To create smart data queries and visualizations, an App design process optimizes the potential of the approach by completing the workflow, enhancing the different visual analyzes in a very intuitive manner. AR and VR technologies provide new ways of space visualization and architecture interpretation, promoting and developing building reading skills. Thanks to the design of specific tasks aimed at users such as first–year architecture students, the App aims to optimize the reading of the anatomy of the ribbed cross vault and the 3D spatial relationships of its different architectural elements.

Algorithmic Modelling in AR Applications

For years now, the procedural generation of 3D models has played an important role in architectural production. The possibility of creating parametric processes capable of remodelling a three–dimensional element in a largely automated way allows the definition of even very complex rules for the generation of elements [Tedeschi 2014].
This type of approach is particularly interesting when dealing with elements with particularly complex geometries and at the same time constrained by the need to correspond as closely as possible to the physical models to be represented. An emblematic situation is that of Scan–to–BIM processes applied to complex historical elements, like gothic vault systems; these elements are in fact very often absent from the normal native libraries of BIM tools, and their complexity highlights the numerous constraints that BIM environments present in terms of modelling, since they are by nature information modellers and not 3D modellers [Argiolas et al. 2019].
The use of development environments based on Visual Programming Languages (VPL) has made it possible on several occasions to get around the deficits of the modelling tools of BIM environments, by releasing the modelling process from the single element, and linking it to the category of elements and therefore to their invariances [Bagnolo et al. 2019] (fig. 1). In the case of gothic vaulting systems, the hypothesis has been put forward that the definition of the geometry and curvature of the ribs is sufficient to define the entire vault [Willis 1910], to the extent that in certain geographical contexts materials and techniques do not lead to noteworthy stylistic variations [Agustín–Hernández et al. 2018].
This is possible thanks to the use of modelling algorithms developed by means of special environments such as GrassHopper for Rhinoceros or Dynamo for Autodesk Revit, both of which are now highly integrated with Revit; this makes it possible to keep the entire model creation phase within the BIM environment, significantly limiting the problems that can arise from the passage of data between software through export/import of models.
The algorithms also represent a container of information regarding the model, constituting a real metadata of it; in the algorithm, in fact, information on the geometric rules used for the realisation of the model components remains accessible, as well as how these components are assembled together and therefore, what is the hierarchical organisation of the model.
The use of augmented reality technologies is now an established practice for the communication of architectures, whether they are just designed or built, especially for the historical heritage [Spallone, Palma 2020]. It is possible to see how there is a bidirectional link between BIM models and augmented reality for the communication of architecture; if it is true that the immersiveness offered by AR plays a fundamental role in the process of 'telling the story' of architecture, it is equally true that the organisation of the elements and their classification, typical of the BIM methodology, offers a further level of deepening and understanding of the building organism.
In our specific case, notwithstanding the considerable impact of the mixed visualization of the model as a whole, the possibility of breaking down the various elements in real time and managing them autonomously in their graphic representation, offers an enormous expansion of perspectives of use. Even the mere hierarchization of the elements, in the case study based on the idea of the Uniclass 2015 classification [NBS Enterprises Ltd 2021], allows us to offer the user a reading by levels of the objects, facilitating their comprehension (fig. 2). Another advantage can be derived from the implementation of the logic of levels of detail (LOD) of the BIM models, which lends itself well to adapting the amount of information dis-

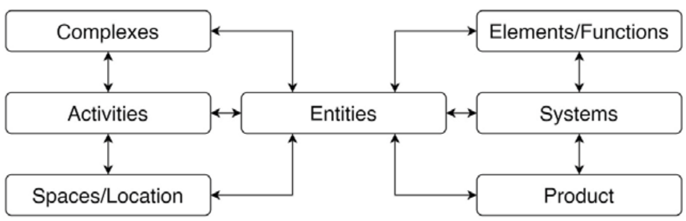

Fig. 2. Classification in Uniclass 2015.

played and its degree of precision. This translates into a differentiated visualisation according to the level of "zoom" with which the user observes the objects.
The implementation of the model of the Church of Our Lady of Hope within AR scenes was carried out using the real–time development platform Unity [Unity Technologies 2021], for the design and programming of all the interfaces and mechanics of the app. In addition to the standard modules, Vuforia [PTC 2021], a free package for the creation and management of AR cameras and targets, and PCX [Takahashi 2021] for the import of point clouds were added.

Exploration and User Interface Design

The software as configured, allows the possibility to live two main types of experiences, one in augmented reality in third person and one in virtual reality in first person.
Once the application is started and the 'start' button is pressed, the software enables the camera and the device is ready to recognize a target which can be:
• figurative, as in our case study in which the building plan was chosen;
• coded, such as QR Codes.
Once the target has been identified, the 3D mesh model appears on the screen and, at the same time, the control panel located in the lower part of the interface is enabled, allowing you to activate various functions. Hide/unhide elements (fig 3). Pressing the 'layer' button opens the sheet showing the elements according to classification system based on Uniclass 2015 of the building organization. The software allows you to turn them on and off individually with the relative box. Pressing on the text item switches instead to the detail screen, which specifically analyses the element (fig. 4). Organization in pre–packaged documents. Clicking on the square allows you to view the model according to the predetermined drawings such as plans, sections and axonometric views (fig. 4). General information. The 'i' button takes you to a tabbed screen on the historical information of the building which also recalls a photographic section. The browse button allows you to switch from augmented reality to virtual reality mode; starting from a first–person view, typical of some video games, it is possible to virtually move in the external and internal space of the building thanks to the aid of two virtual pads, one dedicated to the movement of the camera, the other to the movement in the model. In this navigation mode, thanks to on the PCX package, it is possible to switch from navigation on the polygon mesh model to the point cloud produced by the survey with the LIDAR, which allows a comparison between the two products and an even more immersive detail view.

Fig. 3. View of the AR mode with the hide/unhide feature.

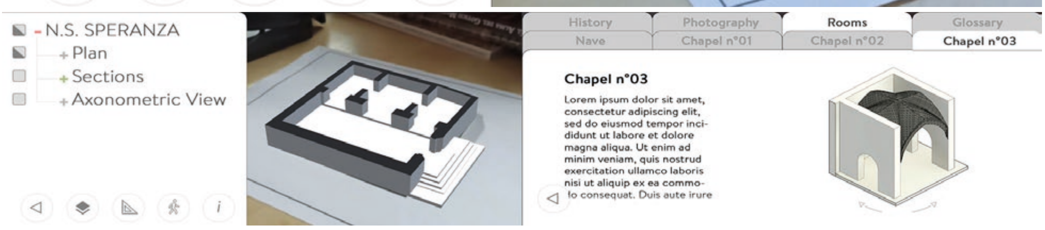

Fig. 4. View of the preset drawings mode (left), and the detail screen (right).

Conclusions

Representing the meaning embodied in complex works of architecture like vaulted systems, this approach allows a novel way to interact with the history and the theory of architecture. The combination of AR technology with the use of touch screen technology of mobile devices makes the manipulation and visualization of semantically–enriched 3D models very simple and intuitive. Interaction can take place either through QR codes or printed images like architectural plan. Improving 3D scene synthesis systems, the app allows a range of semantic queries into 3D model datasets. Strictly depending on the characteristics of the specific category of architectural components, the features included in the app prove to be very effective in the communication and representation of architecture. The research plans to continue by implementing in the 3D model all the constructive elements of the different parts of the church as well as sacred art and sacred furnishings of historical and cultural interest.

Acknowledgements

Although the study was jointly performed by the authors, most of the paragraph *3D digital representation as effective communicating framework for Cultural Heritage* was written by Vincenzo Bagnolo; most of the paragraph *Algorithmic modelling in AR applications* was written by Raffaele Argiolas; most of the paragraph *Exploration and User Interface Design* was written by Nicola Paba; the *Conclusions* were jointly written by all the authors. The 3D laser scanning was carried out at LabMAST, DICAAR, University of Cagliari. LIDAR point clouds product by Sergio Demontis and Valentina Pintus. Research project funded by Fondazione di Sardegna – year 2019. Surveying, modeling, monitoring and rehabilitation of masonry vaults and domes (RMMR). CUP: F72F20000320007.

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