SCIRES it

SCIentific RESearch and Information Technology
Ricerca Scientifica e Tecnologie dell'Informazione
Vol 12, Issue 2 (2022), 15-28
e-ISSN 2239-4303, DOI 10.2423/i22394303v12n2p15

CASPUR-CIBER Publishing, http://www.sciresit.it

DEVELOPMENT OF A 3D ISOVIST TOOL. THE VISIBILITY OF THE ARCHITECTURAL SPACE OF THE UNIVERSITY PALACE IN GENOA USING PANORAMIC PHOTOGRAPHY

Cristina Càndito, Alessandro Meloni**

*Department of Architecture and Design, University of Genoa– Genoa, Italy.

Abstract

The present contribution is a part of a study about architecture visibility, as an opportunity to understand spatial features and their effects on user perception. One of the starting points is the vast range of scientific literature and applications about the concept of Isovist, as a tool to visualize the portion of space visible to a user, although limited only to bidimensionality. The purpose is to identify a three-dimensional version of Isovist, here called *PanoProj*, which takes advantage of the contrast between a realistic representation of the panoramic photography and the dynamic resources of the parametric virtual model. This paper presents an application on the University Palace of Genoa, a 17th century Jesuit college, which is the place where some architectural features, generated by the combination of typology, territory, and local traditions, could be verified, showing the potential of the studies about space visibility.

Keywords

Architectural space, Isovist, Panoramic photography.

1. *Introduction*

The present paper is aimed at developing a method that helps to represent the visibility of a space, as it is perceived by a user who navigates an architecture. The perception is simulated in order to complete the intuitive results through a new three-dimensional version of the Isovist method, that allows the delimitation of the visible portion of space. The process identified exploits the potential offered both by parametric modelling and panoramic photography.

The intention is to take advantage of realistic characteristics of panoramic photography, which represent the whole space visible from a single point of view, and their contrast with the schematic representation of a non-realistic virtual model. The result is the *PanoProj* tool that allows us to distinguish the portion of space that is visible to a user as a representation from a different point of view in the virtual model.

This contribution uses an historical building as a case study to show the potential of the *PanoProj* tool in understanding the relations between architecture and users and to verify some spatial features of the subject studied.

2. *A university headquarters of the 17th century*

A university headquarters of the past was chosen as a case study because of its peculiarity: the University Palace of Genoa (Italy) is one of the numerous examples of 17th century Jesuit Colleges although also influenced by the local models of aristocratical palaces.

The University Palace in Strada Balbi was built thanks to an agreement between the Order and the important Genoese family Balbi, who occupied a part of the city with its own residences, granting a plot to the Jesuits (Colmuto Zanella, De Negri 1987; Poleggi 1987;Della Torre, Patetta 1990; Wittkover, Jaffe 1992; Càndito 2001; Bösel 2012). The first drawings were realized in 1630 by Bartolomeo Bianco (1579-1640), architect and engineer from Como. The complex design phases of the building also involved the mathematician Orazio Grassi (1583 1654), rector of the college from 1646, who was previously appointed in Rome to examine the projects of the Genoese Jesuit college. For the present research, it is useful to be aware of the space disposition of the College, which was built starting in 1633, with the courtyard located at a higher level than the Entrance Hall, to be more suitable to the natural slope of the terrain.

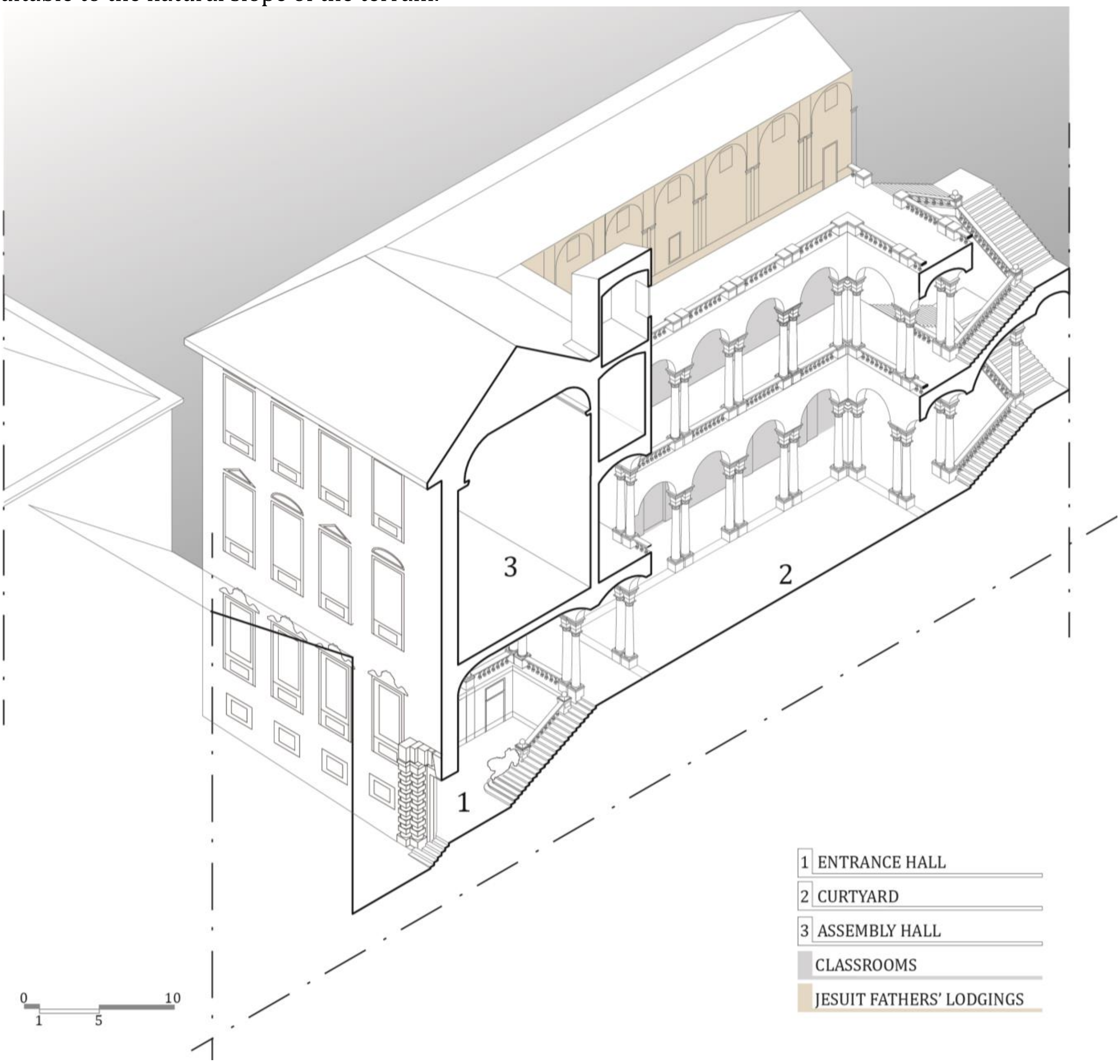


Fig. 1: University Palace of Genoa. Axonometric section of the model

The classrooms line up in depth, facing the two levels of the courtyard porch. Above the classrooms there are parts of the Jesuit fathers' lodgings. Along the main street front there is a double-height Assembly Hall (first and second floor) and two libraries on the second floor: the current Sundial Hall and the Main Library (fig. 1).

3. *The development of Isovist tool and its use*

The discussion about architectural visibility has its roots in the theory of visual perception. Within this broad discipline, for the present research, the more relevant studies involved the concept of the visible portion of space. This feature can be represented with the help of Isovist, described as the polygonal representation of the visible space, that changes with the position of the observer (Gibson 1947).

Isovist, as a defined area generated by the visual rays, is developed with the help of digital methods (Nagy 2017). It can now be found as a component in the widespread software Grasshopper - Rhinoceros (McNill) permitting the dynamic generation of the 2D polygon of Isovist which moves during a simulated users navigation of a space (fig. 2).

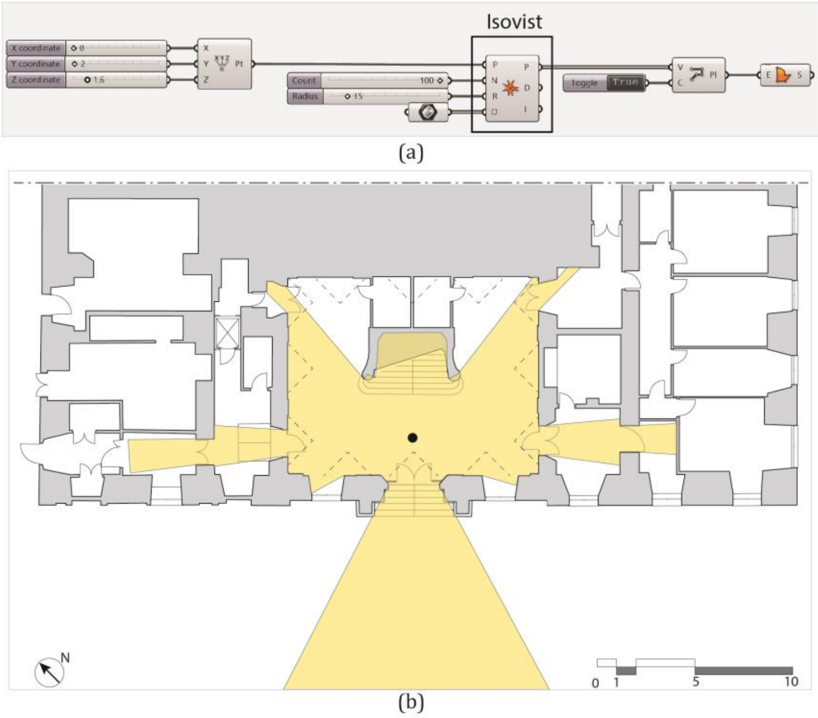


Fig. 2: Ground floor plan with a 2D-Isovist obtained with the Isovist component in Grasshopper

Isovist offers a variety of measurable elements that could be helpful in transforming a qualitative observation into a quantitative one. Over the years, Isovist has been used to observe and measure spatial features that have been able to help interpret architecture (Benedikt, McElhinney 2019). For example, the visual openness measured with the help of Isovist is related to user satisfaction of dense urban areas (Fisher-Gewirtzman 2010) because it generates sense of safety, directly connected with the knowledge of space and orientation (Conroy Dalton et al. 2015; Mahdzar et al. 2019). This new tool is recognized as an integration of traditional studies about the legibility conditions of an environment (Lynch 1960), the interaction between space and the observer (Gibson 1979), and the wayfinding phases process (Golledge, Stimson 1997).

The three-dimensional potential of Isovist was expressed by Benedikt (1979), who defined it as the "set of all points visible from a given vantage point in space and with respect to an environment". Some studies introduced new elements in order to extend it to visibility graphs (Turner et al. 2001) and to transform the polygon in a polyhedron, permitting the generation of an Isovist volume into the virtual model, which can be described by its shape and measurable characteristics (Penn et al. 1997; Varoudis, Psarra 2014; Lonergan, Hedley 2015; Krukar et al. 2020).

Starting from the viewshed concept, defined as the terrain visible from a major viewpoint (Lynch 1976), a 3D version was proposed with the viewsphere tool (Yang et al. 2007). The combination between third dimension and dynamism is the aim of studies (Ünlü et al. 2019) that use sequential three-dimensional Isovists as polyhedral portions of space that have their centre at the observer's viewpoints changing along a path.

Furthermore, the realism of images has been carried forward by studies adding the contribution of visual features of cylindric form of panoramic photography (Fisher-Gewirtzman 2016) or 3D point clouds (Dalton et al. 2015) and proposing the use of a Lidar tool (Lu et al. 2019).

What is important in the present research, however, is the use of the contrast between a non-realistic digital model and a projection of panoramic photography. The movement inside the model simulates user navigation and the subsequent appearances, which can be observed from any point of view.

4. The PanoProj tool in a virtual model

The visualization of a series of representations of the space visible to an observer was conceived in different phases: the realization of a virtual model capable of hosting parametric applications, the choice of the way in which the panorama photos are inserted into the model, and the projection of photo images into the same model. The combination of the instruments used suggested the name of *PanoProj*.

4.1 The virtual model

The University Palace was subjected to different kinds of surveying methods. The whole building was surveyed with metric procedures and image based modelling and nodal photography techniques were applied to certain spaces[1].

A non-realistic three-dimensional model focusing on the opened space of Entrance Hall and courtyard was carried out. This model is not intended as a final result, but as a support for the next phases which are realized in a parametric modelling environment in order to take advantage of the transformation needed in a user movement simulation.

4.2 Panoramic photography insertion

For the present study we used panoramic photography[2] as an effective tool to simulate realistic images taken from a point of view and extended to the whole space. Panoramic photography, as it is known, portrays a place with an angle of 360 horizontal degrees and 180 vertical degrees covering the surface of a projective corresponding sphere developed approximately in an equirectangular projection.

It is possible to project the panoramic image on various geometric surfaces. Studies previously cited (Fischer-Gewirtzman 2016) used cylindrical projection to describe the most perceptually relevant spatial factors in the vision of an external environment. Other research experimented with spherical representation as an effective tool for investigating (Jabi 2001) and surveying architecture (Calvano 2018).

In the present workflow, however, the cubic representation was chosen because it provides six different perspectives each in a plane surface (fig. 3), which can be used as single images to be projected into the virtual model applying the Grasshopper Image Sampler component. The six perspectives share the same viewpoint at the centre of the cube, and they differ in the direction of the gaze, obviously perpendicular to each face. The other projections of the panoramic photography (spheric or cylindric) share the same viewpoint, as they are produced from a single shooting point, so they result in projective correspondence, and they offer the same perception to the observer.

Moreover, each perspective composing the cubic projection is close to a natural vision. For this reason, it was previously used for an intuitive identification of a 3D Isovist (Càndito, Meloni, Castro 2020). The same cubic projection was the basis for experimentation with immersive techniques that hybridise photographic shooting with graphic integrations (Olivero et al. 2019).

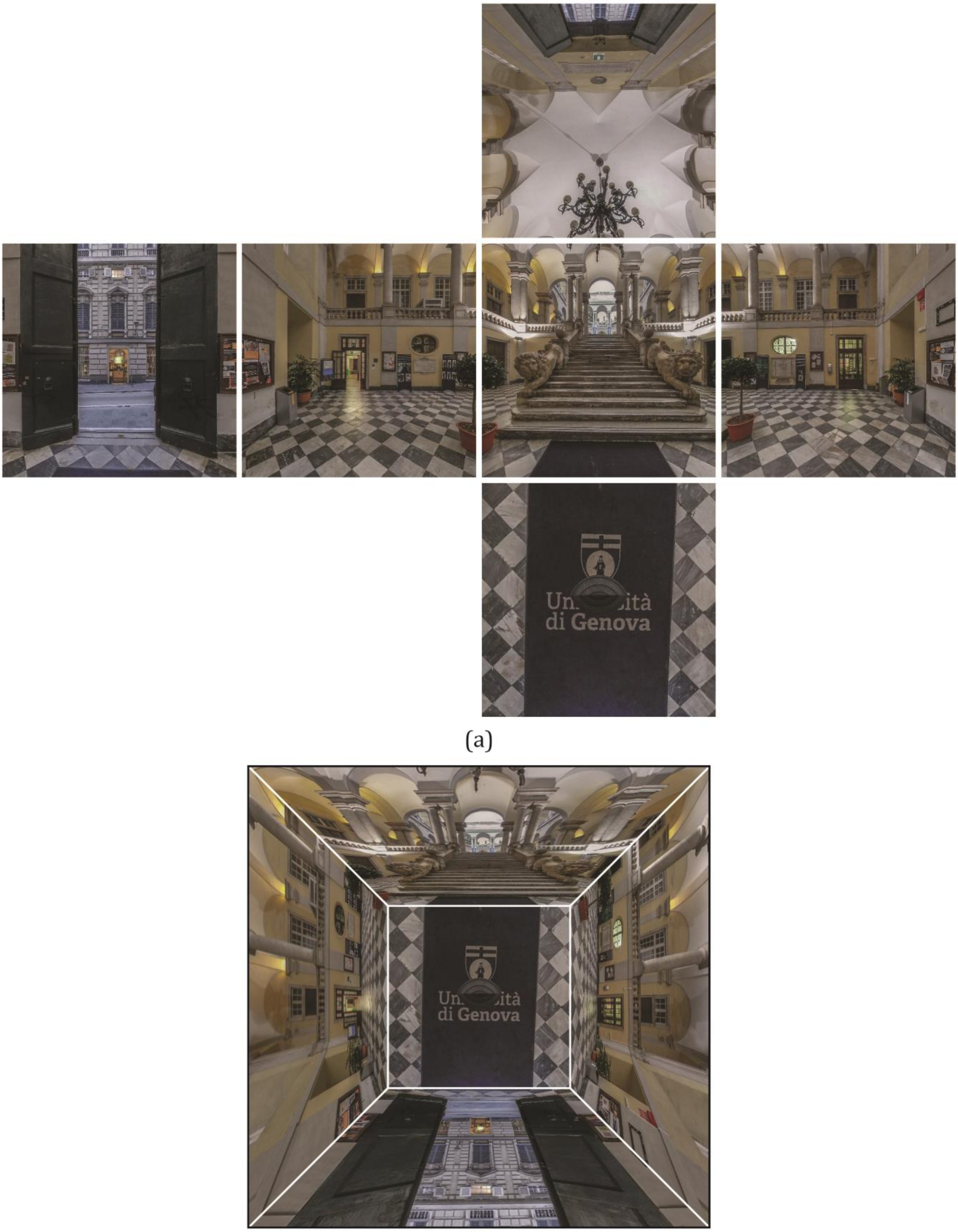
In this phase, the grid of a cube of 3.20 mt. per side was built in the virtual model. It has the lower face coinciding with the floor in order to have the viewpoint in the centre (1.60 mt. height) used to the panoramic shot. The cube can be moved with its centre, to simulate the user shift, always taking advantage of the dynamic features of the parametric model (fig. 4a). The viewpoint and the edges of the cubes are respectively underlined with a sphere and pipes (fig. 4b).

The single panoramic images were positioned in the correspondent faces, with the aforementioned Image Sampler component, that could be customized in terms of transparency values, with the help of the Human plugin. The result was observed from a camera placed at the shooting point, with the target perpendicular to the surface of the cube (fig. 4c). The same focal length of the shot (2.60 mm.) was used.

In this paper we describe a path with its start at the Entrance Hall (step A) and its end at the centre of the courtyard (step C). In order to reduce the algorithmic calculation, the representation of a single face coherent with the main direction can be chosen, as it is comparable with the portion of the space approximately perceived by a user (90 degrees), but we can also add other apposite portion of images extending the angle to 180 degrees or more.

[1] Realistic 3D-models of some rooms are realized by image modeling techniques, due to their features, such as the Sundial Room which is not the subject of this paper.

[2] We used the *Ricoh Theta Z1* camera, equipped with two lenses with a focal length of 2.6 mm and an angle of view greater than 180°.



(a)

(b)

Fig. 3: Panoramic photography projection: cubic projection of the Entrance Hall (ground floor) and its upper view

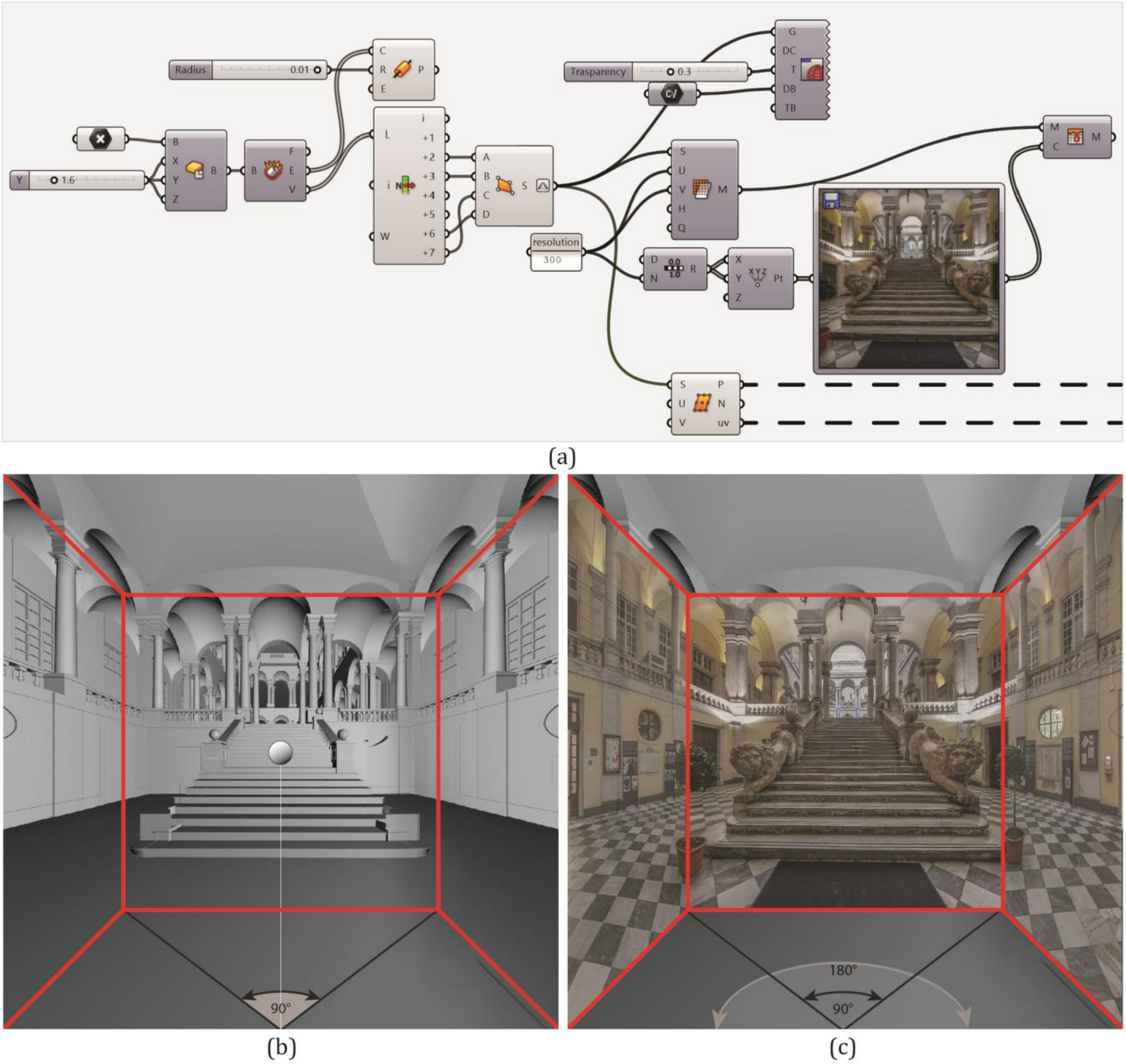


Fig. 4: The virtual model (*PanoProj* phase 1) and the insertion of a moveable panoramic cube (*PanoProj* phase 2). Entrance Hall at the ground floor (step A)

4.3 The cube projected into the model

The third phase of *PanoProj* consisted in the projection of the image on the surfaces of the model in order to obtain the representation of the limits of the space viewed by a user along the path. This kind of projection is not automatically generated within a three-dimensional modelling software; in Rhinoceros and Grasshopper, for example, only the one generated by an infinite centre are realized with the Projection component. However, there are various studies which identify the process using a camera as a centre of projection by a script code (Majewski 2019) or applying mathematical functions (Expression component), in some case changing the domain of geometric entities related to the projected image (Gross 2019). The second solution was preferred for this tool, consisting in a projection of different points of a grid superimposed on the image, by the construction of visual rays and their intersection with the model surfaces.

The first aspect analysed concerned the understanding of the characteristics and potential of the Image Sampler component, in particular regarding the attribution of a numeric value to each point of the grid according to the pixels of the image.

Although it is possible to maintain the chromatic characteristics of the image using the RGB channel of Image Sampler, it was decided to use the black and white version, as it is identified by a numerical value according to the degree of brightness in a range from 0 (black) to 1 (white). In this way, the points of the grid described became centres of circumferences whose rays coincided with the respective value of brightness (fig. 5a).

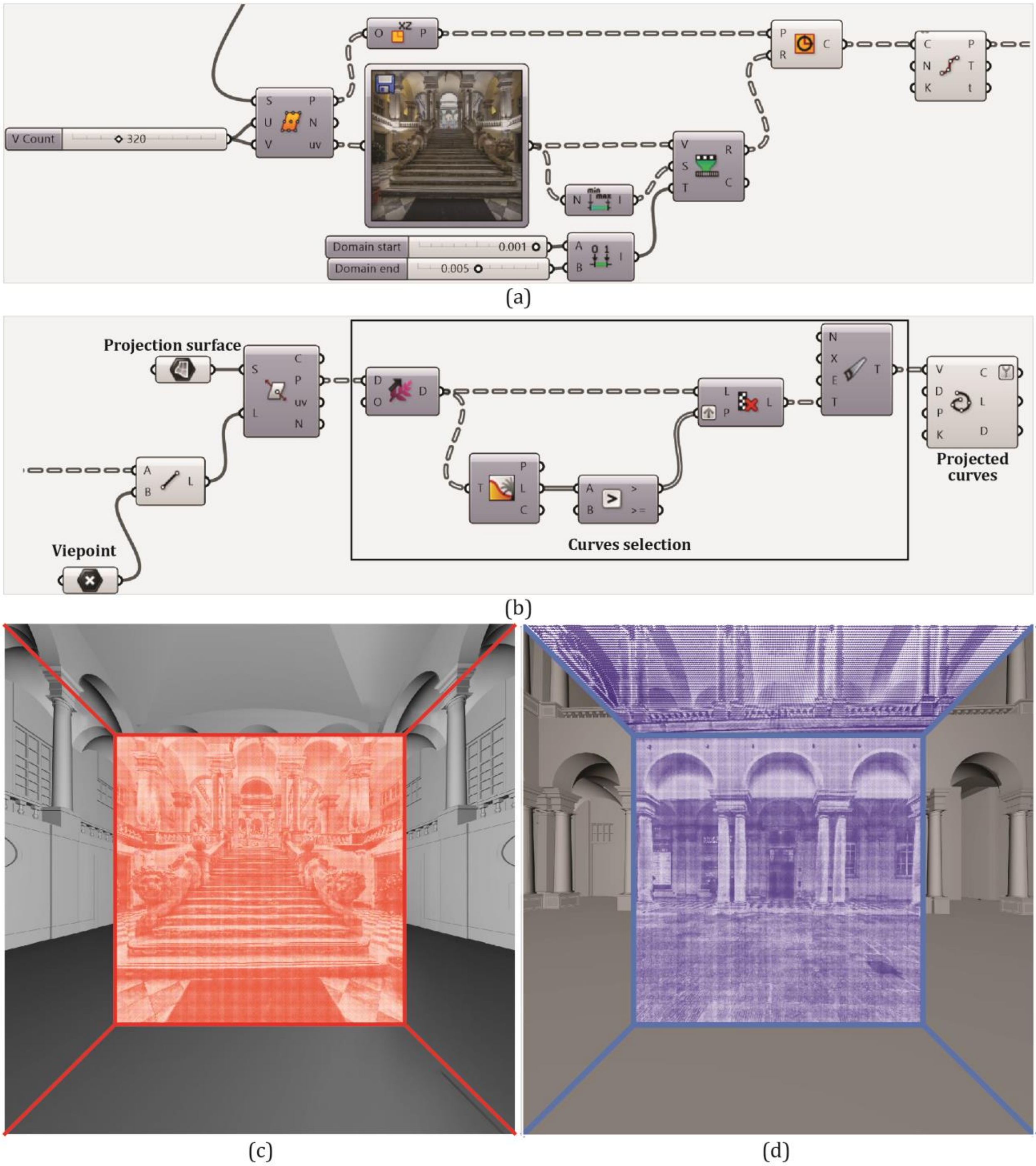


Fig. 5: *PanoProj* phase 3 algorithm: the projection of the cube into the 3D-model. (a) definition of the circumferences algorithm (b) projection of the circumferences points algorithm; (c) Entrance Hall (ground floor)-Front face of the cube; (d) Courtyard (first floor)-Left and Top faces of the cube

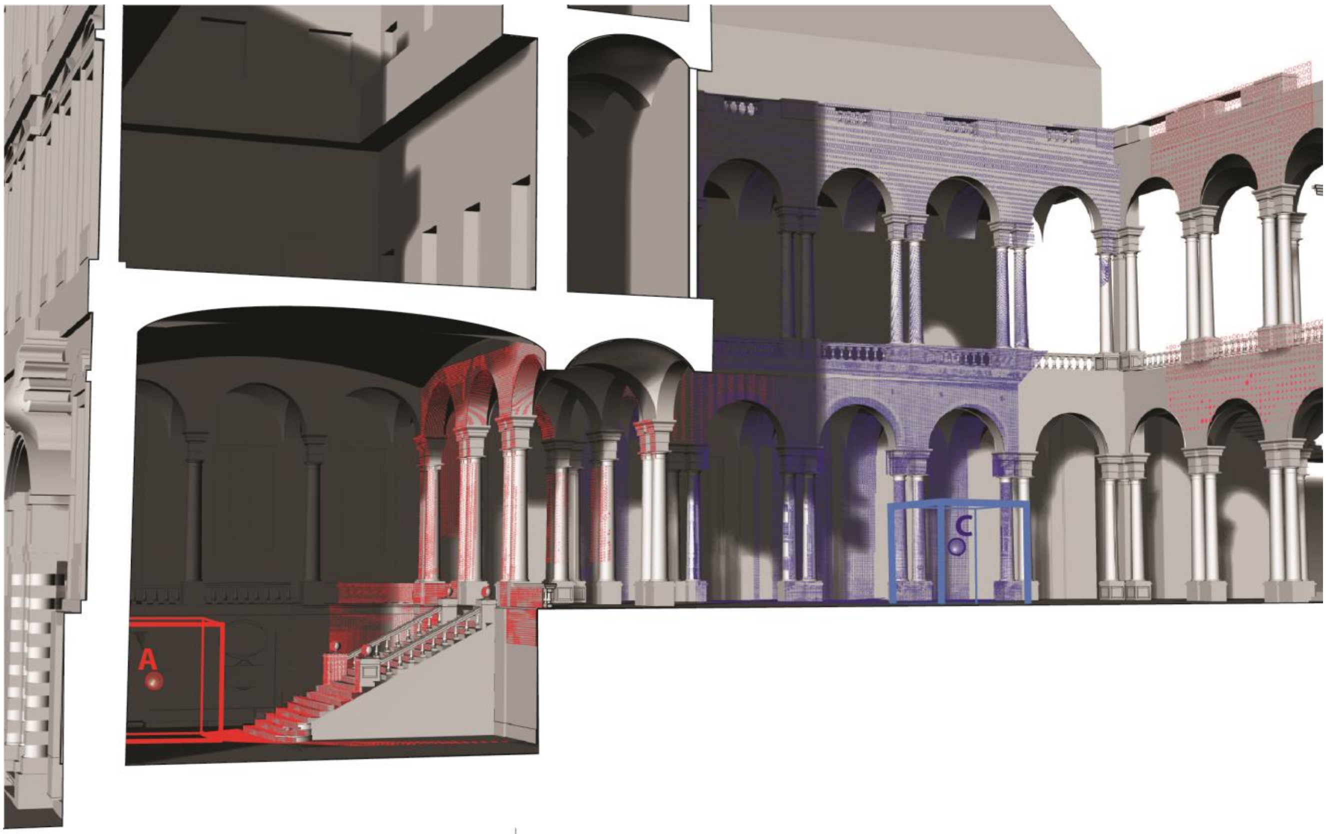


Fig. 6: *PanoProj*: perceived surfaces and cubes of the start (step A) and the end (step C) of the path, as it is seen in fig. 5

Each face of the cube was calculated in order to match the image features: it is reparametrised and divided with the number of the image pixels (u= 320; v= 320).

Other applications used different geometries regarding the representation of the data provided by the Image Sampler, as spheres (Tedeschi, 2010, p. 110-111), whose sizes are always dependent on the brightness of the image, or horizontal or vertical segments of variable length (Gökmen 2019).

The algorithm was simplified by the help of Remap domain component which reduced the circumferences to an appropriated scale (Olthof 2021). Then, they were projected onto the three-dimensional model surfaces (Gross 2019) (fig. 5b) using the Divide Curves component that identified 10 circumferences points, each of which projected with a single visual ray originated from the viewpoint. Rays were intersected with the surfaces of the model (Surface Line) generating the projected points. The Shift Path and Tree Statistics components were finally used to exclude those circumferences that had some points which were projected outside the surface in consideration. The final step consisted in tracing the curves (Interpolate Curves) projected after being remodulated and selected. The process was repeated for each individual surface of the model which received the projection, permitting separate analysis.

The sum of all the projections on the different surfaces coincides with the discretised image that materialized the simultaneous visualisation on the model of the users and what is visible by them (fig. 6).

5. Public and private courtyards

The *PanoProj* tool can lead to spatial meaning interpretation of the examined architecture. In the Entrance Hall (step A of the analysed path) of the University Palace, we can observe the limited importance assumed by the two-dimensional Isovist (fig. 2) in this kind of space. From this point of view, in fact, the users see, principally, the monumental staircase with the sculptured lions designed by Domenico Parodi (beginning of the 18th century) (fig. 4). They can appreciate the sensation of being immersed in a double-high space, so they can perceive not only the front-view of the first-floor courtyard loggia at the top of the staircase, but also its portions extended on both sides as far as the façade. They can also see a part of the second-floor porch, the staircase positioned in the opposite part of the building and a glimpse of the sky (fig. 5 and 6).

At the second step of the path, at the top of the first staircase, the view doesn't meaningfully change, and users have a view of the Entrance Hall and the courtyard, although in a more extended way. Observers in this position can perceive a vast portion of the elevation of the courtyard as we can see in the panoramic image (fig. 7). In the two-dimensional vertical Isovist (fig. 8a) one can observe the limitation of the view caused by the vauls of the porch.

It is interesting to observe that, with the planar Isovist, we obtained a visible portion of space, although limited, through the twin columns (fig. 8b). This is not reflected by the panoramic photo that shows a minimal overlapping in the higher part, which is due to the tapering of the columns. The three-dimensional Isovist always leads to a more detailed observation of the space.

Fig. 7: Panoramic image from the porch of the courtyard, first floor (step B)

With the help of a three-dimensional Isovist, the peculiarity of the Jesuit College of Genoa can also be appreciated. Due to the steep terrain of Genoa, some aristocratic palaces were built with a characteristic disposition that allowed conspicuous land levelling to be avoided. This happened in some of the well-known Strada Nuova Palaces, for example in Doria Tursi Palace (1564) by Domenico e Giovanni Ponzello, and Tobia

Pallavicino Palace (1558-61) by Giovan Battista Castello. A similar structure was adopted by the same Bartolomeo Bianco in the Gio Agostino Balbi Palace, differently transformed by Andrea Tagliafichi in 1774 (Colmuto Zanella, De Negri, 1987).

Jesuit colleges usually have two courtyards: a public one with the classrooms and a private one with the fathers' lodgings. Far from being transgressive from the traditional architectonic rules of the Order, the solution chosen by Bianco shows an effective separation of the two functions which does not limit itself to putting the private function on the third floor, above the two levels of public spaces. In fact, from the courtyard and its porch (steps C and B of the path), naturally interpretable as the most public space, users can appreciate a view open to the main spaces of the college: the entrance, the first-floor classrooms, the staircase to the second floor, the second-floor porch with the main Assembly Hall.

However, the fathers' lodgings are out of sight as they are set back in a calculate way, and visitors are not able to see them, as is shown by the vertical projection of the Isovist (fig. 5-8).

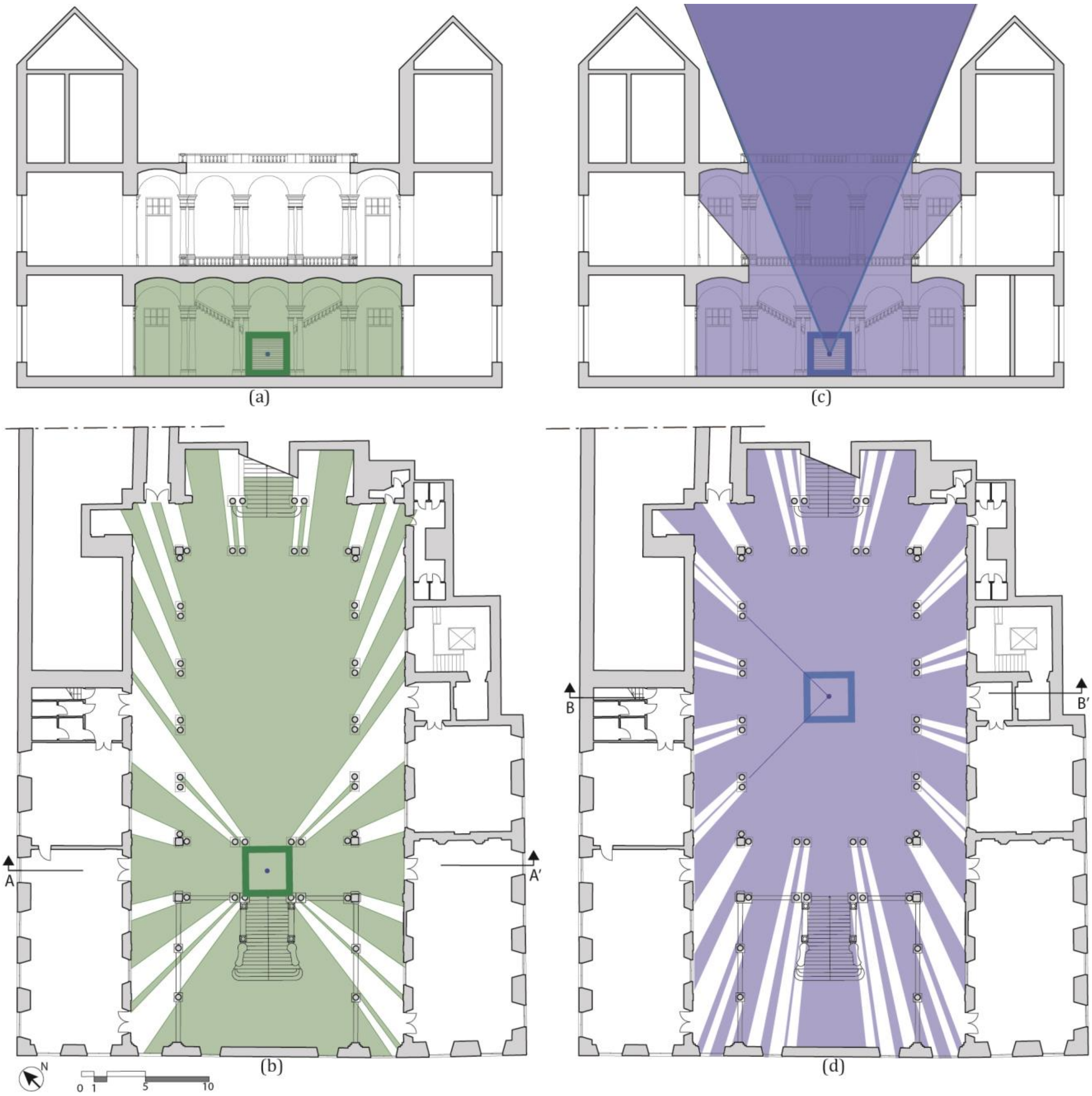


Fig. 8: Two-dimensional planar and vertical views. Left: the porch of courtyard, first floor (step B); Right: Public and private views from the courtyard, first floor (step C)

6. Conclusion

The study presents a possible combination of 3D virtual model and panorama photo in a new version of three-dimensional isovist, which has been called *PanoProj*. The workflow entails creating a parametric virtual model of the space studied with a sequence of moveable cubic configurations which incorporate cubic projections of panoramic photography. These panoramic photos are projected using a parametric algorithm. The result is a sort of virtual tour which provides a series of representations of the space visible to the observer, perceptible from different points of view offered by the virtual model.

Although the simulation of movement in the architectural interior space should be perceived as fluid, a limited number of positions are represented in this paper: three steps from the Entrance Hall to the centre of the courtyard. Another limit is the selection of some faces of the cube at a time, for modelling computation, but this also coincides with the approximation of the natural limit of the angular extension of a defined human view. At the same time, the other cubic face projections may be added, as we have demonstrated.

We chose as a case study, the 17th century University Palace of Genoa in Italy, because it is a peculiar Jesuit College with the only courtyard at a higher level to the Entrance Hall. The sloping terrain imposed these choices, but the privacy necessary for the fathers' lodgings, granted by a second courtyard in all the other Jesuit Colleges, has not been ignored. In fact, the Isovist allowed us to confirm the invisibility of the private structure from the public courtyard.

Further observation of the visibility of spaces demonstrated the necessity for a three-dimensional isovist because the two-dimensional version does not permit a complete involvement of all the visible spaces. For example, from the double-height space of the Entrance Hall, we can easily observe how many users can anticipate the space of the first-floor courtyard and its annexed public spaces.

PanoProj is used only for qualitative analysis, however as it is intended as a 3D-Isovist tool, it can be applied to the study of spatial features through the potential computation of the digital parametric model. Indeed, in this research, it was sufficient to define the space with its boundary surfaces, but the polyhedron representing the visible volume during its dynamic transformation can also be identified and be measured through its geometric properties.

Finally, *PanoProj* can help in studies about the perception of space, although it is clear that it should not be the only method used. In fact, a profound knowledge of the historical and physical context of an ancient building should always be the starting point in order to identify where and how different tools should be applied for the investigation purposes.

Acknowledgements

Although the paper was conceived as a team by the authors, paragraph 4.3 was written by Alessandro Meloni, and the rest of the article by Cristina Càndito. The virtual model was realised by Alessandro Meloni and the images were conceived and realised by the authors.

We would like to thank Ilenio Celoria for his collaboration on site with the photography.

The present research was carried out in part with the help of P.R.A. 2020 funding (Athenaeum Research Project), entitled "Architectural illustration between geometry and perception"; scientific coordinator: C. Càndito.

REFERENCES

Benedikt, M. (1979). To Take Hold of Space: Isovists and Isovist Fields. *Environment and Planning B: Planning and Design*, 6(1), 47-65. doi: 10.1068/b060047.

Benedikt, M., & McElhinney, S. (2019). Isovists and the Metrics of Architectural Space. *BLACK BOX: Articulating Architecture's Core in the Post-Digital Era.* Conference ACSA 2019. Pittsburgh, March 27-30, 2019.

Bösel, R. (2012). Episodi emergenti dell'architettura gesuitica in Italia. in Á. Zamora, J. Ibáñez Fernández, & J. Criado Mainar (Eds,), *La arquitectura jesuítica. Actas del Simposio Internacional* (pp. 71-89). Zaragoza: Institución Fernando el Católico.

Calvano, M. (2018). Spherical panoramas for architectural surveying. From image to 3D model. *Building Information Modeling, Data & Semantics*, 3, 6-15.

Càndito C. (2001), *Occhio, misura e rilievo. Gli strumenti ottici e catottrici per l'architettura e il recupero del Collegio dei Gesuiti a Genova*, Genova 2001; second edition: Firenze: Alinea 2005.

Càndito C., Castro A., & Meloni A., (2020), *Rappresentazione, percezione e wayfinding. L'architettura per l'università del passato e del presente / Representation, Perception and Wayfinding. University Architecture of the Past and Present*, in CONNETTERE. Un disegno per annodare e tessere / CONNECTING. Drawing for weaving relationships. Atti del 42° Convegno internazionale dei Docenti della Rappresentazione. XVII Congresso U.I.D., 18 settembre 2020, Milano: Franco Angeli, pp. 1820-1841.

Colmuto Zanella, G., & De Negri, E. (1987). L'architettura del collegio. In F. Lamera., G. Pigafetta (Eds), *Il Palazzo dell'Università di Genova. Il Collegio dei Gesuiti nella strada dei Balbi* (pp. 209-275). Genova: Università degli Studi di Genova.

Conroy Dalton, R., Holscher, C. & Spiers, H. (2015) Navigating Complex Buildings: Cognition, Neuroscience and Architectural Design. *Studying Visual and Spatial Reasoning for Design Creativity*, 3-22. doi: 10.1007/978-94-017-9297-4_1

Dalton, N., Conroy Dalton, R., Marshall, P., Peverett, I., & Clinch, S. (2015) Three dimensional Isovists for the Study of Public Displays. Conference: 10th Space Syntax Symposium. London: Space Syntax Laboratory, The Bartlett School of Architecture, University College London.

Della Torre S. L., & Patetta, L. (1990) (Eds). *L'architettura della Compagnia di Gesù in Italia. XVI-XVIII secolo*. Atti del Convegno. Milano, Centro culturale S. Fedele, 24-27 ottobre 1990 (pp. 13-26). Genova, Marietti, 1992.

Fisher-Gewirtzman, D. (2010). Internal space layout and functionality as a major aspect influencing visual analysis for environmental and urban systems. *WIT Transactions on Ecology and the Environment*, 129, 431-442. https://doi.org/10.2495/SC100371

Fisher-Gewirtzman, D. (2016). Integrating weighted views to quantitative 3D visibility analysis as a predictive tool for perception of space. *Environment and Planning B: Planning and Design*, 45(2), 345-366. doi:10.1177/0265813516676486

Gibson, J. J. (1947). Motion picture testing and research, *A.A.F. Aviation Psychology Program. Research Reports* (7), Washington D.C.: U.S. Government, Printing Office.

Gibson, J. J., (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin Company.

Gökmen, S. (2019). *Grasshopper Tutorial: Image Baed Mapping. Parametric Online*. https://www.youtube.com/watch?v=PGbYo4FTkOQ (retrived 20 July 2021).

Golledge, R. G, & Stimson, R. J., (1997). *Spatial behavior: a geographic perspective*. New York: Guilford Press.

Gross, E. (2019). Project (move and scale) curves in perspective view on a surface. *Perspective Projection. Rhinoceros Forum*. https://discourse.mcneel.com/t/project-move-and-scale-curves-in-perspective-view-on-a-surface/77586/2 (retrived 8 June 2021).

Jabi, W. (2001). Visualizing and investigating architectural space using spherical panoramic imaging. *2000 ACSA Technology conference. Emerging technologies and design: the intersection of design and technology*. Washington, DC: Association of Collegiate Schools.

Krukar, J., Manivannan, C., Bhatt, & M., Schultz C. (2020). Embodied 3D isovists: A method to model the visual perception of space. *Environment and Planning B: Urban Analytics and City Science*, 48(8), 2307-2325. doi: 10.1177/2399808320974533

Lonergan, C., & Hedley, N. (2015). Unpacking isovists: A framework for 3D spatial visibility análisis. *Cartography and Geographic Information Science*, 43(2), 87-102. doi: 10.1080/15230406.2015.1065761

Lu, Y., Gou, Z., Ye, Y., & Sheng, Q. (2019). Three-dimensional visibility graph analysis and its application. *Environment and Planning B: Urban Analytics and City Science*, 46(5), 948-962. doi: 10.1177/2399808317739893

Lynch, K. (1960). *The Image of the City*. Cambridge: MIT Press.

Lynch, K. (1976). *Managing the Sense of Regions.* Cambridge: MIT Press.

Mahdzar, S., Jaberolansar, S., & Jamil, A. (2019). The effect of spatial configuration on sense of safety through street legibility. Conference: 12th International Space Syntax Symposium. Beijing Jia Tong University, China. Proceedings of the 12th Space Syntax Symposium 54-2.

Majewski, R. (2019). Project (move and scale) curves in perspective view on a surface. *Projection. Rhinoceros Forum*. https://discourse.mcneel.com/t/project-move-and-scale-curves-in-perspective-view-on-a-surface/77586/2 (retrived 8 June 2021).

Nagy, D. (2017). View analysis with isovist, Generative Medium (blog). *Catalog of lecture notes, technical tutorials, and other content from an advanced computational design course at Columbia University's Graduate School of Architecture, Planning, and Preservation (GSAPP).*

Olivero, L. F., Rossi, A., & Barba, S. (2019). A Codification of the Cubic Projection to Generate Immersive Models. *Diségno,* 1(4), 53-63. doi: 10.26375/disegno.4.2019.07

Olthof, O. (2021). Image Sampler – Grasshopper Tutorial. Owen 02. https://www.youtube.com/watch?v=iAm8XnROuTY&t=274s (retrived 15 July 2021).

Penn, A., Conroy, R., Dalton, N., Dekker, L., Mottram, C., & Turner, A. (1997). Intelligent architecture new tools for the three-dimensional analysis of space and built form. *1st International Space Syntax Symposium.* London: University College London.

Poleggi, E. (1987). La strada dei "signori" Balbi. In F. Lamera, G. Pigafetta (Eds.), *Il Palazzo dell'Università di Genova. Il Collegio dei Gesuiti nella strada dei Balbi* (pp. 91-105). Genova: Università degli Studi di Genova.

Tedeschi, A. (2010). *Architettura Parametrica. Introduzione a Grasshopper*. Potenza: Le Penseur.

Turner, A., Doxa, M., O'Sullivan, D., & Penn, A. (2001). From isovists to visibility graphs: a methodology for the analysis of architectural space. *Environment and Planning B: Planning and Design*, 28(1), 103-121. doi: 10.1068/b2684

Ünlü, A., Edgü, E., Şalgamcioglu, M. E., Çanakçioglu G., & Yilmaz E.A. (2019). Isometric measurands on perceived spaciousness: exploring volumetric isovist. *12th Space Syntax Symposium,* 132, 1-20.

Varoudis, T., & Psarra, S. (2014). Beyond two dimensions: architecture through three-dimensional visibility graph análisis. *The Journal of Space Syntax*, 5(1), 91-108.

Wittkover R., & Jaffe, I.B. (1992). *Architettura e arte dei Gesuiti*. Milano: Electa.

Yang, P. P. J., Putra, S. Y., & Li, W. (2007). Viewsphere: A GIS-Based 3D Visibility Analysis for Urban Design Evaluation. *Environment and Planning B: Planning and Design*, 34(6), 971-992. doi: 10.1068/b32142