The Digital Narrative of the Eladio Dieste's Church in Atlantida, Uruguay, by Tools Integrations Analyses

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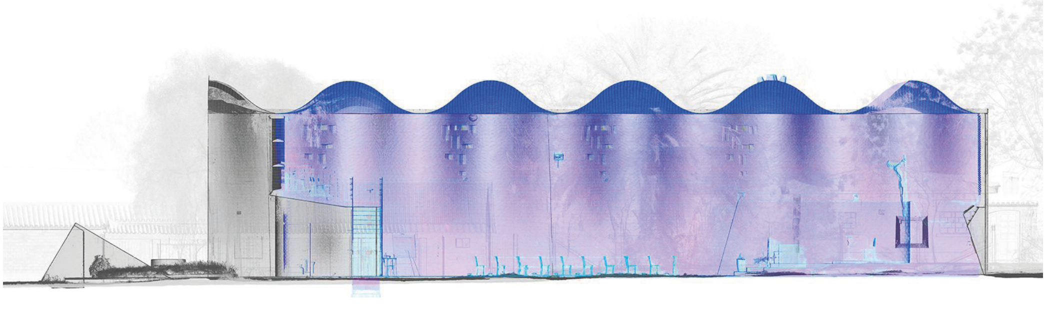
Abstract

This research focuses on the Church of Cristo Obrero y Nuestra Señora de Lourdes, located in Atlantida, Uruguay, which was designed by Uruguayan engineer Eladio Dieste from 1956 to 1960. This architectural work is significant because of the experimental innovations in structural design and construction technology implemented by Dieste. The Church of Cristo Obrero y Nuestra Señora de Lourdes was the foremost application of continuous Gaussian vaults in reinforced brickwork under thin-shell roof modules by the engineer, together with governed surfaces on its lateral walls. The tools integration adopted during the on field research wants to demonstrate how current technologies could be used and combined to obtain a reliable database. The digital description was carried out by the 3D survey blending 5 different source of data (terrestrial lidar (2 tools), terrestrial photogrammetry, aerial photogrammetry, and slam technology). The result of the data comparison aims at highlighting a suitable and affordable methodology in terms of data capturing through the integration of the tools currently available on the market. To evaluate the geometric-morphological quality of the obtained point clouds, the one acquired with Leica c10 was used as a metric reference for analyzing deviations of other tools.

Keywords:
Digitisation, 3D documentation, point cloud analyses, Dieste, church.



Longitudinal section of the point cloud model of the Cristo Obrero Church. Intensity data visualization: the interior, surveyed with the *BLK2360* laser scanner, in false colours display, the exterior, surveyed with the *C10* laser scanner, in black and white.

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Introduction

This contribution is based on Eladio Dieste's (1917-2000) work, exemplifying inventive design in 20th century Latin America. His buildings are a testament to technological research integrated within the local industrial framework, whose cultural significance transcended the limits of the South American nation, garnering interest in both academic circles and specialized media. By utilizing brick as his primary material and employing conventional vaulting techniques, he has achieved architectural solutions characterized by remarkable simplicity and spatial beauty.
Possessing exceptional architectural sensitivity, he devised an innovative building system: 'reinforced ceramics', through which he created several forms of lamellar vaulting structures, notably 'Gaussian vaults' and 'self-supporting vaults'. His structures, identifiable by their curved walls and ceilings of exposed brick, engage with other contemporary discourses in Brazilian context, and primarily represent a synthesis of his skill in form manipulation with an effective and sustainable construction approach.
The Cristo Obrero church in Atlántida (1955-1960) signifies the inaugural architectural accomplishment stemming from the extensive research on reinforced ceramics conducted throughout the latter part of the 20th century. The building complex is made up of a large central nave with a rectangular floor plan of 528 square metres, where the presbytery and the altar are integrated, and to which are linked the sacristy and the antero-christy, as well as the confessional areas [Sabalsagaray *et al.* 2017].
The aim of the integrated survey of Church was to develop a point cloud database capable of fulfilling several functions. In addition to the documentary aspect, the aim was the formation of an accurate metric model for the comparison of the design drawings and the morphology of the actually realised work, in particular for the double curved surface of the roof [Melachos, Florio 2024]. Furthermore, the point cloud constitutes a geometric basis for an eventual informative modelling of the building through the scan-to-bim process and should be prepared to carry out some analysis on the state of preservation of the external wall surfaces [Balzani, Maietti, Kühl 2017]. The models are placed within a specific reference system and may be utilized for various aims, contingent upon the data quality.
The mapping process focused on the production of thematic maps of perimetral walls according to an abacus of decays implemented in a BIM system could be extremely useful for the analysis and conservation of the church [Aricò *et al.* 2024]. Finally, the survey was an opportunity to test a SLAM technology and compare it with static LIDAR survey technologies. For these reasons, the integrated survey involves the use of several instruments, depending on the type of data they can acquire, in relation to the specific purposes.

The Church of Cristo Obrero y Nuestra Señora de Lourdes

The Church of Cristo Obrero y Nuestra Señora de Lourdes, is located in Atlantida, Uruguay, and was conceived and designed by engineer Eladio Dieste from 1956 to 1960. The significance of this architectural work stems from the engineer's embodied experiments in structural design and construction technology. The Church was the initial significant application of continuous Gaussian vaults in reinforced brickwork under thin-shell roof modules by the engineer, together with ruled surfaces on its lateral walls [Melachos, Florio 2018]. The design and construction efforts were facilitated by the integration of tradition and innovation, including the use of transportable frames at the construction site. In conjunction with these technical and design innovations, both external and interior remarkable architectural spaces were developed, emphasizing efficiency in the construction process, which established Eladio Dieste as a structural artist [Ochsendorf 2004].
The Cristo Obrero church exemplifies Dieste's experiments from the early years of his professional career, featuring huge concrete and reinforced ceramic roofs, along with elevated water tanks. Each project, characterized by varied applications, necessitated significant ingenuity in its design [Carbonell 1987; Torecillas-Perez 1996]. The form of each construction imparts a distinct character, alongside the colours, dimensions, and textures of the bricks.

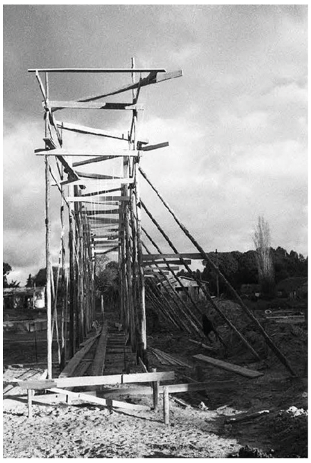
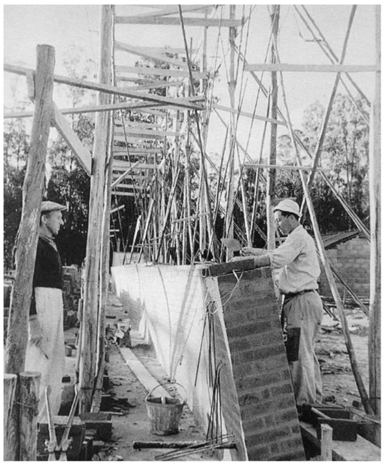

Fig. 1. Images of the construction site of the Church during the late fifties. Highlights are the interesting wooden ribs used to create the sinuous roof structure (Courtesy of Eladio Dieste Foundation).

The opportunity to build the parish complex in Atlántida arose for Dieste at the establishment of his professional collaboration with Eugenio Montañez, formalized between 1954 and 1956 [Pablo Bonta 1963]. Throughout the years, it became evident among the company's colleagues that Montañez represented the financial aspect and administrative organization, but Dieste embodied the creative element, an indefatigable innovator in structural design and construction methodologies. The imagery of the Church of Cristo Obrero y Nuestra Señora de Lourdes has been predominantly influenced, since its inception, by the configuration of the nave's lateral walls (fig. 1). The objective of this shape was to create buttresses that would absorb the thrusts of the vault sequence in an aesthetically and architecturally attractive manner. The structure was founded on a beam, supported by piles, measuring 30 × 30 centimetres, which constitutes the linear foundation for the walls on each side of the church. Upon completion of the lateral walls of the church and the formwork for the roof edge beams, steel turnbuckles, averaging 32 millimetres in cross-section, were installed to counteract the lateral thrust produced by the vaults. Throughout the construction process, the tensors assisted in stabilizing the walls, which had not yet achieved balance due to their structural structure. The roof was constructed using a movable formwork, upon which vault portions of six meters each were created.

Fig. 2. Images of the church taken by the authors during the on field campaign.

Unlike the temple, which was founded on piles connected with a concrete beam flush with the fill made in the ground, the type of foundation of the tower is direct, made on a circular base of approximately 3 m in diameter and 30 cm thick at a depth of 1.20 m. The tower was built on a circular base of approximately 3 m in diameter and 30 cm thick at 1.20 m deep. Although there are no plans of this foundation, there is reference to it through the annotations and calculations made by hand by Dieste.
On July 27, 2021, the Church of Christ Obrero y Nuestra Señora de Lourdes, located in Atlantida (Uruguay), designed and built by Uruguayan engineer Eladio Dieste (1917-2000) between 1956 and 1960, was included in the UNESCO World Heritage List. The UNESCO selection criteria classify this very special building as the highest spatial and aesthetic expression of a constructive and technological innovation (fig. 2). The design approach draws on tradition, while reinterpreting and innovating it, and opens structural and formal opportunities in architecture impossible to conceive and realize until that time with traditional brickwork [Melachos *et al.* 2023].

The tools integration

The integration of three-dimensional surveying technologies has become indispensable for generating precise spatial models of intricate settings. These methods depend on many equipment that must work together to generate high-quality data. The incorporation of such technology is essential to guarantee dependability, efficiency, and precision in data collecting and processing. Inadequate integration of 3D surveys may lead to inaccuracies, redundancies, and inefficiencies, so compromising its intended purpose [Martinez Espejo Zaragoza, Caroti, Piemonte 2021]. During the digitisation campaign, carried out by a staff of three people and completed in 7 working days the equipment used were:
- *Leica C10* static laser scanner registered with topographic method;
- *Leica BLK360* static laser scanner registered with cloud-to-cloud method;
- *Lixel K1* SLAM laser scanner;
- *UAS Drone DJI pro4* for digital photogrammetry;
- *Canon EOS 90D* for digital photogrammetry.

Despite the age of the tools, the *Leica C10* is still a very reliable machine in order to have rough data directly from the sensor, not manipulated by algorithm as often nowadays happens with recent laser scanner. Its data were used as a semi-topographic net on the which other source of information were linked. The table 1 shows the features of each equipment graphically highlighted in figure 3.

Equipment	Short description	Accuracy	Potentials	Weaknesses
A_*Leica C10*	Time of flight laser scanner, maximum distance 300 meters, angle of view 360H vs 270V, acquisition speed 50.000 pts/sec.	Distance: +- 4 mm at 50 meters; Target acquisition: +- 2mm at 50 meters.	Data not manipulated by algorithm and external manual levels (bubble type) + electronic level in onboard control.	Acquisition speed is very low if compared with more recent tools. Heavy machine (17 kg)
B_*Lixel K1*	Compact SLAM laser scanner; it integrates 56 million pixel panoramic vision modules and a 360° LiDAR, capable of 200.000 pts/sec.	Distance: +- 2cm up o 70 meters	Light machine (1 kg); generation of real-time coloured 3D models; good for tiny spaces or long and narrow path; Good RGB data.	Huge amount of data produced; user experience makes the difference on the final result.
C_*Leica BLK360 G1*	Laser scanner with acquisition speed of 360.000 pts/sec, maximum distance 60 meters, HDR image at 3 levels.	Distance: +- 6mm at 10 meters; Distance +- 8mm at 20 meters.	Light machine (1,1 kg); scan registration through app FIELD 360, quick scan time ideal for fragmented spaces.	Lack of manual or digital levels; short ditsance range in case of tall or very long buildings.
D_*Drone DJI pro4*	UAS <249g equipped with GPS + Galileo + BeiDou; anti collision sensors 360; remote control, maximum distance 18 km	48 MP camera 4K video ouput	Easy to use, big screen on he remote control and anti collision sensors make the flight safe.	Battery last less than 30 minutes, in case of strong wind even less.
E_*Canon EOS 90D*	Camera lens 18-135, continuous shooting at 10 fps.	32 MP camera 4K video ouput	Long lasting batteries; 220,000-pixel RGB+IR exposure sensor ensures accurate exposures.	AF system not customisable as on the 7D2 and 5D4.

Tab. 1. Tools used for the digitisation of the church.

The methodology adopted during the 3d survey and the data elaboration

The structure of the survey was carried out with a *Leica C10* laser scanner, an instrument with the best accuracy characteristics and the greatest range among those used (fig. 4), whose scans were registered using the topographic method (average error 2 mm), a choice that also allowed the optimisation of the number and position of the scan stations [Bianchini *et al.* 2022].
The areas involved are the exteriors, where there was a need for a greater range and to beat targets positioned even at medium distances, and, internally, the main hall of the church, in order to have a geometrically accurate description of the internal surface of the roof. The inside detail survey was carried out with a *Leica BLK360* laser scanner, which is more agile in setting up and suitable for the acquisition of small to medium-sized spaces. In addition, this instrument was also used outside, in order to carry out a comparative analysis of the data acquired with all instruments. These two sub-models (exterior and interior) were registered

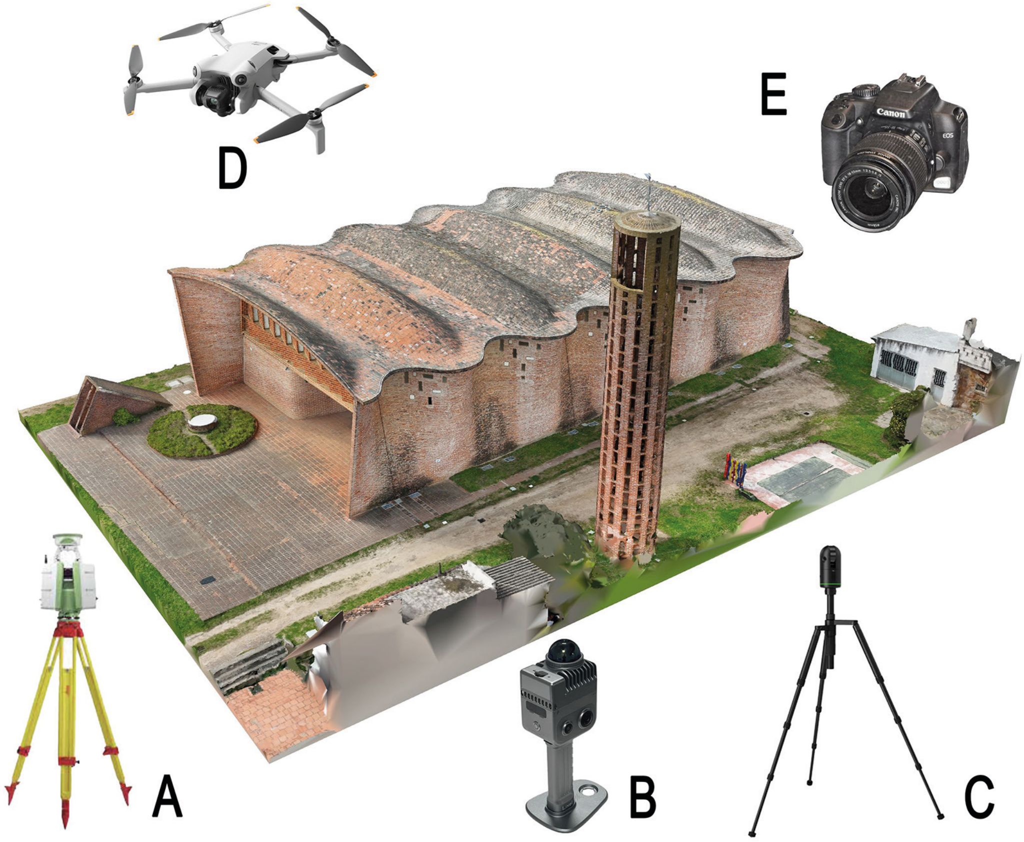

Fig. 3. The integrated survey was carried out using *Leica C10* laser scanner (A), *Lixel K1* SLAM scanner (B), *Leica BLK360 G1* laser scanner (C), *Drone DJI pro4* (D) and a camera *Canon EOS 90D* (E).

internally using the cloud-to-cloud method (average error 5 mm) and subsequently rototranslated onto the cloud of the *Leica C10* by means of 14 points (10 exterior, 4 interior), materialised by means of the black and white targets. For the acquisition of the geometry of the external roof's surface and the completion of the bell tower (the shadow cones of the terrestrial laser scanner acquisitions were excessive at the top of the tower), a photographic campaign was carried out by drone (*Dji Mini 4 Pro*), aimed at the elaboration of a point cloud by means of a digital photogrammetry process. This model, positioned in the same

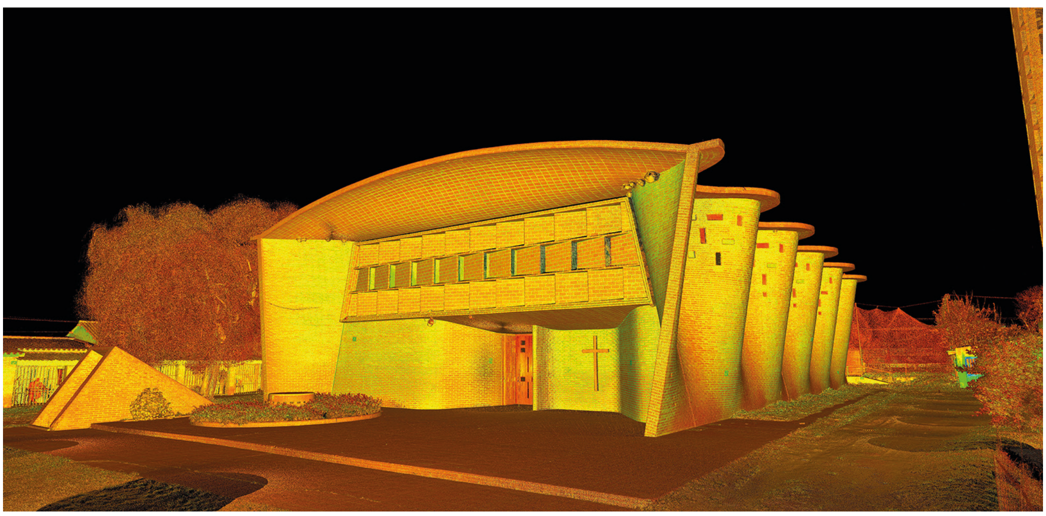

Fig. 4. The high resolution point cloud acquired by the laser scanner *C10* (elaboration by the authors).

Fig. 5. Textured mesh model by photogrammetry (drone + terrestrial camera data, image by the authors).

reference system as the cloud obtained by laser scanner, also provides the description of the colour data of all external surfaces (fig. 5).
The SLAM device tested in this survey was an *XGRIDS Lixel K1*, with which both interiors and exteriors were surveyed with two separate closed ring paths. The registration was done using the cloud obtained from the *Leica C10* laser scanner as a basis.

Final remarks

The survey approach described in this contribution therefore led to the formation of a database consisting of several point cloud models, obtained from the 4 different technologies. The models are positioned in a single reference system and can be used for different purposes, depending on the quality of the data. Of these, the first is the one that returns the most accurate data, both due to the characteristics of the instrument, characterised by the lowest instrumental error among those adopted, and due to the method used, which allows the systematic registration error to be contained. To assess the geometric-morphological quality of the other point clouds [Suchocki 2020], the one obtained with this instrument was used as a metric reference on the basis of which the deviations could be analysed.
The parts examined are the external surfaces of the church. With regard to the cloud obtained by the *BLK360*, it can be seen that most of the surfaces do not deviate more than 1cm from the reference cloud, with the exception of some areas in the upper parts (fig. 6). Fo what concerns the one obtained by SLAM, as expected, the areas with significant deviations are greater, as well as having a lower density of points [Campi, Cera, Falcone 2024]. The cloud obtained from the photogrammetric process returns values of less than 1cm on almost all surfaces, obviously excluding the areas not covered by the reference cloud, i.e. the extrados of the roof. A further analysis was made by taking a horizontal section at an elevation of +5.50 m above the floor, analysing the deviations in the horizontal plane (XY) and extrapolating the cloud-to-cloud distance graph.
The BLK360 and photogrammetry-derived clouds are found to have comparable errors, with modal values around 2 mm (fig. 7). In contrast to Lidar techniques, UAS photogrammetry provide swift data acquisition across extensive regions, penetrating difficult terrains that laser scanner may be unable to penetrate. UAS photogrammetry has produced high-resolution images providing it a significant adjunct, especially for cap-

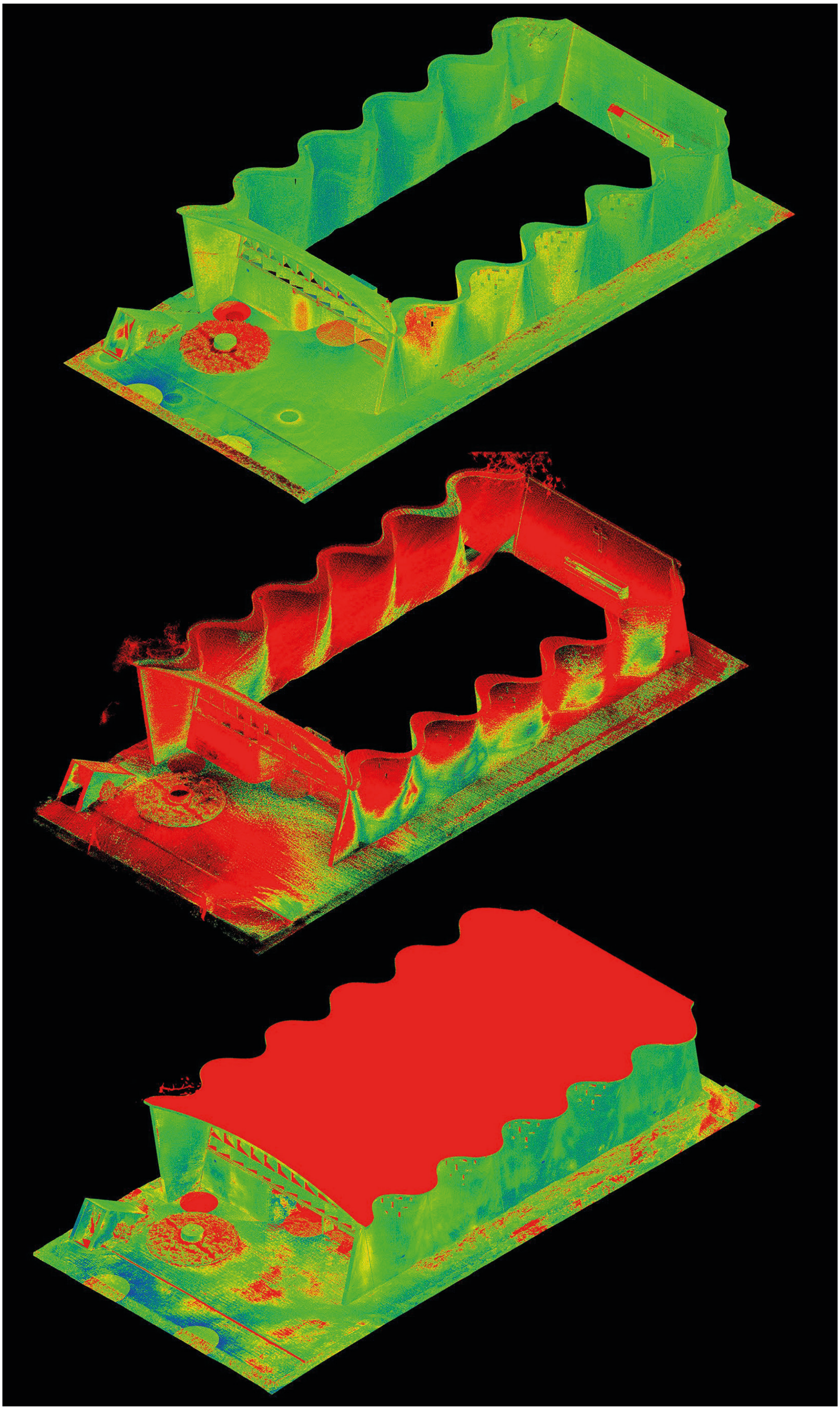

Fig. 6. Comparison of the different point clouds with the *LeicaC10* cloud: *Leica BLK360* (top), SLAM *XGRIDS Lixel K1* centre), digital photogrammetry (down). In red points with distance >1cm (elaborations by the authors)

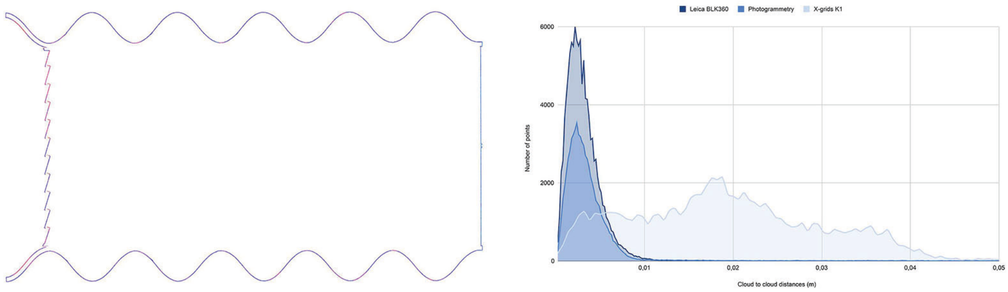

Fig. 7. Comparison of the different clouds with the *LeicaC10* cloud: *Leica BLK360*, SLAM *XGRIDS Lixel K1*, digital photogrammetry. Section at +5.50 m with the deviation graph in the xy plane (elaborations by the authors).

Fig. 8. RGB visualization of photogrammetric point cloud (left) and SLAM *XGRIDS Lixel K1* (right) point cloud (elaborations by the authors).

turing intricate structures inside extensive Cultural Heritage contexts that necessitate a cartographic scale approach [Li *et al.* 2025].
The SLAM cloud shows more distributed values, with a modal value of around 1.8 cm, but with a considerable number of points with deviations as high as 2.5 cm. From a colorimetric point of view, the SLAM point cloud has a RGB data quality comparable to the photogrammetric point cloud (fig. 8). Indoor environments showed higher accuracy levels if compared with outdoor environments. The cloud-to-cloud comparison method provided the most direct and accurate measurement of point cloud data [Gharineiat *et al.* 2024].

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