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DIGITAL DOCUMENTATION STRATEGIES FOR THE KNOWLEDGE OF THE BASILICA OF SANTA MARIA IN TRASTEVERE

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ABSTRACT:

Within the Cultural Heritage documentation field, this contribution illustrates the adopted methods for the first digital documentation of the Basilica of Santa Maria in Trastevere in Rome.
The research activity carried out included the survey of this historic building as well as direct and indirect research connected with its transformations. The tested workflow illustrates the relevance of the activities carried out in terms of knowledge implementation, conservation, monitoring, and dissemination of tangible and intangible aspects of this layered religious architecture.

Example of the outcomes of the integrated survey of the Basilica of Santa Maria in Trastevere in Rome.

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1. INTRODUCTION

The preservation of cultural heritage is of paramount importance because it helps to preserve history and identity. In this regard, the documentation of historic buildings plays a key role. With the advent of digital approaches to documentation, it has become possible to document, analyze and interpret the built environment with much more precision and detail than in the past and simultaneously allow for multiple possibilities to be able to communicate it. Using digital technology, the digitization of cultural heritage allows a comprehensive understanding of the physical aspects of a site, as well as its embedded intangible features, such as the cultural values and traditions associated with it.

Within this context, the present contribution illustrates the approaches adopted for the digital documentation of the Basilica of Santa Maria in Trastevere, including direct and indirect research related to its evolution over time. The Basilica, being a unique example of layered architecture with beginnings in the IV century and modifications reaching the XXI century, became a representative case study to define an integrated methodology aimed at the construction of an integrated model enriched with qualitative and quantitative information.

The present research presents the first outcomes of broader research aimed at the digital documentation of all the Roman Basilicas.

Within this framework, apart from the documentation of the single Basilica, the broader goal consisted in the definition of a replicable recording strategy systematizing the integration of the different techniques to capture the shape, geometry, and color of the recorded buildings, as well as to interpret stratifications and "reused" architectural elements.

Considering the richness of the indoor and outdoor environments of the Basilica of Santa Maria in Trastevere has been selected as a pilot project.

From an operative point of view, the research team set up a method to analyze and understand the architectural elements and ornamental components, differing in geometry, material, color, and texture.

The documentation process, handling a lot of information and data, also focused on systematizing all information acquired through the digitization process with information derived from iconographic and historical research.

Therefore, the research was not limited to the digitization and computerization of this religious building. It included also interpretation and systematization activities oriented toward a comprehensive knowledge of this historic building.

Additionally, the research also addresses the dissemination and communication issues reflecting on accessible (from the cognitive and cultural perspectives) ways of communicating large amounts of heterogeneous data of the recorded religious architecture.

Further, the research comes to develop different levels of information structurally related to integrated models.

The outputs and uses of these models have been developed to improve the understanding and interpretation of the Basilica that is articulated and complex from different points of view (size, geometry, morphology, color, iconographic and historical information, etc.,).

2. THE DOCUMENTATION OF THE BASILICA OF SANTA MARIA IN TRASTEVERE

2.1 An outstanding example of layered religious architecture

The Basilica of Santa Maria in Trastevere is located in the namesake square, between Via della Paglia and Via della Lungaretta, on the west bank of the river Tiber, south of the Vatican, in the Trastevere district in Rome.

The Basilica stands in an unusual corner location, next to the seventeenth-century Palazzo San Callisto and in front of the Palazzo Leoni Pizzirani in Santa Maria in Trastevere Square (fig. 1). This religious building is an outstanding example of layered architecture whose construction began in the IV century and then modified in the VIII and IX century. Whilst, most of the architectural elements and components contained in the Basilica of Santa Maria in Trastevere date back to the XII and XIII centuries, with major changes in the XVI and XVIII centuries. The Basilica was probably the first official place of Christian worship in Rome. According to legend, it was built by Pope Callistus I in the III century and completed by San Giulio I in 340 (Attenni, Ippolito, 2021).

Figure 1. Aerial view and front view of the Basilica of Santa Maria in Trastevere. Source: authors.

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Figure 2. Interior view of the Basilica of Santa Maria in Trastevere. Perspective drawing by Paul-Marie Letarouilly, in the 19th century (Letarouilly, 1857).

Mainly rebuilt under the pontificate of Pope Innocent II (1130-1143), the Basilica was decorated and restored also re-using ancient Romans ruins such as marble, capitals, and columns, of which those from the Baths of Caracalla that can still be recognized today (Luciani, 1987).
In the following centuries, the Basilica has been the object of several renovations, among these notable ones were promoted by Pope Clement XI (1659-1721) designed and realized by architect Carlo Fontana consisting in the reconstruction of the portico[1] preserving and integrating the mosaic of the XII century. Later, Pope Pius IX (1792-1878) promoted the last considerable intervention in the building designed by the Roman architect Virginio Vespignani (Rocca, 1988) (fig.2). Therefore, the architecture of the Basilica combines different styles, showcasing a unique blend of heterogeneous architectural and artistic periods.
Nevertheless, from the architectural point of view, the Basilica maintains the spatial configuration of the XII century.
The exterior of the basilica is made up of brick and travertine stone, creating a simple yet majestic appearance with its smooth lines and superimposed architectural elements. The main façade anticipates the interior structured into three naves divided by twenty-two ancient granite columns, of various diameters, all with Ionic and Corinthian capitals.

The indoor spaces present a heterogeneous[2] and rich decorative apparatus[3]. The extraordinary blend of styles and reused by architectural elements, coupled with its artistic and architectural features witness the rich history and religious traditions of Rome as recognized by the inscription in the World Heritage List in 1980[4].

2.2 Setting up a documentation method to understand and interpret the architecture of the Basilica

Considering the layered architecture of the Basilica, a solid documentation methodology, involving different techniques and tools has been defined. The adopted method aimed at five main goals:

1. implement the knowledge of the Basilica,
2. support the architectural interpretation of this layered fabric,
3. plan informed conservation and monitoring actions,
4. communicate and disseminate tangible and intangible aspects of this historic religious architecture.

Addressing these goals, the adopted methodology defined an integrated recording strategy, including the integration of different survey techniques and tools that allowed us to grasp the knowledge of shape, geometry, and color as well as to interpret the stratifications and the ‘reused’ architectural elements (i.e. column shaft, capitals, etc.,) adopted in the construction and renovation of the church over the years.
More specifically, the adopted approach paid particular attention to the architectural and decorative elements such as capitals, columns’ shafts, mosaics, sculptures, woodcarvings, and stucco works.
For the architectural elements, the adopted scale was 1:50 meters, while for the details the scale was set at 1:20 meters. The data acquisition phase has been planned, considering that the acquisition workflow for both Structure from Motion (SfM) photogrammetry and 3D laser scanning included specific requirements and settings due to the site and material specifications (i.e. reflective surfaces, lighting conditions, and complex geometries).
Additionally, the documentation activity verified the usability of the extensive past graphical documentation. A comparison between the analyzed and digitalized existing drawings and the developed survey defined the level of reliability of the existing graphical documentation. This operation was useful to understand the level of accuracy to identify whether and when to use the existing drawing as a reference to check changes and conditions of the inside and outside of the fabric in comparison to the documented current state of conservation of the building.
Then, archival documents (including texts, images, and drawings) were used to classify the surveyed elements (considering, for instance, that there are 22 types of orders only inside the main nave of the Basilica).

[1] In 1702, architect Carlo Fontana remodeled the front portico. It houses fragments of friezes and ornaments from the ancient basilica, as well as Christian epigraphs. From the exterior, the portico appears surmounted by a balustrade decorated with statues of four popes.

[2] The heterogeneity is to be understood in relation to the different decorative elements, materials, and techniques adopted, the typology of the figurative and decorative subjects, the period of realization, etc.

[3] One of the main character-defining elements of the church is the mosaics, especially those on the facade (“Mary enthroned with the Child” and those in the basin and the apsidal arch (depicting the "Life of the Virgin"), made in the XIII century by the painter and artist Pietro Cavallini. The rich coffered ceiling is carved and gilded with polychrome backgrounds, designed by the Italian painter Domenico Zampieri known as the ‘Domenichino’ (1582-1641) with the image of "L'Assunta" in the center (Kinney, 2016). In 1860, the floor was almost completely rebuilt by the architect Vespignani with the floor mosaics typical of the XIII century (Cecchelli, 1933).

[4] Along with the other monuments of the historic center of Rome, since 1980 the Basilica is part of the UNESCO site named “*Historic Centre of Rome, the Properties of the Holy See in that City Enjoying Extraterritorial Rights and San Paolo Fuori le Mura*”. The site underwent some significant modifications to the boundaries in 1990 and minor boundary modifications inscribed in 2015. (UNESCO, 2023).

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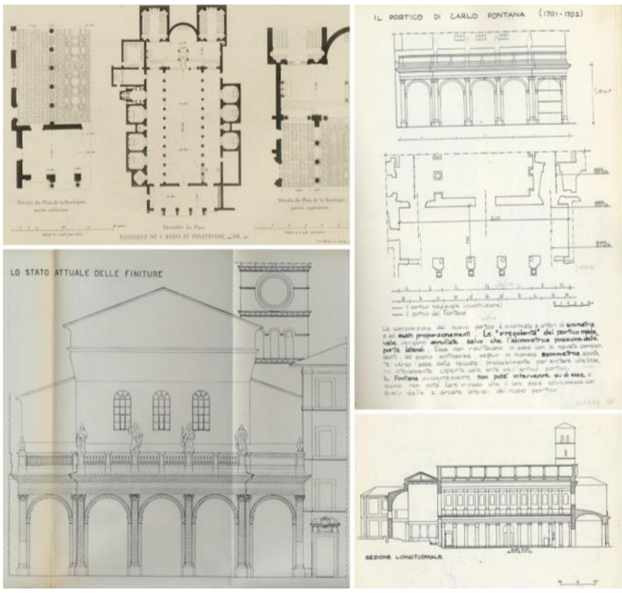

Figure 3. Example of the existing drawings that have been analyzed and interpreted. Source: (Luciani, R., 1987) and (Letarouilly, 1857).

Concerning the classification approach, this included geometrical and morphological analyses. In this process, the segmentation of the different architectural elements has been a pivotal step in the analysis and interpretation process. In the classification, the definition of the categories is derived from the study of the existing drawings and archival documents. This allowed us to know, record, and systematize the analyzed components and elements.
The information included not only technical information but also data concerning the historical and cultural dimensions such as column and capitals’ provenance, reused elements, mosaics’ meanings, etc. The documentation approach tests the relevance of the activities carried out in terms of knowledge implementation, conservation, monitoring, and dissemination of tangible and intangible aspects of this layered Basilica.
In the definition of the adopted documentation method, particular attention has been paid to its replicability and scalability considering that the digital documentation of the Basilica of Santa Maria in Trastevere is part of a broader initiative aimed at the digital documentation of all the Roman Basilicas.

3. THE SURVEY STRATEGY

3.1 Integrated data acquisition

Roman Basilicas are undoubtedly among the most prestigious due to the importance of their foundation, their architectural types, and the role they play as part of Italy’s cultural heritage.
Systematic studies of the Basilica of Santa Maria in Trastevere have concentrated not only on its well-known history, architectural elements, Cosmatesque floors, and the mosaics on the façade towards the square, but also on the apse, the interior, its numerous artworks (fig. 4), and the names of the great architects who inputted into the construction of the complex.
However, compared to the several studies that have focused on these issues, there was no updated documentation about its current state; had there been, we could have archived its quantitative and qualitative characteristics, verified the hypotheses regarding its structural framework and construction phases, and monitored its state of conservation and the degradation of its surfaces.

Figure 4. The internal space of the Basilica of Santa Maria in Trastevere (central nave, Cosmatesque floor, wooden and coffered ceiling). Source: authors.

This lack of data provided fertile ground for a research project to verify existing data and the interpretations formulated by former studies; the project was based on a survey that covered the entire surface of the basilica, and much more besides.
Archival research revealed how the communication of data relative to this space has never included its urban setting: the square takes its name from the Basilica, unusually positioned in a corner of the square (fig. 1). The complex urban and architectural space requires multifaceted comprehension of the building’s morphology and structure, artistic and historical treasures, and symbolic-religious importance.
The objective of our research was ambitious: to convey all this data.
We began by collecting and digitalizing all the very heterogeneous archival documents. This allowed us to classify the main architectural elements inside the Basilica, understand and assess the most important moments in its construction, and also verify its current state. At this point, we realized that all the graphic documents and drawings drafted in the early nineties had to be updated since the plans and elevations of the complex only described the basilica without linking it to its surroundings. In addition, these drawings were the result of the restitution of a survey performed using traditional methods; however, their contents could be considerably enriched by the methodologies currently available. Therefore, we planned a new survey that could satisfy not only current documentary requirements, thanks to mass acquisition methods, but also the requirements regarding preservation. The latter involved several aspects: data storage of all the design devices which, on the one hand, makes it possible to optimize the visuals of internal space and, on the other, characterize space and make it unique; accurate documentation of the alignments of the structures and interaxes of the columns; in-depth study of important decorations such as the Cosmatesque floor and the mosaic in the apse.
The primary objective was to understand and document the spatial and architectural configuration of Santa Maria in Trastevere; the first phase of the surveying and survey operations was to critically interpret the acquired data. To do this we embarked on a long process to integrate and systemize the data in the digital models.
As we all know, these models are digital copies of real objects; they can be inspected, broken down, and segmented in different ways and based on different criteria.
They allow us to perform studies that integrate and, in a certain sense, go beyond the ones tested in loco.

Figure 5. The Basilica of Santa Maria in Trastevere, numerical model from the elaboration of 3D laser scanner survey.

Models are the result of critically processing the survey campaign; this is performed by merging mass acquisition methods (3D laser scansion and Structure from Motion processes) with a topographical survey (fig. 5).
The main objective of the topographic acquisition was to establish a system of local coordinates; targets were positioned all around the surveyed area as well as in certain characteristic points of the façades of the buildings in the square, on the exterior of the basilica, and several important points in the interior. Materialization of the targets inside the areas to be surveyed, and the choice of the characteristic points (identified directly on the surfaces), allowed us to recognize them in the photographs used during the photogrammetric process and in the numerical model, thereby facilitating the next phase involving the construction of the 2D and 3D models.
This kind of structured topographical reference made it possible to orient and align data from different but typologically homogeneous sources (the points clouds) using a grid of known points as a reference.
The numerical model obtained from the alignment of the scansions made it possible to record the architecture's spatial configuration and check its metric and geometric features. Nevertheless, this model does not accurately reflect the state of preservation of the surfaces and how they were treated. So, the interpretation of the chromatic and material values was delegated to the data acquired using appropriately rectified digital images. This was performed by integrating ortho-metric views in parallel projection taken from the models created using Structure from Motion (fig.6, fig. 7). Both processes enabled us to metrically control the data in question. The support of the surveyed topographical points allowed us to establish the orientation of the planes to create 1:50 scale drawings of the elevations and 1:20 drawings for some architectural details. Colour was checked bearing in mind the state of the context around the basilica and adopting a different approach for the exterior and interior. Photographing the façade was inevitably linked to an assessment of natural lighting. More specifically, we had to privilege homogeneous lighting to minimize contrast and be able to select fixed parameters for the whole photographic set.

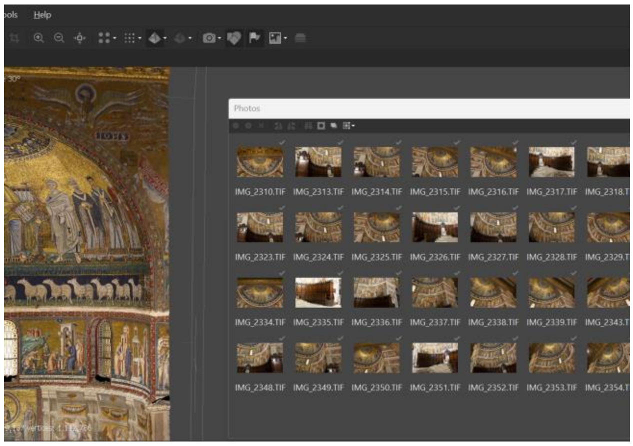

Figure 6. The apse mosaic, texturized mesh model from Structure from Motion.

The images were taken with an overcast sky; this provided diffuse lighting and the required homogeneity thanks to soft shadows that tended to remain the same throughout the campaign. Instead, the shots taken inside the basilica were set up to create as much homogeneous lighting as possible; we identified and compensated for the shadow cones by inserting additional light sources. Construction of the models also included using a color checker during the acquisition phase to correctly balance the whites in the images and, during processing, select the right color temperature, thereby improving the accurate restitution of the scene.

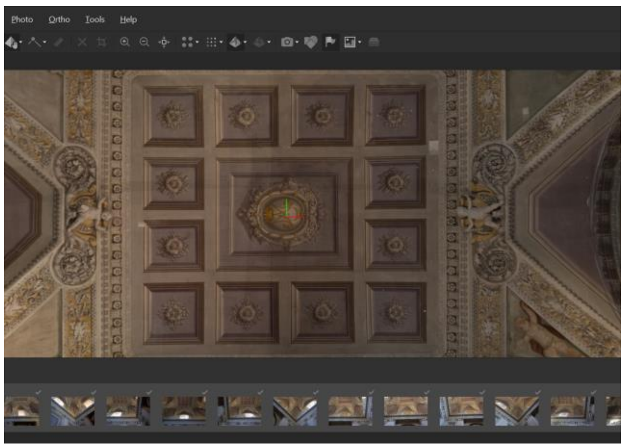

Figure 7. The chapel's ceiling is texturized mesh model from Structure from Motion.

This approach, based on different elaboration processes, allowed us to create a single three-dimensional, integrated digital model enhancing the way we could dynamically and interactively examine several features. To fully represent the characteristics of the object in question we identified the horizontal and vertical sections required to define the 2D and 3D models which, when interpreted, turn raw data into structured information.

3.2 Integrated data elaboration

Another set of objectives was more directly associated with conveying the processed data in integrated models. The latter is the key element behind the dissemination of features that are difficult to understand at first sight, features we know about only thanks to textual data.

The analysis and processing of the acquired data allowed us to create a new system of integrated models which were obtained thanks to the crucial, synergetic use of survey methods. Developing a method is extremely important because when it is based on scientifically controlled data acquisition it produces models of a huge area, such as Santa Maria in Trastevere. Conveying certain aspects of such a complicated topic is the result of an in-depth analysis of the genesis of the architectural space and specific elements.

The processing phase is therefore a crucial moment of synthesis, based on the acquired data it extracts the information required to interpret the work according to the scale of the models. It involves turning data regarding the urban, architectural, and detailed scale into heterogeneous 3D and 2D models (fig. 8); this is what makes surveying a crucial scientific operation and not one that is simply linked to increasingly automatized procedures facilitated by the use of software programs.

Another group of elaborations is related to the representation of the metrical and morphological characteristics of the church.

Creating two-dimensional models begins by initially organizing the data; this is achieved when we draw the image, establish its limits, and identify its forms. It is followed by semantic decomposition, making it possible to pass from the absence of an ontological structure, characteristic of a points cloud, to the organization of the data. This activity is based on recognition of the parts, their relationships, and links; it creates a deeper level of interpretation based on what every element represents in its specific context (Boström et al. 2007).

In this case, two-dimensional drawings make it possible to perform an analysis on a 1:50 architectural scale, interpret the spatial relationship between the church of Santa Maria in Trastevere and its boundaries, establish its relationship with the outdoor areas, as well as the arrangement and relationship between the main space and the porch, and between the central nave and the lateral ones. In short, they provide an organic vision of its style, form, and decorations.

Afterward, several portions of particular interest to architectural restoration projects were studied more in-depth using a bigger scale so that the details could be analyzed from the point of view of conservative restoration.

The drawings are an abstraction of the geometric and formal qualities of the church; since they are two-dimensional they will only lead to a real comprehension of the space if interpreted simultaneously (fig.9, fig.10).

Figure 8. The facade of the Basilica, orthoimage from Structure from Motion (SfM), and 2D model.

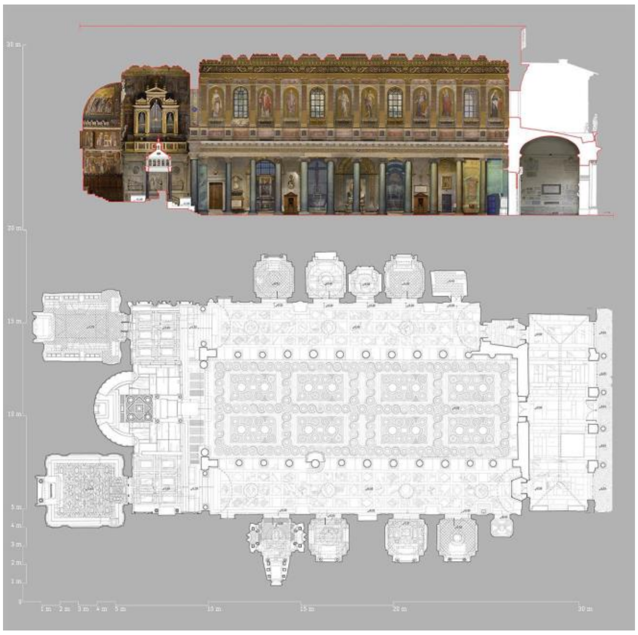

Figure 9. Plan and section of the Basilica, 2D models, and orthoimage from Structure from Motion.

The first piece of information provided within the framework of our approach was the location of the Basilica in the city and where it stood vis-à-vis the city center and important architecture that help to simply and quickly position it in the minds of visitors. The next step was to provide information about the relationship between the building and the urban fabric of the Trastevere district by identifying the irregular space created by the square between the basilica and the other buildings along the urban façades. Indeed, as anticipated, the position of Santa Maria in Trastevere is rather unusual. It is located in one corner of the square between Palazzo San Callisto and the House of the Canons; the portico is aligned with the adjacent building and the façade is recessed compared to the others.

On the contrary, the three-dimensional model immediately corresponds to the real object, making it possible to add supplementary levels of information compared to those regarding morphology. A different operational procedure is used to construct the three-dimensional model. It initially extracts the morphometric characteristics from the polygonal three-dimensional model obtained from the Structure from Motion processes.

The polygonal model acquires meaning and increases its similarity with the real object by exploiting the acutely evocative

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Figure 10. Vertical section, orthoimage from Structure from Motion and 2D model.

nature of the digital images. Apart from the fact that this makes the 3D model the ultimate instrument to divulge contents, its quality is nonetheless defined by its semantic structure, i.e., the structure of the information it contains.
After clarifying the importance of the structure of the information in virtual space, it is important to point out that the possibility to access a huge amount of data does not, in itself, provide knowledge (Khalenghi, Khamis, Karray, 2013).
So, ultimately, it is crucial to not only establish how discrete models interact with distinct objects but also understand how heterogeneous data can be introduced and made available in a certain three-dimensional environment (Bianchini, Griffo, 2020).
The procedures developed based on the principle of projection are all those that help to texturize the three-dimensional models. Instead, spatial union takes place by merging the range-based procedures used by the laser scanners, and the image-based procedures used by the photogrammetric processes.
These three types of association establish the constraints required for a correct approach to knowledge whose main characteristic is not so much the representation of the object, but the correct management of the data and information obtained during the acquisition and processing phases – data and information that can always be critically interpreted.

4. CONCLUSIONS

The adopted method showed the opportunities for an integrated survey strategy and the relevance of digital tools to analyze and interpret religious architecture.
In terms of knowledge, the survey and the morphological and geometrical analysis allowed a better understanding and interpretation of the constructive and decorative elements to both specialists and the broad public.
The research develops different levels of information structurally related to integrated models that have been developed to improve the perceptual accessibility and enjoyment of a space that is articulated and complex from different points of view to enable the use of the space by different types of users ranging from specialists to the general public.
Regarding conservation and monitoring, the integrated survey allowed the generation of a digital twin of the building with a high level of accuracy.
The vast amount of heterogeneous information has once again made explicit the potential of data integration for building models of architectural heritage.
Further research opportunities derive from the outcomes of the documentation activity. Indeed, the generated integrated models open up new possibilities for the dissemination of the analyzed and measured aspects able to spread the knowledge of this outstanding example of religious architectural heritage to heterogeneous audiences.
Finally, in terms of scalability, the adopted method can be replicated in the study of other Roman Basilicas.

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