The Brazilian 20th Century's Houses. Digital Documentation for Preservation and Enhancement of Modernist Architecture and Design Processes

Marcello Balzani and Luca Rossato

Abstract This essay wants to contribute to the international discussion related to the conservation of the XX century modernist architectures, highlighting the crucial role of the preservation of the master's legacy. It is a matter of memory conservation that can be achieved by means of technology integration and analyses methodology able to greatly improve the knowledge on these projects. The contribution describes an ongoing research path that, along the past five years, has been already able to digitally document dozens of modernist buildings in many regions within the Brazilian territory. Thus, the text explores the possible integration of several techniques such as digital elaborations, 3D modelling and 3D surveying, in order to identify the right tools and all the information to improve the knowledge of, not only the buildings, but also the design process applied by the XX century's masters. Above All, three famous modernist houses are here analyzed by the proposed methodology: *Casa de Vidro* (by Lina Bo Bardi, 1949), *Casa Olivo Gomes* (by Rino Levi, 1951) and *Casa das Canoas* (by Oscar Niemeyer, 1953). These three projects are the most suitable case studies to explore the design methods of the great masters that along the 50s and the 60s significantly influenced the meaning of "modern house" in Brazil. Designed by the three of the most important architects and built in 3 different regions between São Paulo and Rio de Janeiro, the houses are considered among the most significant examples of modern architecture in Brazil.

Keywords Digital preservation · Technologies · Brazilian modernism · 3D survey and modelling · Memory

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1 Introducation

1.1 The Brazilian Modernist Movement and Its Masters

In the early years of the 20th century, the need for renewal of the national architectural scenario began to be felt also in Brazil. The impetus for the advent of the new era came in 1920, when the Simonsen group contracted the Russian professional Gregori Warchavchik for a work in São Paulo. Warchavchik's first project was the Modernist House. Since then, a group of professionals, who soon made Brazil one of the main centers of the world's modernist architecture, mixed the architectural styles of Le Corbusier, Walter Gropius, Mies Van der Rohe and Frank Lloyd Wright into a fully Brazilian modernist style [26]. The movement in Brazil was triggered by the assimilation of cultural and artistic trends launched by the European vanguards in the period before the First World War, such as Cubism and Futurism. The new modern languages posed by the European artistic and literary movements were gradually assimilated by the Brazilian artistic context but focusing as elements of the Brazilian culture. According to Lúcio Costa, Brazilian Modernism is justified as style which affirms the identity of Brazilian culture and represents the "spirit of the time". It is considered the Week of Modern Art, held in São Paulo in 1922, as the starting point for modernism in Brazil [7]. After the disclosure of the Modern Movement there was a subdivision into various stylistic trends. Among these the two most important in terms of production and masters were the ones developed in Rio de Janeiro and São Paulo [23], the two big cities became the centers of architectural discussions at that time. Active figures of this revolutionary period were: Affonso Eduardo Reidy, Carlos Leão, Ernâni Vasconcelos, Jorge Moreira, Lucio Costa and, subjects of this investigation, Rino Levi, Lina Bo Bardi and Oscar Niemeyer.

Rino Levi (1901–1965) was born in São Paulo, son of Italian parents, he studied architecture in Milan and Rome. He was one of those responsible for the transformation of the architecture of the city of São Paulo and is one of the exponents of modern architecture in Brazil. Levi initially studied at the Academy of Brera in Milan, moving later to the School of Architecture in Rome, where he graduated in 1926. Even before finishing his studies in Rome, Rino Levi sent a letter from Italy to the newspaper Estado de São Paulo (published on October 15, 1925) under the title "Architecture and aesthetics of cities", which was classified as one of the first manifestations around modernist architecture in Brazil. He was a student of Marcello Piacentini in Rome [17]. On his return to Brazil in 1926, Levi was employed by the Companhia Construtora de Santos, taking up the position that was before occupied by Gregori Warchavchik.In the early 1930s, he designs his first modern buildings for clients of Italian origin living in São Paulo. The experience developed with these residential projects, lately allowed Levi to design the *Casa Olivo Gomes* built in 1951 in São José dos Campos [2]. The house is probably one of the best projects conceived by Levi and along with the gorgeous gardens designed by Brazilian landscape architect Roberto Burle Marx is an important icon of modernist architecture of this country (Fig. 1).

Fig. 1 Casa Olivo Gomes and its gorgeous garden in 2015. Image by Luca Rossato

Lina Bo Bardi (1914–1992) migrates from Milan to São Paulo in 1947, one year after marrying the art critic and gallery director Pietro Bardi. Lina, who graduated in architecture in 1939 in Rome, came from past experiences of collaboration with Carlo Pagani and Gio Ponti in Milan and had developed for this a great passion for art and design. When her husband Pietro was in charge of the direction of the Art Museum of São Paulo by the Brazilian magnate Assis Chateaubriand was natural for her to follow him and jump with energy and conviction in the new and unknown Brazilian reality and into the debate about architectural work in progress at the time [22]. *Casa de Vidro* is the first project built by Lina in Brazil and probably the most important and charming one [10]. If for importance and dimension the new MASP museum (1957–1969) and the cultural centre SESC Pompeia (1977–1986) are undoubtedly his most famous achievements, it is in its own house that Lina expresses all the strength of the ideas linked to her way of doing architecture (Fig. 2), creating an object worthy of being counted among the best private residences built during the thirty years after the Second World War [1].

Oscar Niemeyer is still the most renown Brazilian architect (1907–2012). His personal life and his career were deeply affected by the constant political shifts that Brazil was experiencing in the twentieth century. He was able to emphasize the "liberated sensual curve" in each architecture he designed thanks to the new technologies connected to the use of reinforced concrete in Brazil [19]. In 1988, at

Fig. 2 Casa de Vidro surrounded by the vegetation in 2017. Image by Marcello Balzani

81, Niemeyer was awarded the Pritzker Architecture Prize, the architecture's most prestigious award.

Casa das Canoas was designed by Niemeyer in 1951 as his family home. It is considered one of the most significant examples of modern architecture in Brazil and is well recognized by specialists in art history as a synthesis of modern architecture and authorial self-creation that flourished in Europe and in America [13].

Niemeyer's ideologies in terms of society, politics and architecture and his style are expressed to the full in the architecture of the house at Canoas, which was a remarkable achievement of Modernist architecture [24]. The most interesting feature of this projetc is the fusion of organic architecture and minimalist architecture. The house puts geometric regularity in crisis but does not alter the formal purity. The idea about integration between the building and the surroundings was one of the driving forces of the design (Fig. 3). It was not just about creating a beautiful setting around the dwelling, the architect wanted to make the house a part of the forest landscape [25].

1.2 Digital Documentation for Preservation and Dissemination Purposes

The issue regarding the forms that define places or buildings (even the modernist ones), seems to belong to the capacity to describe and "take them away". Knowing

Fig. 3 Casa das Canoas in 2014: the integration between the building and the nature. Image by Luca Rossato

how things are made is not easy. From a certain perspective, it is shared experience, the act of possession, of union, of formal participation, but describing and representing all of this is something different. If human experience becomes qualitative, giving it emotional meaning, writes Merleau-Ponty [18], then the relationship with the other qualities (which often have nothing in common with it) start to become understandable. As Bergson wrote in "Matter and Memory" [5], this relationship is never frontal, but rather "oblique and clandestine" and it is precisely in the capacity to make it stand out and express that we can understand how it is often things that shape our attempt to endure. Time is, after all, hesitation and if memory is a weak attempt at defense, material (that which is sacrificed in the arduous ritual of conservation, reconstruction or, most of the time, negation of the interpretive process) can be a concrete intuition of duration in the translation of the survey and the project. Experience teaches us that there are natural processes that are irreversible which is like saying that the world around us (us included) is ageing and changing day by day with no hope of going back. Expressing the value of the asset, one attempts to identify and valorize its uniqueness and thus to make every operation worked upon it reversible, in the sense of being as little contaminating, destructive, interpretative, and dispersive as possible, to allow those who come later to be able to enjoy the same asset and be able to take further reversible action with constructive and conservational technologies that are even less invasive and more preservation focused [14].

Since the 70s, the technological support to the field of heritage preservation and enhancement (Fig. 4) has improved the knowledge and analyses on historic buildings and developed a new business model [15]. Through the work of several research centers, mainly located in US and Europe, operational methodologies involving 3D geometric models and virtual representations of monumental architecture have been developed. These tools can effectively support a wide range interdisciplinary analyses in sectors related to the conservation and restoration of archaeological sites and architectural structures. These technologies are particular efficient when applied to 3D surveying, solid prototyping of architectural features and artefacts, multispectral surveying, the study of historic materials and the technical-structural problems of historic structures [11]. Digital tools and computer aided drawings could be integrated in surveys in support of projects for the restoration and conservation of the architectural and archaeological heritage in relation to the environment and geographical area. Furthermore, as stressed by A.M. Ronchi about digital literacy "there is a need to channel the creative energies of young people by promoting digital literacy in the field on new ICT-enable or empowered creativity and expression. There is also a need to create a proactive environment that enhances the overall quality of eContent products. Digital and social divides must be bridged in order to provide access and added value to citizens. Digital technologies and ICT tools provide an incredible opportunity to encourage growth and prosperity. Digital content and services empowered by broadband communications, both wired and wireless, could have a significant impact on society. One of the first steps in this direction is to promote human networking and the exchange of experiences and skills amongst different groups and communities" [20].

The major surveying technological tools (3D laser scanner mostly integrated on total stations and digital cameras) are continually updated with regards to speed of

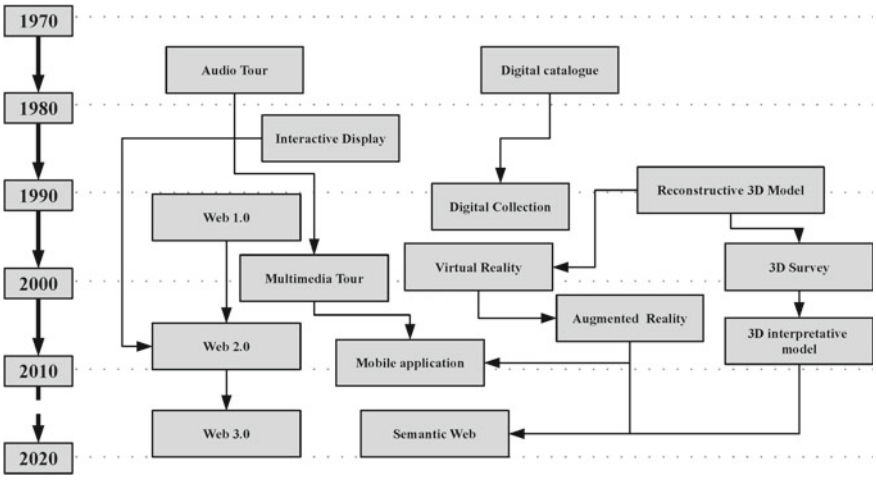

Fig. 4 The development of technologies applied to Cultural Heritage along the last 50 years

acquisition, accuracy of the data in relation to the relevant operating range, portability and lightness of use, interface flexibility. The degree of innovation that the industry offers to the professional market is not always supported by a level of information and technical knowledge capable of absorbing the real potential of use. For this reason DIAPReM (Development of Integrated Automatic Procedures for Restoration of Monument), a research center at the Architecture Department of Ferrara University has, for over twenty years, tried to develop optimized procedures and applications that make technology transfers from the productive sector to the construction network (professional engineers, service companies, ministries, local authorities, construction and restoration companies) more accessible and cost-effective [3]. Since 1997 DIAPReM has been developing operative procedures for the 3D geometric modelling and virtual representation of architectural complexes of a monumental nature as an analytic tool to aid in a comprehensive interdisciplinary approach to the study of such complexes. The research center is especially engaged in sectors relating to the preservation and restoration of archaeological sites and architectural works. Its specialties include 3D surveys, solid prototyping of architectural features and antiquities, multi-spectral analysis, the study of historical material and technical and structural problems for architectural and archaeological sites. Nowadays, working between innovation and documentation strategies, the problems are found in the logic of creation, management and use of real 3D data. The descriptive process is, in fact, strongly linked to the traditional two-dimensional drawing, even when it tries to imitate the results represented in the spatial complexity. This procedure is historically connected to the simplicity of such models: the discreet and simple elements of a two-dimensional representation offer a series of limited configurations that are easy to understand and use. The introduction of instruments (with their potential only apparently intelligent) has generated the idea that the processes of awareness and understanding are not needed, or at best, are less required. It is exactly the opposite. These technologies (from automatic design to laser scanner survey), objectively powerful for speed, accuracy, display capacity, trigger the need to further develop a new critical-conceptual instrument [8].

2 Operating Database for Modernist Architecture

2.1 A Multifaceted Approach

The modernist heritage can be represented using the most suitable technologies. All the available tools are not gadgets, but digital instruments to facilitate the understanding and study of both built and unbuilt projects, offering opportunities of analysis in an immediate way. That is why the real key to a revolution in this field is certainly the use of telematics networks for knowledge sharing. The professionals, researchers and students can access information about the works, wherever it is

stored, and compare them all similar works. In contrast to this potential, it is important to highlight today and even more in the near future, the abundance of data on the network generates pathological effects, including uncontrolled proliferation of references and lack of validity and reliability of the information transmitted. The set of data, paper documents, drawings, photos, 3D survey, non-invasive analysis, is a source, which, if not properly structured, and cleaned up to remove redundant information, it could appear to be out of control both in terms of accessibility and verification of the information accuracy. Nowadays there is a repeatable model that allows step by step, from conception, composition, until the finalization of the data through a methodology for data cataloguing. Understanding architecture project and being able to reproduce them with digital technologies will also improve the conservation of design process. The preservation of the architectural projects by the masters is becoming nowadays a crucial point. Very often cultural foundations that manage the archives of the great architects of the twentieth century are not always able to ensure an effective conservation because of lack of funds. Modelling the modernist architectural projects also means preserving the lessons learnt in terms of architectural and spatial composition [12]. Nevertheless, technologies need to be planned in synergy together from the first moment.

A multidisciplinary and cooperative approach is nowadays needed in order face many challenges linked to cultural heritage documentation and preservation [6]. Along this direction, the work carried out by the authors since 2013 in Brazil has highlighted the huge potential of this approach. A methodology able to integrate tools and skills, where Italian and Brazilian researchers were involved and pushed to work together following the main aim of documentation and dissemination of amazing architectures. For what concern this study, the three houses designed by Oscar Niemeyer, Lina Bo Bardi and Rino Levi, were analyzed by a flexible and adaptable methodology in order to obtain useful and usable set of data (Fig. 5).

2.2 The Setting up of a Digital Archive

The modernist cultural heritage is currently experiencing loss of documentation and lack of maintenance due to several reasons related to crucial factors. Knowledge of the modernist housing stock is an essential element for the architectural design knowledge of that period.

In our opinion the real key towards a proper preservation action is probably the development of integrated analyses and activities able to set up digital database containing both bi-dimensional and three-dimensional information (Fig. 6).

By this workflow it's possible to have a reference mapping of the state of preservation of the building stock in order to be able to plan interventions and manage the uses to which they can be put. In this framework the use of HBIM models takes advantage of the tools offered by data sharing within virtual environments, new surveying techniques and documentation. The architectural 3D digital model is the mediator between intellect and tangible reality, and it takes the form of a digital replica of the

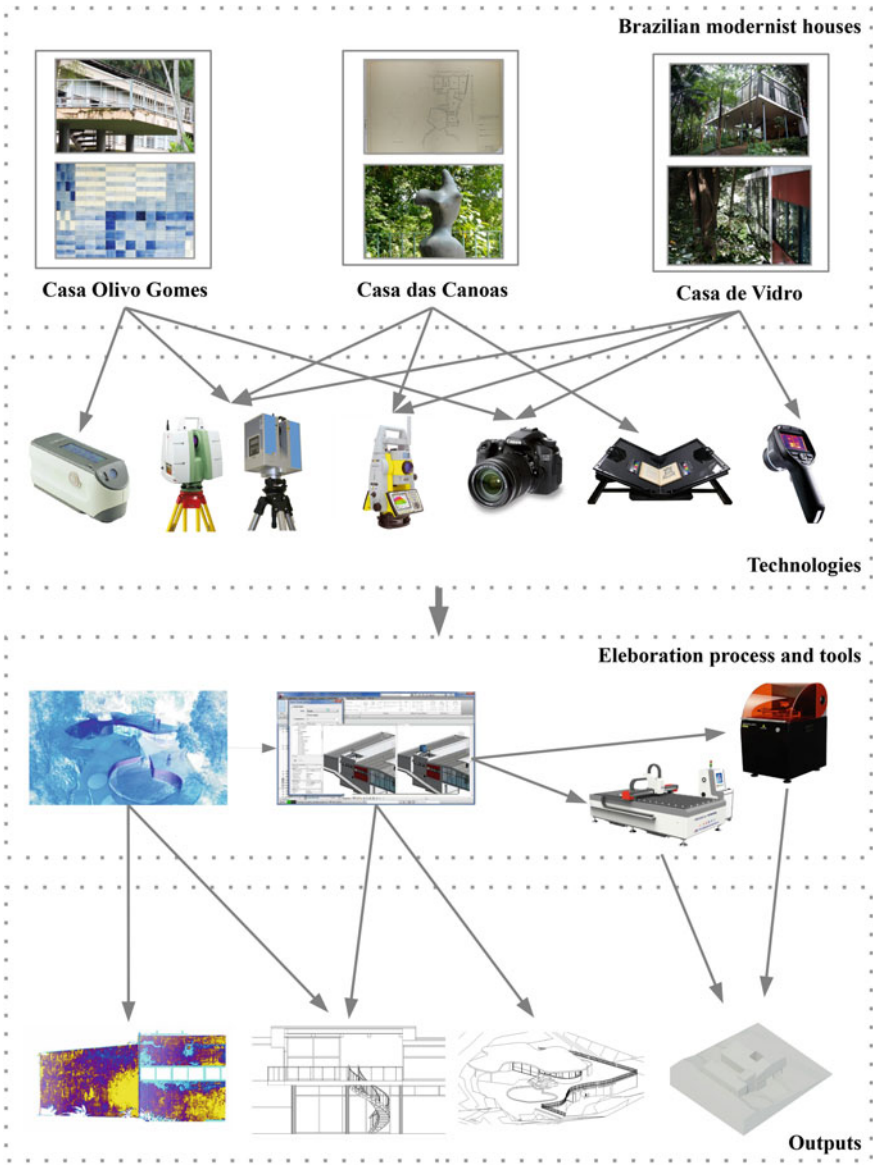

Fig. 5 The integrated methodology developed by the authorsr for *Casa Olivo Gomes Casa das Canoas and Casa de Vidro*, in Brazil

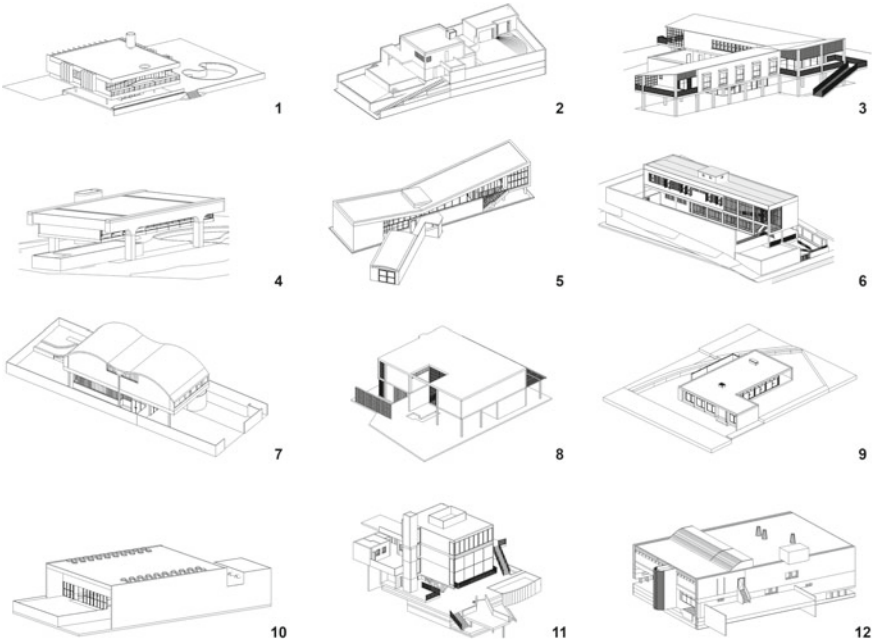

Fig. 6 Some of the Brazilian buildings from the 3D model archive conceived along the research at the Architecture Department of the University of Ferrara (1. *Residência Nadir Zacarias,* 2. *Casa Modernista Rua Itápolis,* 3. *Casa Saavedra,* 4. *Residência José da Silva Netto,* 5. *Residência Vilanova Artigas,* 6. *Casa Bettega,* 7. *Residência Suarez Brandão Lopez,* 8. *Casa na Rua Suécia,* 9. *Residência Antonio Mauricio da Costa,* 10. *Residência Telmo Porto,* 11. *Residência Cunha Lima,* 12. *Casa Celso Siveira Mello*)

observable phenomenal reality. Thereby the model expresses—i.e. contains—the history and it's passage through time; a *visual narration* that is part of the historical process and critical analysis [9].

All this aims to provide a tool for acquiring all the documentation needed for renovations and restorations, seismic surveys, energy efficiency assessments and so on. Furthermore, through digital database of modernist buildings is possible to analyze the dynamics of the urban fabric and the acquiring compositional design and technological elements, that have allowed to evaluate the morphological evolution and offered an opportunity for a methodological comparison. This research activity, developed in cooperation with the staff and students of the Architecture Department of the University of Ferrara, was able to create an archive of more than one hundred modernist buildings constructed in Brazil. By the study of documentation available on-line and found in institution archives 3D models were conceived and later studied. From the different analyses carried out within this research project on modernist building in Brazil it has been possible to highlight some indicators which can be used in order to have a clear picture about the buildings morphology and main factors that could threaten its conservation [21].

The overall situation related to each building was then expressed by a radar chart (6 axes) in the which 6 indicators were identified and evaluated giving them a mark from 1 to 10 case by case.

The 3 couples of indicators identified by the areas in red for critical danger (Heritage Hybridization—H.H.and Degradation by Use—D.U.), in yellow for moderate danger (Lack of Documentation—L.D. and Lack of Protection—L.P.). Green areas mean the effort of interventions toward the preservation (Maintenance—M and Restoration Activity R.A.). In this way each diagram could quickly highlight the overall preservation state of each identified building. The couples of indicators were made up trying to combine the main factors threatening the conservation of the modern heritage that the research was able to identify: the estimation of each level was then express through the grade (Fig. 7).

At the end of the analyses three main areas (macro groups) of critical factors for building conservation have been identified in technological, natural, and urban (listed in order of importance).

For what concern the technological factors they could be an obstacle in conservation processes and even during the general maintenance of these buildings. For instance, the industrialized construction introduced many new materials, new uses for traditional materials, and component-based systems. Traditional detailing was abandoned, and it was often claimed that buildings were maintenance free. In the

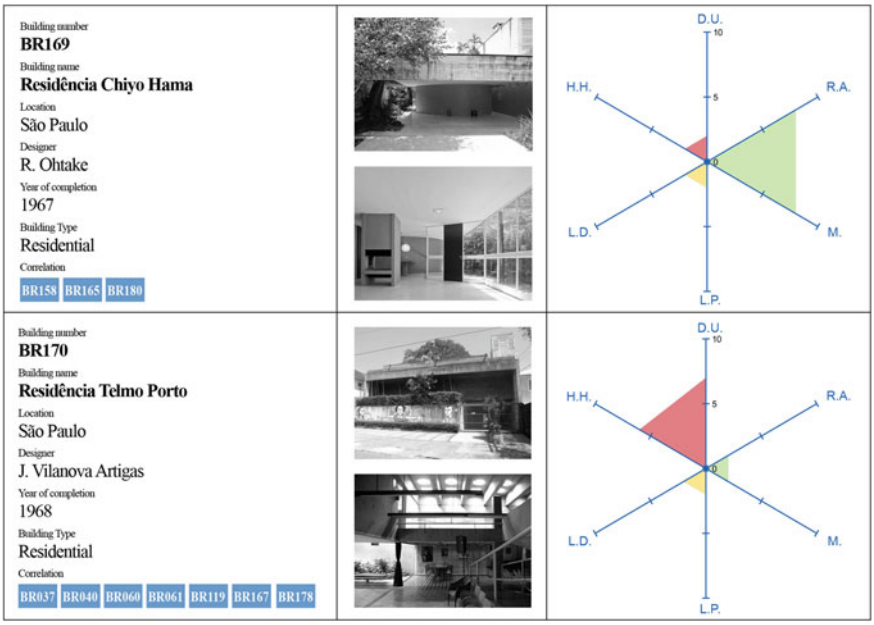

Fig. 7 Comparison between two modernist houses (same period) by architects R. Othake and J. Vilanova Artigas investigated through digital database: thanks to the colors diagram it's clear the differences in terms of preservation between the two buildings

fiscally austere post-war era, limited budgets, and shortages of materials such as steel and timber, together with the de-skilling of the building industry, meant that building quality was sometimes compromised. These factors have resulted in a building stock with a reduced life cycle [16].

Speaking about natural factors we should emphasize that Brazil is tropical country which climate and vegetation could be very aggressive toward cultural heritage. Furthermore, in some area of Brazil rain are strong in wet seasons. Furthermore, some recent collapses of cultural heritage in this country have been caused by the uncontrolled vegetation growth (roots and branches can badly damage the structures). In some cases, natural characteristics of the site such as orography can also be an obstacle toward the site conservation.

The urban factors are also worthy of consideration as they that can led to the bad conservation of a modern building or even to its destruction in case the urban economic pressure is unbearable for the owner. This is the case where, especially in high developing countries, the need of space in valuable area puts some modern buildings in danger. If not adequately protected by-law these architectures could be demolished and replaced by tallest buildings to be sold on the building market.

3 Integration of Technologies for Modernist Buildings

An effective digital database, useful for preservation and valorization purposes must take into consideration all the key factors and contain different level of information.

These layers should be organized in connection with the degree of knowledge achievable with the most suitable technique. The three case studies described by this contribution are thus some examples of the application of these documentation activities at different level of knowledge.

At a first level (see *Casa Olivo Gomes* by Rino Levi), thanks to a huge effort of documentation along the research, the investigators were able to collect more than 250 buildings. These were catalogued and thanks to 3D BIM modelling procedures and integrated surveys the overall knowledge on some of them was greatly improved. These data should now be used as a base for students and academics (not only in Brazil) for further analyses on buildings or more specific research on the modern architecture.

Secondly, great importance in this process of knowledge and toward a real scheduled maintenance plan had the 3D integrated surveys. The cooperation with the scanner's manufacturers (involved as sponsors in some activities) in Brazil has shown how it could be possible to use expensive tools even in low budget projects (see *Casa das Canoas* by Oscar Niemeyer). These actions were also useful in order to evaluate the impact of the research: beside the important outputs analyzed by the three-dimensional database (that allowed high technology analyses on the buildings), several awareness program (seminars and conferences) on stakeholders have been based on these surveys. This helped to improve the spreading out of new technologies in heritage field in both the countries and has led to the creation of a laboratory

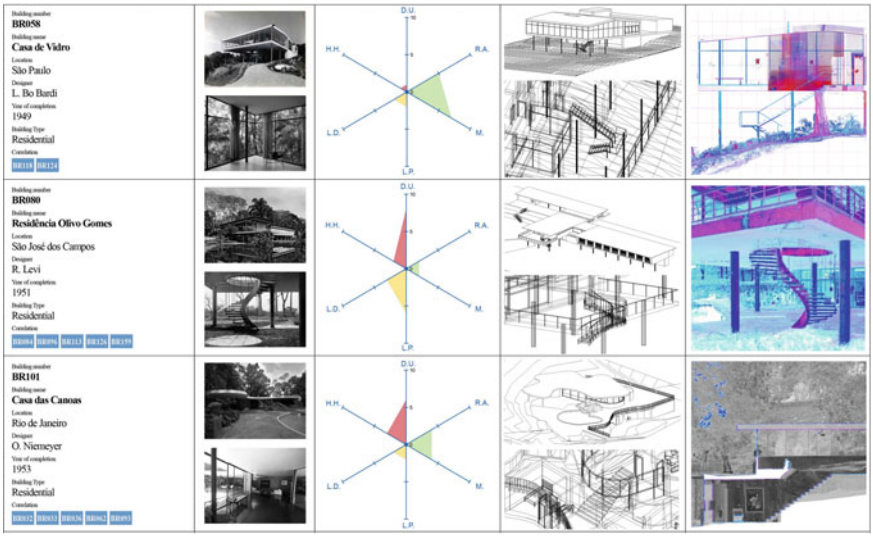

Fig. 8 The digital archive developed during the research could allow integration of analyses based on different scale of investigation: from identification of threatening factors to 3D analyses and point cloud elaboration for conservation or enhancement purposes

net able to autonomously develop local methodologies for the modern building's preservation.

Finally, a third level of analyses have brought some indication for the preservation of modern buildings by integrated methodology. For instance, diagnostic investigation (see *Casa de Vidro* by Lina Bo Bardi) based on point cloud's elaboration helped toward the creation of a maintenance plan in order to reduce the need of crucial restoration works (Fig. 8).

3.1 BIM Model as Knowledge Tool: Casa Olivo Gomes *by Rino Levi*

Through the analyses of examples of high quality built heritage it is possible to investigate the dynamics of the construction and design processes highlighting technological elements that have led to a morphological evolution of case studies and offered an opportunity for a methodological comparison.

Along the creation of the BIM model of *Casa Olivo Gomes* the adopted "architectural redrawing" process has been based on critical survey of bibliographic sources and the 3D laser scanner data base. Even if the 3D point cloud wasn't complete due to bad weather during the documentation activity on site, thanks to interpretation and dimensional homogenization the definition of the 3D model was quite accurate. The building was fully represented through computer-generated images by

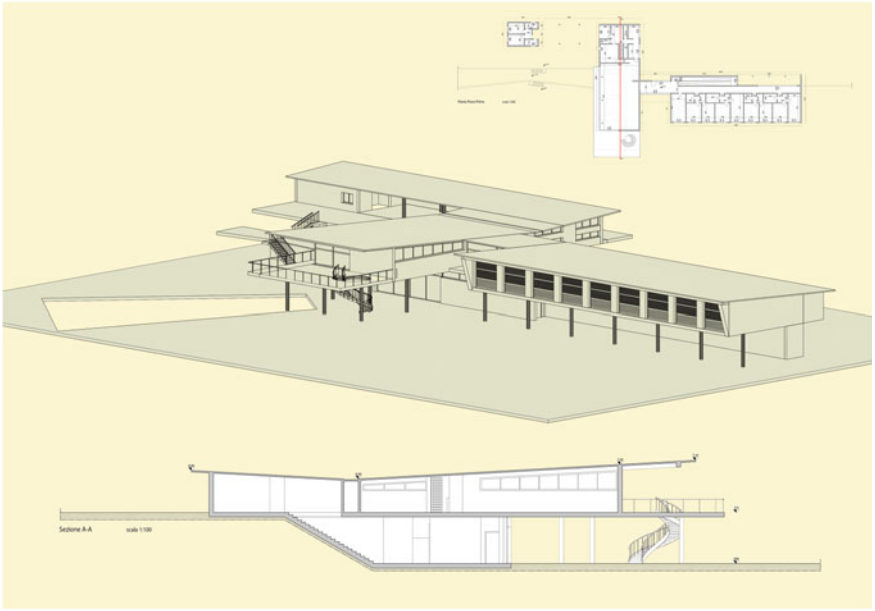

Fig. 9 Digital images of Casa Olivo Gomes: axonometric view and cross section from the BIM model developed along the study. Graphic elaborations by Luca Rossato, Paolo Lisotti, Elenea Tredici, Ambra Marconi

plans, sections and 3d views (Fig. 9). In carrying out this work it was possible to verify some hypotheses raised at the beginning and also during the development of the research: the study of the project contributed to a better understanding of the architectural work by Rino Levi.

The research also proved that the methodology adopted in the analysis of the project, with the use of original drawings and point cloud models, was fundamental to the study and the sharing of the information. From the studies carried out, which involved redesigning, graphical analysis and 3D reconstruction of the house, it can be concluded that only with the proper documentation (both 2D and 3D) it is possible to plan the right conservative intervention on this type of houses.

3.2 Point Cloud of a Modernist House: Casa das Canoas *by Oscar Niemeyer*

The case study *Casa das Canoas* is a significant contribution to an issue of permanent validity, since the emergence of the preservation of the modern heritage dramatically highlighted the lack of knowledge, organized and finalized information on this type of architectural heritage in Brazil. The integrated research at Casa das Canoas in Rio

de Janeiro, is part of the activities of the DIAPReM research centre carried out on field in Brazil with the aim of documentation, knowledge and preservation of one of the most important architectures of the Brazilian architect Oscar Niemeyer.

The research project has been asked by the Oscar Niemeyer Foundation, which was trying to identify an appropriate methodology for documentation and conservation of the architecture designed by the great Brazilian master, after his death in 2012. Thus, the main objective of the work was to develop a detailed architectural analysis, to have an accurate database useful for site restoration work or management plan.

The total region computed for the 3D research campaign also included the external area of the house and garden as well. This is because, on one hand the landscape design was an essential part of the general design process by Oscar Niemeyer and on the other hand to study the effects of vegetation on the state of conservation of the building.

The topographic survey was performed by Leica Total Station TPS 1201, whilst the detailed topographic survey (based on targets acquisition) consisted in open polygonal with control points for the targets. The 3D survey was performed with Leica C10 Laser Scanner (lidar technology) with a medium resolution of 1 cm and it will use green and blue reflective targets for the scan's registration. At the end the scanning station were 128 with almost 2 billion of registered coordinates. The investigation on site was completed by a photographic documentation carried out with a Canon Eos 5D used during the survey for image capturing. During the registration process of the database the building plans were analysed to understand whether, during the construction phases, the original project by the master Niemeyer was carefully performed or not. Thanks to the 3D database, it was possible, for the first time, to locate exactly the two levels of the house, which do not overlap. In this way the position of the two independent floors of the house were defined and these data can be very useful in case of a future plan of restoration or maintenance work required on the house (Fig. 10).

The database and the other digital data allowed the setting up of a final report on the main preservation issues of the building that can be listed as follows:

– due to the local climate vegetation is growing very fast on external walls and on horizontal surfaces.
– part of the house is slowly moving towards the hill slope and an intervention need to be urgently planned.
– big cracks cross the bedrooms ceiling and rainwater is leaking inside the house, plaster is becoming very fast darker and weaker.
– swimming pool pavement shows cracks and deterioration, and further analyses are required to better understand the causes of this problem.
– great geological instability of the slope subject to strong storms is a serious degradation factor.

The 3D survey will be a strong base for future conservation projects, and it will preserve the memory of this extraordinary house.

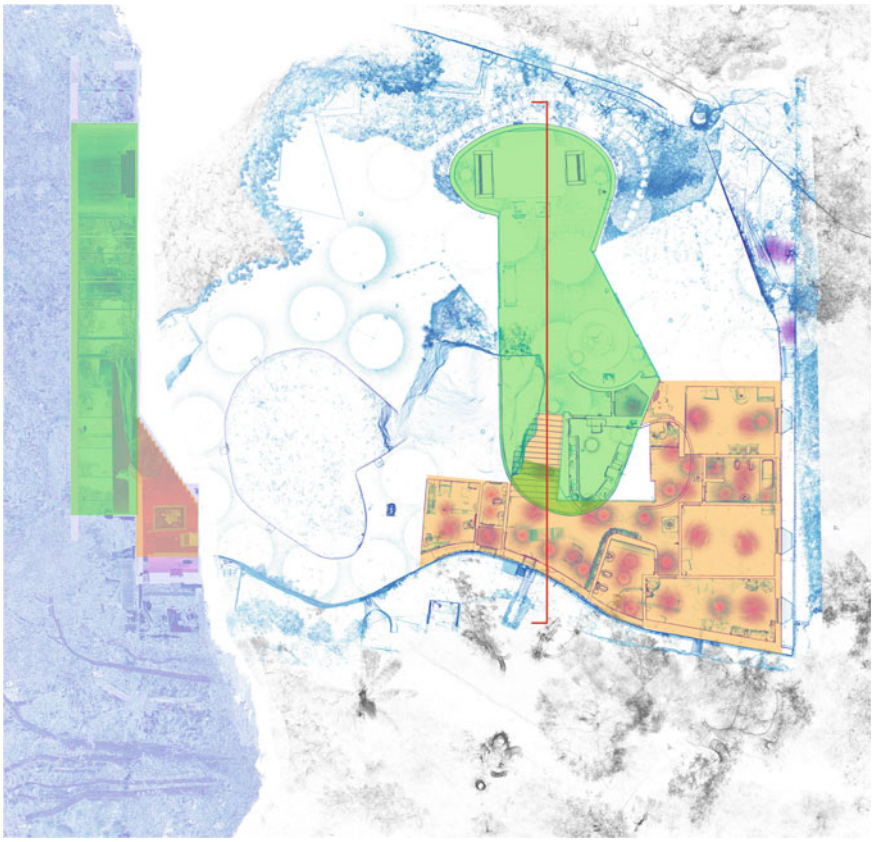

Fig. 10 Digital elaboration that shows, for the first time with high level of accuracy, how the 2 levels of the house are just slightly overlapped as conceived by Oscar Niemeyer (green area identifies the ground floor and the orange area the basement both in plan and section)

3.3 Diagnostic Analyses from Point Cloud: Casa de Vidro *by Lina Bo Bardi*

The digital geometric model of *Casa de Vidro*, conceived in cooperation with the Lina Bo e P.M. Bardi foundation and the IAU USP in São Carlos (SP), was obtained with the documentation campaign performed by DIAPReM centre in 15 days of work on site. The 3D data were carefully registered, and the main outputs was a very accurate database by the which is now possible to have morphological information about the house.

Furthermore, the one of the main objectives of the project was the creation of an affordable methodology and use of data among the different entities of the cooperation net established in order to set up a full conservation plan of the site. For this reason, the point cloud model, in this case, was also used to investigate the surface

characteristics displayable on the data base (Fig. 11). By the modification of intensity values acquired with the laser scanner on each point the process of data capturing highlighted areas with specific features to be mapped such as different materials, degradations, previous restoration works, etc. [4].

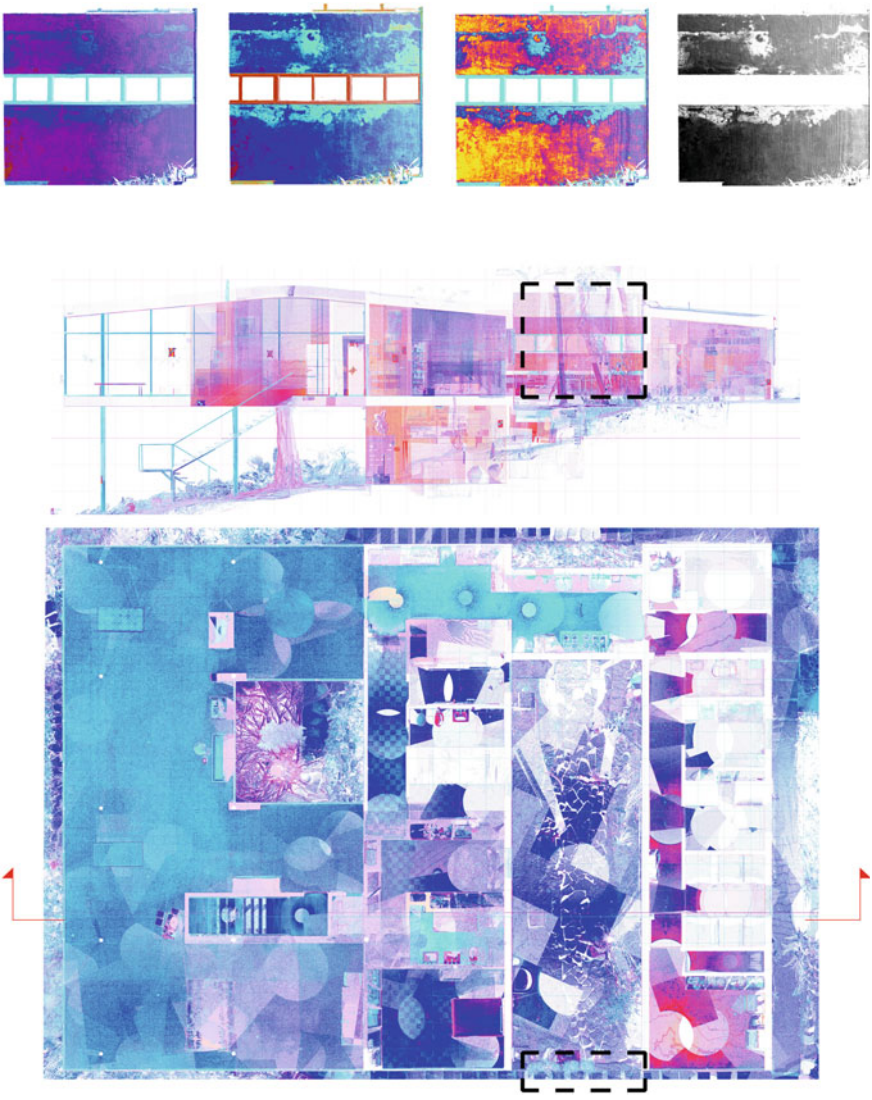

Fig. 11 The 3D database of *Casa de Vidro*, beside the generation of very accurate plans and sections of the house, allowed also macroscopic investigations to manage additional information related to surface characteristics visible on the point cloud. The 4 set of intensity values (on the top of the image) on the point cloud were performed considering different parameters

This approach was used on some areas of the façades of the house, to test the potential of an integrated diagnostic documentation. In this way, merging 3D data with photo and visual analysis of the surfaces it is possible to represent conservative issues; the diagnostic analyses on *Casa de Vidro* were used as an effective tool for the detection and evaluation of the state of conservation of the construction materials.

This case study stressed the importance of the integration of historical documentation, 3D survey, macroscopic analyses and colorimetric characterization, towards the collection of historical, metric and conservative data. All these information were then stored into HBIM model of the house which became a very powerful tool for the conservation of the Lina's house (Fig. 12). Based on this integrated procedure it is possible to achieve thematic drawings/representations develop conservative strategies based on a multi-layered and integrated 3D data base [4].

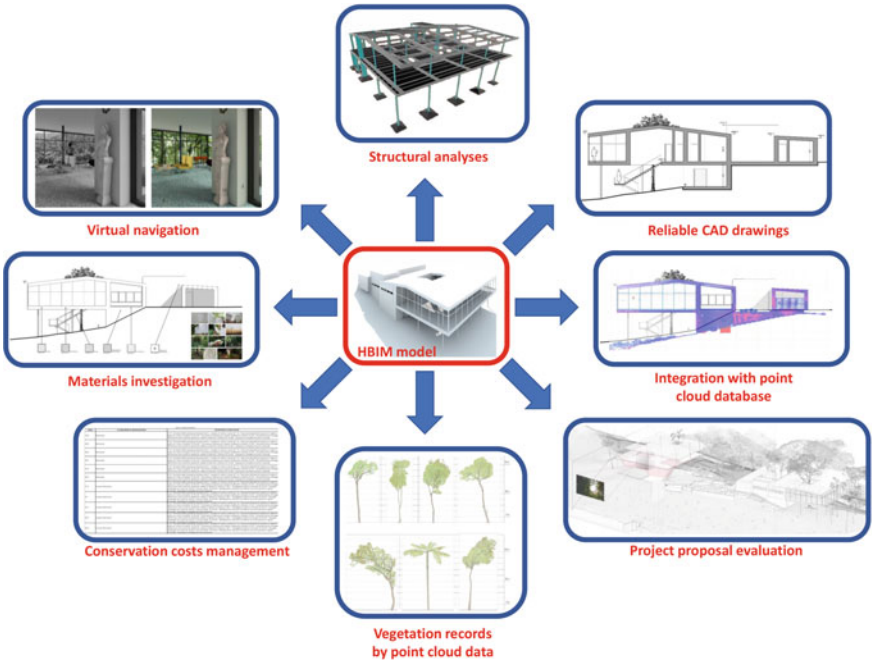

Fig. 12 The HBIM model of *Casa de Vidro*, can be a powerful tool for the conservation of the Lina's house allowing structural and diagnostic analyses, virtual navigation and costs evaluation for both maintenance and project proposal activities (which could be based on accurate drawings extracted from the point cloud database)

4 Final Remarks

The great opportunity to document some of the most significant architectures conceived by the masters of modernist architecture in Brazil has shown how the integrated methodology is able to reveal new aspects of the buildings and to analyse spaces and surfaces by means of innovative methods that have allowed to define new and completely unexplored research paths. In the representative phase there is a motivational value, which makes the survey-representation a real project itself, with significant critical implications aimed at the determination not only of geometric precision but, especially in architecture, of visualization and conceptual representation of reality (see the *Casa Olivo Gomes*' 3D model). 3D database elaboration makes also possible to highlight some architectural features such as the stairs structure and the precise shape of statues, water bodies and other structures.

The three-dimensional surveys have proved to be essential to represent areas that would be otherwise impossible to analyse, for example elevations immersed into the vegetation and the surrounding landscape (for instance at *Casa de Vidro*), and to find planimetric matches essential to understand the architectural "philosophy" on which the architects have based the realization of the houses (see *Casa das Canoas* case study).

Furthermore, the research project was a great opportunity to investigate different methods for the digital acquisition of surface characteristics such as colour, texture, morphology, and macroscopic features of decay by spectrophotometric analysis. These findings could then be confronted with chromatic data obtained by spectrophotometric analysis.

In conclusion, some considerations can be outlined in order to point out a possible procedure to exploit the 3D survey and modelling methodologies for enhancement and conservation of the modernist assets. First of all, the research has shown that interdisciplinary competences are needed in order to manage survey procedures and cultural heritage analysis. The outcomes from 3D data acquisition can be a useful integration of non-destructive techniques and monitoring technologies able to identify deterioration mechanisms acting on original materials and structures and critical areas for deeper investigations. Awareness of accuracy and limits of different technologies is the starting point to merge 3D metric survey purposes with a multidisciplinary approach to diagnosis that need to be shared with local stakeholders.

Thanks to these joint efforts the digital documentation outputs from HBIM models to the most advanced 3D diagnostic procedures, are going to be a strong base for future management and conservation plan and they will preserve the memory of these extraordinary houses.

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