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SCIentific RESearch and Information Technology
Ricerca Scientifica e Tecnologie dell'Informazione
Vol 7, Issue 2 (2017), 115-132
e-ISSN 2239-4303, DOI 10.2423/i22394303v7n2p115

LOW COST SURVEY AND HERITAGE VALUE

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Abstract

In the last two decades, the approach to surveying, profoundly modified by massive acquisition methodologies, has strongly influenced the construction of 3D models, which come closer and closer to reality. Various operations performed on numerical models prove to be necessary for defining geometric or mathematical models, which become ever more congruent with architectonic and archaeological artifacts. Today models are the point of departure for all the activities aimed at a more profound knowledge of the object. Different fields of operations connected with Cultural Heritage - from cataloguing to preservation, from designing to restoration and valorization - begin to present the enormous potentialities inherent in models obtained through 3D surveys. In some cases to observe artifacts in various scales and from different viewpoints, it is such to explore such models than the work itself. Moreover, they make it possible to design and prepare reconstruction, reinforcement and restoration operations directly in three dimensions as well as to document different transformations the artifacts underwent in the course of centuries. Models prove to be an indispensable element not only at the stage of preparation, preservation and valorization but also at that of prevention, which at present seems to be the most efficient and far-sighted means for ensuring the stability and security of architectonic and urban heritage.

Keywords

Cultural Heritage, surveying, survey, 3D massive acquisition, 2D/3D models, Cuba, Inps Building

1. *Introduction*

Every organism of architectonic heritage is a complex system that embraces interlinked tangible (material) and intangible (non material) values which equally contribute to its overall value. In order to grasp its essence it is necessary to study it properly, carry out enquiries that go beyond its exterior aspect and include it significant (constituent) elements. In other words: it is necessary to survey it (Bianchini, Inglese, & Ippolito, 2017; Hess, Petrovic, Meyer, Rissolo, & Kuester, 2015).

Indispensable in achieving this objective are all the activities directed towards a deep knowledge[1] of the artifacts involved in the survey and surveying operations (Bianchini, 2012; Chih-Heng, Mills Jon, Gosling, Bridgens, & Grisdale, 2010).

Taking into account the cultural significance of the object of study and having subjected it to observation and proper cognitive processes, the surveyor enters into a dialogue with the structure so that it becomes possible to preserve it correctly and communicate its value (Bianchini, Borgogni, Ippolito, & Senatore, 2015).

Knowledge is propaedeutic for the evaluation and preservation of cultural heritage, both of which are intimately related with innovative technologies in all the stages of the process: acquisition, management and sharing.

A few decades ago any consideration of cognizing a cultural artifact had to take into account a series of limitations inherent in the traditional instruments applied as well as the long time it took to acquire information. The consistency of data gathered often proved to be insufficient and inadequate to obtain results scientifically exhaustive. Nowadays, observing how this

[1] Whenever in the course of their evolution human beings confronted complex phenomena they invariably sought to develop strategies which enabled them to overcome the limitations imposed by their senses. Descartes demonstrated clearly that this involves two different kinds of knowledge: the common-sense knowledge (which we acquires through experience) and the profound knowledge that can be reached solely by methods and techniques exclusively related to the mind and which are beyond the capabilities of our senses.

process is tackled, we can only conclude that the instruments of massive acquisition, digital representation, the use of systems of fast communication of raw data and 2D/3D models have become almost the only vectors for the study and communication of the architectonic and archaeological artifact (Bianchini, Ippolito, & Bartolomei, 2015).
Technological development of the last two, three decades has profoundly changed the process of knowledge. While considering indispensable the contribution of the scholar at each stage of cognition, it has become evident that the new instruments have transformed surveying operations into semi-automatic procedures capable of gathering millions of points at a low uncertainty level (Baglioni & Inglese, 2015).
The term "digital building recording technologies" leads us to a relevant gathering of data accurate and efficient as to their dimensions, but until now the measurable aspect of a building cannot be considered exhaustive for its cognition.
Hence the necessity to study the dichotomy between quantity and quality of the datum inherent in every survey carried out with instruments of massive acquisition. While the term "quantity" refers to physical parameters, coordinates, positioning and geometry, all of which define the artifact, "quality" describes its contingent or permanent properties, the formal aspect concretely determined. The control over the datum "quality" is connected with the set of parameters which define the properties of measure: precision, uncertainty, repeatability, accuracy. Quality is also involved in the capacity to consider all the aspects of the artifact that make a better understanding of its intangible values (chromatic, material, those concerning its preservation and its context).
Information acquired considerably improve qualitatively when we integrate diverse methodologies, considering that each of them fills in the gaps left by others.
The research's objectives are various; it rests on the profound knowledge of an architectonic complex, deeply stratified, whose complexity will be enhanced in the process of synthetization through digital models, a correct interpretation and management of information. Specifically, the enquiry will be oriented towards an analysis of the quality of the data acquired massively, ranging from the urban scale to that of the detail.
The other fundamental aspect of the study, after years of consistent use of low cost acquisition instruments (Alby, Smigiel, Assali, Grussenmeyer, & Kauffmann-Smigiel, 2009) as a photographic camera, is to test the detail level possible to achieve in terms of metric accuracy as well as metric, chromatic and surface information[2] to document some different urban context. Another fundamental aspect seems to be the comprehension of quality level that the models obtained with photographic data capture achieve as well as their possibility to perform on urban scale. The presented case studies analyze two extremely different in urban environments, for each year of construction, location and formal characteristics. However, both offer the opportunity to show the current potential of the complexity of 3D surveying (Koutsoudis, Vidma, Ioannakis, Arnaoutoglou, Pavlidis, & Chamzas, 2014). The analytic phase of data acquisition and gathering of any information can serve to increase the knowledge of the object under study. Therefore, the great number of dimensional and positional information reduces the danger of a subjective interpretation, it ought to be understood solely as a propulsion for successive in-depth analysis.

2. INPS building'survey. Between geometry, shape and harmony

This survey experience offered the opportunity to test, once again, the integrated methodology applied to urban fronts.
The experiment concerns a study focused on the building in Piazza Augusto Imperatore in Rome. The Piazza, as a result of the intervention of architect Vittorio Morpurgo in 1939, under the direct control of Mussolini[3], is characterized by four strongly diversified fronts (Fig.1).
One side was occupied by the building of Ara Pacis (now replaced by Richard Meier's "Teca");

[2] The comparison between high cost and low cost survey instruments is possible because they give analogous result in terms of models (numerical model) and edit operation to construct mesh models. Infact, since some years, SFM allows to get analogous results of 3D laser scanner by supporting just the cost of a simple camera.
[3] Benito Mussolini (29 July 1883 – 28 April 1945) He was an Italian politician, journalist and leader of the National Fascist Party (Partito Nazionale Fascista), ruling the country as Prime Minister from 1922 to 1943—constitutionally until 1925, when he dropped all pretense of democracy and set up a legal dictatorship. He was the founder of Italian Fascism.

the other side is closed by the Church of St. Girolamo of the Schiavoni with the annexed College of the Illirici and the other two sides – by a pair of buildings called building A and B in the general plan of the project (Morpurgo, 1933; Del Debbio, 1936; Muñoz, 1938).

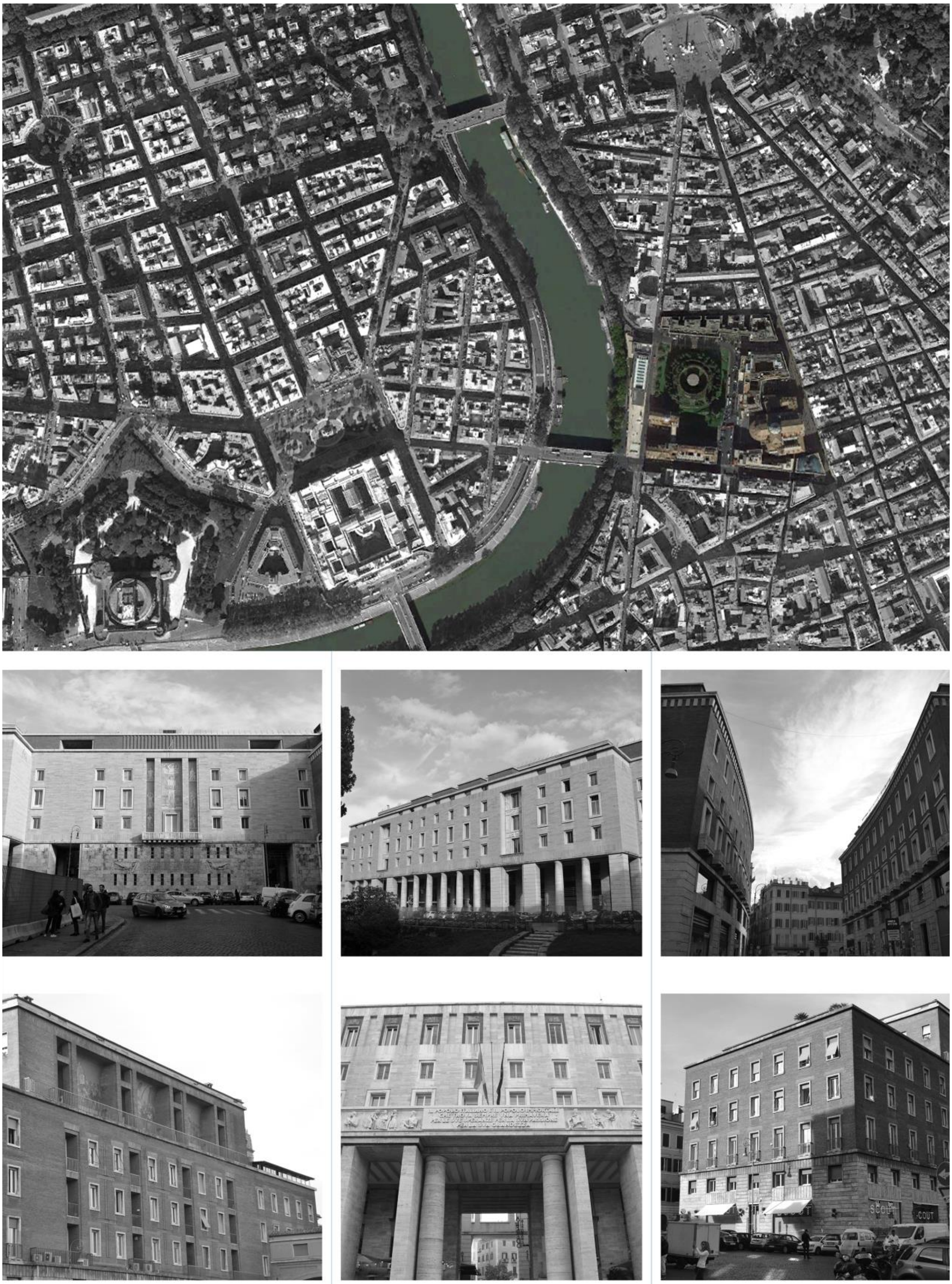

Fig. 1: INPS building at Piazza Augusto Imperatore in Rome

An integrated survey campaign was carried out on the four façades facing a very stratified spatial area also characterized by emergencies realized in different historical periods. The surveying focused mainly on the façade of the buildings, with particular attention to the so called building B, characterized by a declared fascist style, enriched by an evocative mosaic of the "Mito di Roma", by the artist Ferruccio Ferrazzi.

The present study was conducted with the aim of analyzing the façade of the building by studying geometric and proportional rules linked with its composition. The starting point is the surveying data that allows to build 3D and 2D models used to propose some considerations. In particular, the possibility to acquire a huge quantity of data increasingly more reliable from the metric point of has made it possible to make assumptions on both the urban scale and the geometric-compositional aspect of the façade, as well as to the detail scale, by combining aspects related to the materials used and the decorative apparatus.

The integrated surveying operations – which consisted of preliminary topographic phases, with the realization of a polygonal of the square, indissolubly linked with the next digital photogrammetry operations (Fig.2; Fig.3) – made possible the orthogonal restitution of the fronts in metric format (Baglioni & Inglese, 2015; Carpiceci, 2012). More than that, combining topography with photogrammetry operations, allowed us to work on a 2D model (Fig.4; Fig.5) metrically reliable thanks to the topographic survey and accurate in terms of aspect, distinction of materials and state of conservation thanks to the data coming from photography (Gaiani, 2015).

On thus obtained bases, several geometric proportional studies were carried out both on the architectural parts of the buildings and on the decorative inserts. In particular, the studies that have been conducted starting with the piede romano (=29,7 cm), have highlighted the link between the rationalist design and ancient Roman architecture as an obvious piece of propaganda. This is a specific theme of Italian rationalism during the fascist period: in architecture, the attempt to bring back the supremacy of ancient Rome and, in other words, the mith of the Roman empire has been accomplished not only through the monumental dimensions of buildings, their iconography, and the combination of materials but also on a deeper level, by using the roman unit of measurement. This is relevant in order to demonstrate at what extent architects used ancient models to proportionate the space and to manipulate it. The proportional geometric study (Fig.6) focus on the great mosaic has also highlighted the indissoluble relationship between architecture and decoration during the fascist dictatorship, strongly corroborated by rigorous geometry references, golden ratio and recurring modules. In fact, the mosaic of the "Mito di Roma", analyzed by the rectification and frame restitutions by digital photogrammetry, revealed some decorative details of high illustrative value as well as the compositional rules based on the golden section, otherwise unidentifiable. The whole façade is constructed proportioning the relative height of the two orders with a logarithmic spiral, this construction stress the use of a golden ratio to design element. This tool is used not only for the heights but also for the length of the building: The second order of the façade contains two specular logarithmic spirals constructed basing on the height of the order. The intersection of the two spirals delimits an area that comprise the representation on the mosaic of the symbol of the birth of Rome: the she-wolf.

The geometric construction found on the façade is defined through the construction of an equilateral triangle obtained by subdividing the base into 3 equal parts, from the vertices of the base a semi-circle with a 1/3 ray of the side is traced (Fig.7). The base is composed of 5 parts. It is translated, to make it tangent to the two semicircles and to the upper vertex of the equilateral triangle. Thus the basal part and the second score above are identified. The relationship between the basement and the second order is a golden ratio, based on the logarithmic spiral (golden section).

A square defines a golden rectangle by lowering the diagonal on the extension of the base. Approaching this square a square with the larger side of the rectangle on each side, we will always obtain a new golden rectangle (Fig.8). Continuing to build squares on the major sides of the rectangles obtained, we obtain a figure composed of squares arranged in a spiral around a pole O, where the main diagonals of the successive golden rectangles meet. If for the points of encounter of these diagonals with the successive squares let us pass a curve this is the logarithmic spiral. An additional study has been conducted on the relationship between their dimension and disposition of the travertine slabs, which deserve a specific analysis. The slabs are different in size depending on their location. In particular, is it possible to recognize three types of sections where the height remains constant while the base changes in relation to the window position.

Fig. 2: INPS building: topographic and photographic surveying

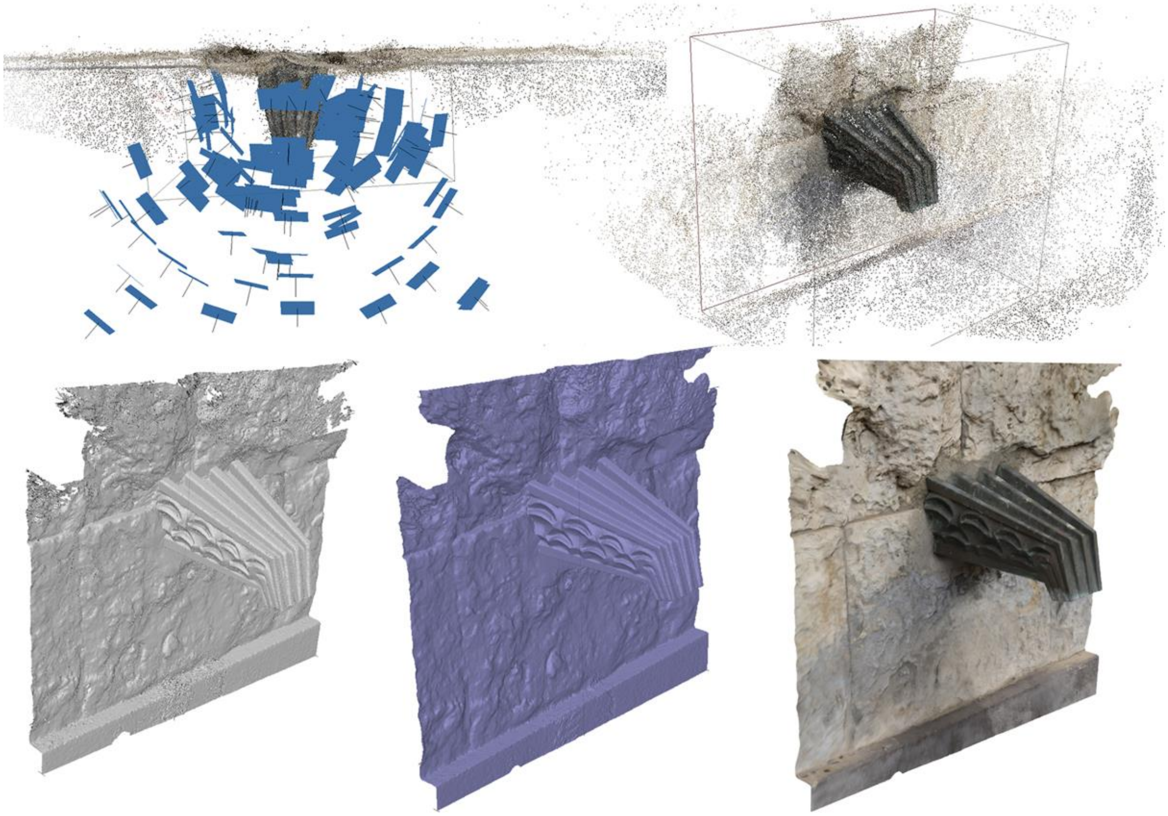

Fig. 3: INPS building: Structure from Motion of detail

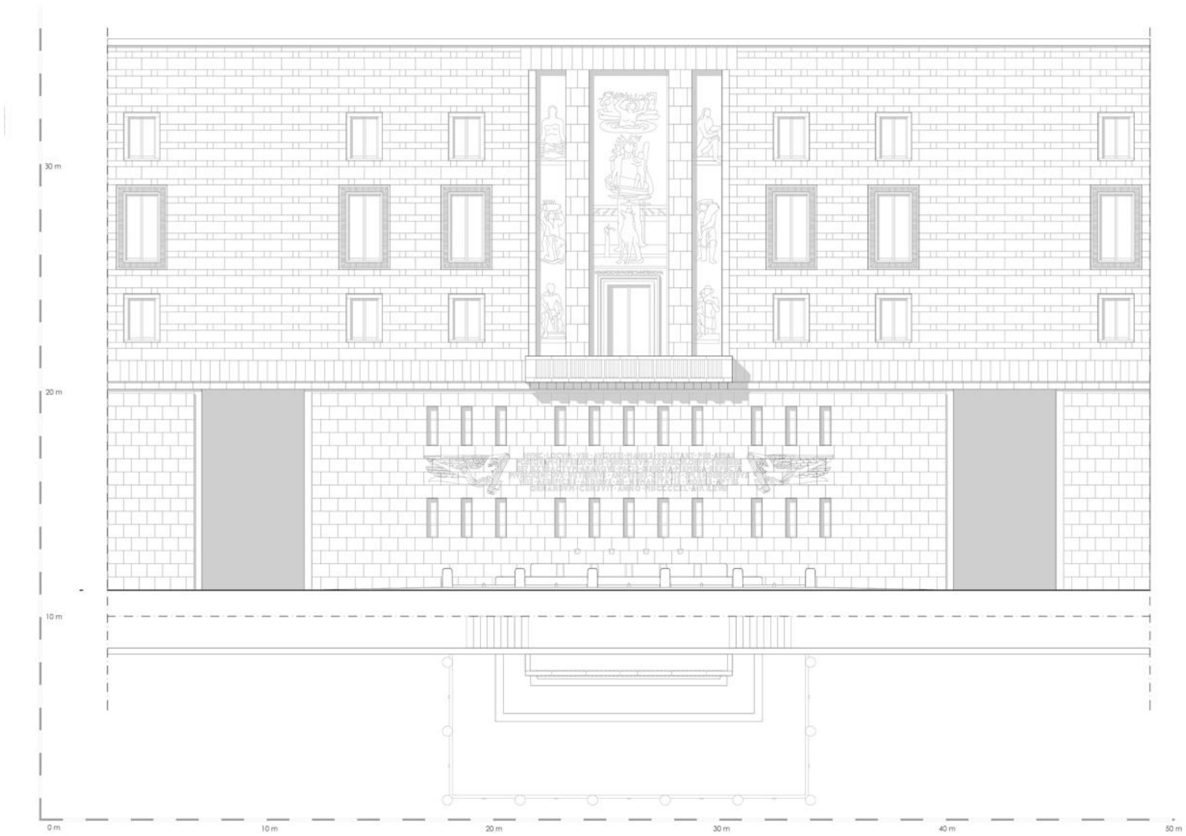

Fig. 4: INPS building façade: 2D model

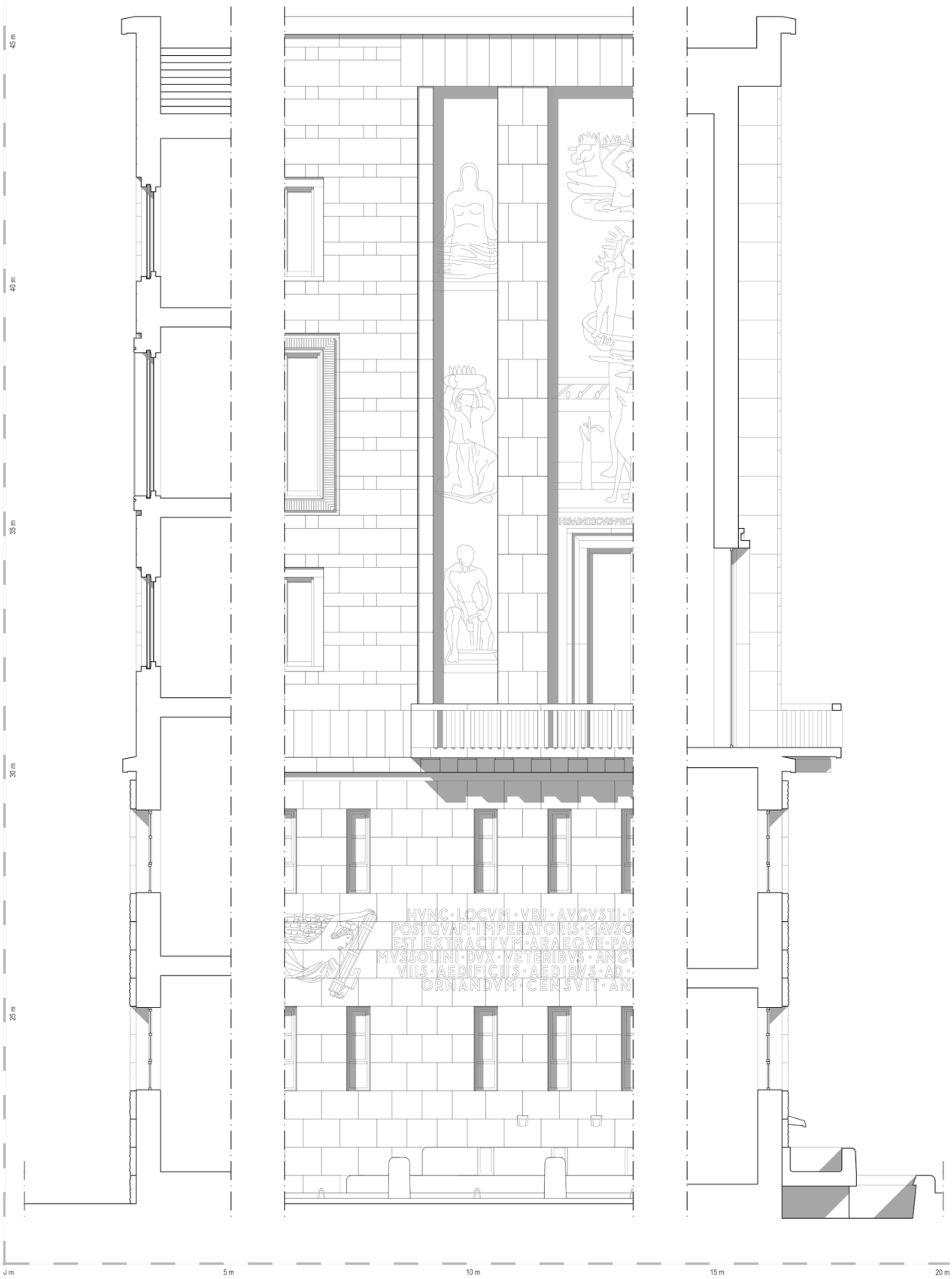

Fig. 5: INPS building façade: 2D model

Fig. 6: INPS building façade: proportional study

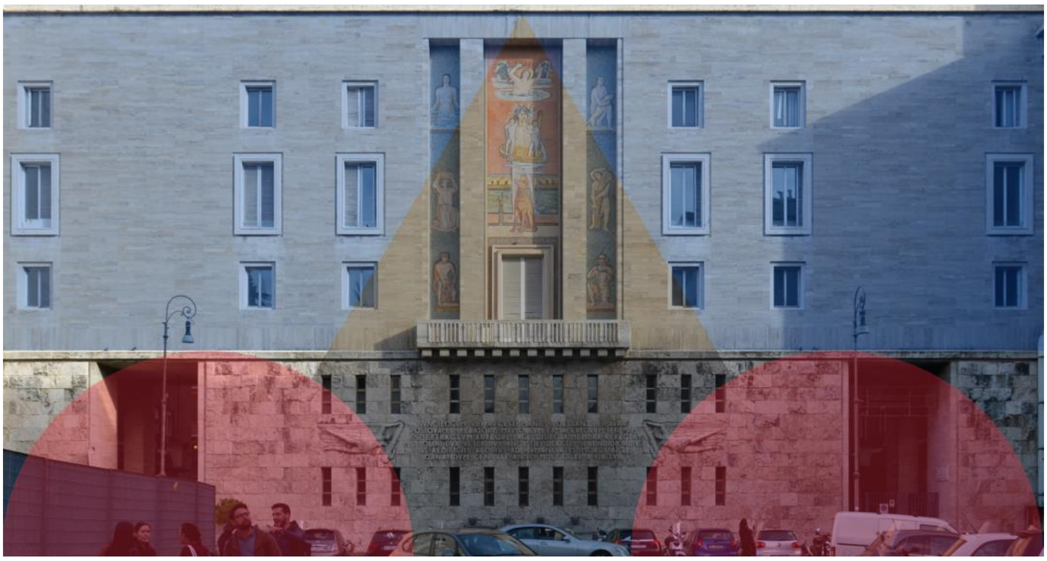

Fig. 7: INPS building façade: geometric study

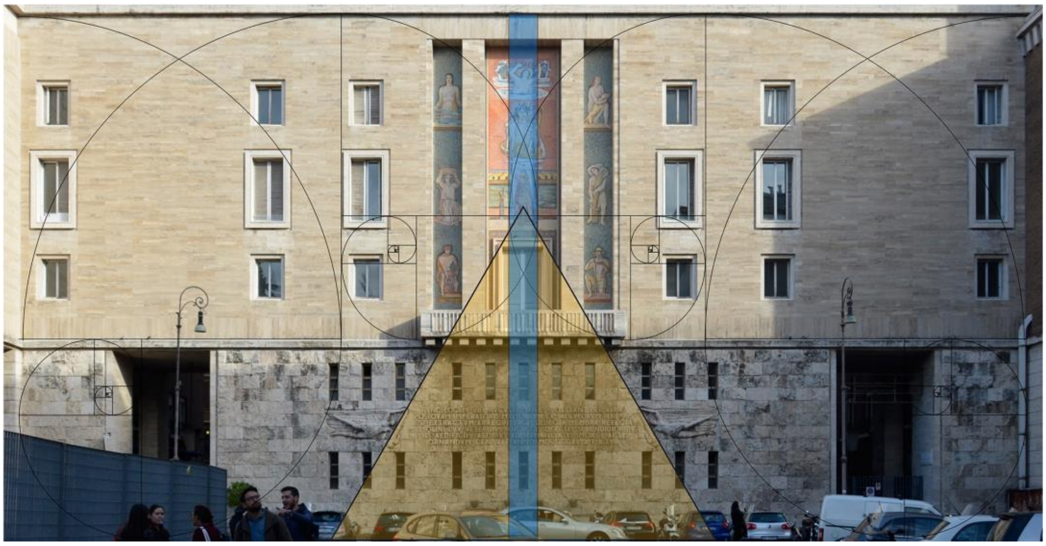

Fig. 8: INPS building façade: geometric study

On this subject, pictures of the final maquette of the project were published on the "Architecture: magazine of the National Syndicate Fascist Architects" magazine (December, 1936), they show a pretty total correspondence between the maquette and the built-up architecture; this is true expecially for the mosaic decoration in which the quality of details is impressive compared whit the one realized.
This study is based entirely on the disciplines of representation, on results from a close synergy with massive acquisition techniques interfacing with descriptive geometry. The elaboration of surveying data has allowed to study deeply the analyzing building. Survey is indispensable for the understanding of aspects of non-immediate perception but without which it is not possible to obtain a complete knowledge of the analyzed object. The possibility to have quantitative and qualitative data, which express the permanent and contingent characteristics of the case study, guarantees the comprehension of the space considered as a complex system of discrete elements gathered from the architect's mind.
It is clear that such considerations may be valid for any element of architectural heritage. Operations of deep knowledge, now increasingly linked with the ability to acquire data and build ever more heterogeneous and dynamic models, have the purpose to preserve, evaluate and popularize cultural heritage.

3. Urban space's survey between photography and measures.

Structure for motion (SFM) application both in medium and large scale permitted to understand the actual potentiality of survey methodology related to architectonic and urban field. The second case of study taken into examination treats the data acquisition pursuing the aim of developing a tridimensional representation of historical buildings belonging to the wide artistic and architectonic heritage located in the city of La Havana. The study is especially focused on 5 principal squares, meaningful locations identifying the reality of Havana's historical center (Venegas Fornias, 2003). The survey was realized on fronts and arcades of 59 buildings associated with those 5 squares, located in the historical center. It's been 30.000 m^2 of floors and as much vertical surfaces for the fronts overall. It's been possible to create photo-realistic models which could give geometrical information, material determination, textures and colors of buildings and squares just with the use of traditional and commercial tools, cheap and easily transportable for their limited weight and space requirement. The fact itself of the research taking place in an uneasy environment constituted on field the main critical point for several complex reasons: the exigency of having every tool reduced to the minimum in term of space, cost and weight, to reduce also the time for survey and photos on field, to face difficulties due to the presence of people unintentionally disturbing the operation. Least but not last the obstacle constituted by the small amount of time available for the survey to take place. This process needs, in fact, particular lighting conditions. Photographic and metric survey's step on field were carried out with traditional techniques accomplishing preliminary surveys at first, always handmade in a systematical way. Direct survey consists in the acquisition system through which priority measures are defined directly on field and personally observing the object of the study. That's because every kind of constituent and every kind of space has its own characteristics. Direct survey imposes measurements on field by putting the focus on distances between specific spots (edges, volumes extremities, frames, openings etc) at the same level trough different proceedings. It also consists in recollecting useful measures to locate every significant spot of the studied object in a determined space. Tools implied in this survey were elected for their practicality, effectiveness, conspicuity, weight and cost and that's why they're considered suitable for Cuban reality. Every block of images recollected for SFM it's been associated with measurements related to reference sizes in 3 dimensions (widths, heights and depths), required for the scaling and while checking the correctness of construction of 3D/2D model. For what is concerning fronts, measurement of widths and heights were executed between specific spots and noted for a preliminary survey with impeccable precision. The following phase was the photographic survey's schedule in order to optimize the time needed for the process while recollecting every necessary information for construction of 3D/2D model. Not a few problems arose during this step for critical issues due to a proper illumination and fixed and mobile physical obstacles. Data recollection had to fulfill the

hedonistic principle of saving time and money and it represented therefore an occasion to deepen and develop a proper and rational methodological criteria.
SFM techniques applied to architecture field makes it possible to recollect data with precision, speed and realism. As much as traditional methods could be refined it would have been necessary to rely on approximations and artifices to make the graphic as much as possible similar to reality. Thanks to new SFM techniques it's very easy to achieve reality, especially when dealing with the representation of surface's details and textures. This permits to gain a full information corps for the restitution of features composing the building and allowing the comprehension of architecture through the drawings. The most important point that have to be respected to achieve a high quality model with SFM techniques is to create a good photographic set from the beginning taking into consideration the position, the angle of the focal axes with respect to the captured surface, quantity and quality of pictures, lighting conditions, surface features of the object.
To recollect an amount of useful and exhaustive pictures for SFM it was essential to use different photographic survey's techniques thus taking proper choices in the phase of calibration and orientation of the camera. For every recollected spot it's necessary to execute the survey from at least two different positions with the same camera at the same focal length. It's also required the whole presence of the building in every picture, that has to be framed to occupy the main portion of the screen: in this way a more precise data elaboration is possible. This type of constraint usually brings the choice of oblique oriented points of view with respect to dominant levels of the building. It also permits an information recovering with the identification of analogous spots on different depths levels. Morphological complexity of the buildings caused the survey phase to be even more arduous because the recollection of architectonic spots composing the construction is articulated on more levels some of which dominants on the others. Every dominant level must have at least a couple of oblique pictures respecting the level itself, and also to get a surface's texture the photographic collimation axes had to be the more perpendicular as possible to the surface to be mapped. Once the choice about camera setting were made, the photographic campaign started following methodologies already defined off-field. Those modalities followed case by case rules which weren't always applicable because of physical obstacles obstructing the view. In particular in those five squares taken into consideration some difficulties were found: some of the restrictions were common like for example the impossibility to capture the whole building front because of fixed or mobile obstacles as vegetation, urban elements, temporary installations like stages or markets, vehicles, people and auto-occlusions that came from buildings articulation (balconies, arcades and other front's articulations). Another requirement which created some problems was the need of having bird's-eye pictures of every construction overlooking the squares. Following the choice of not using drones for aerial photography because it would have been unfavourable in terms of costs, conspicuity and authorizations, the problem was solved individuating bird's-eye point of view from higher buildings around. An additional critical mark was the shooting of complex and wide buildings for which the photographic recollection had to be partial for the lack of possibility to frame it entirely. On a general basis a good photographic set should have 50-70 pictures intended for elaboration. For every square photographic set for building's front and relative arcades and floors several techniques were implied, depending both on the type of object to be restituted and on the analysis' purpose. The 3 combined or integrated techniques implied were: shooting with parallel axes (simple or multiple) (Fig.9), shooting with converging axes (Fig.10) and panoramic shooting (cylindrical, spherical or partial) (Fig.11). Shooting with convergent axes, specific for SFM processes, was used to capture building's fronts by setting the camera in portrait position (vertical) or landscape (horizontal), depending on the object's proportions. For some construction's spots presenting geometrical complexities a deeper study was carried out on columns, floors and arcade's ceilings where spherical shooting were made. Building's fronts were also shot using parallel axes techniques: it consists in the shot of multiple pictures, moving alongside the front and shooting when the picture frame presents at least the 25% of the former frame (similar to classic photogrammetical survey).
For what Is concerning the shooting of external and centrically composed locations like cloisters,

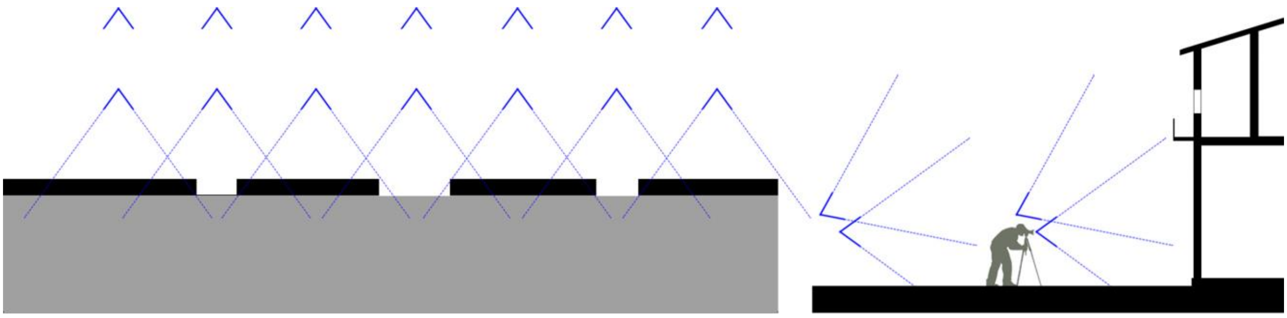

Fig. 9: Shooting with parallel axes (simple or multiple)

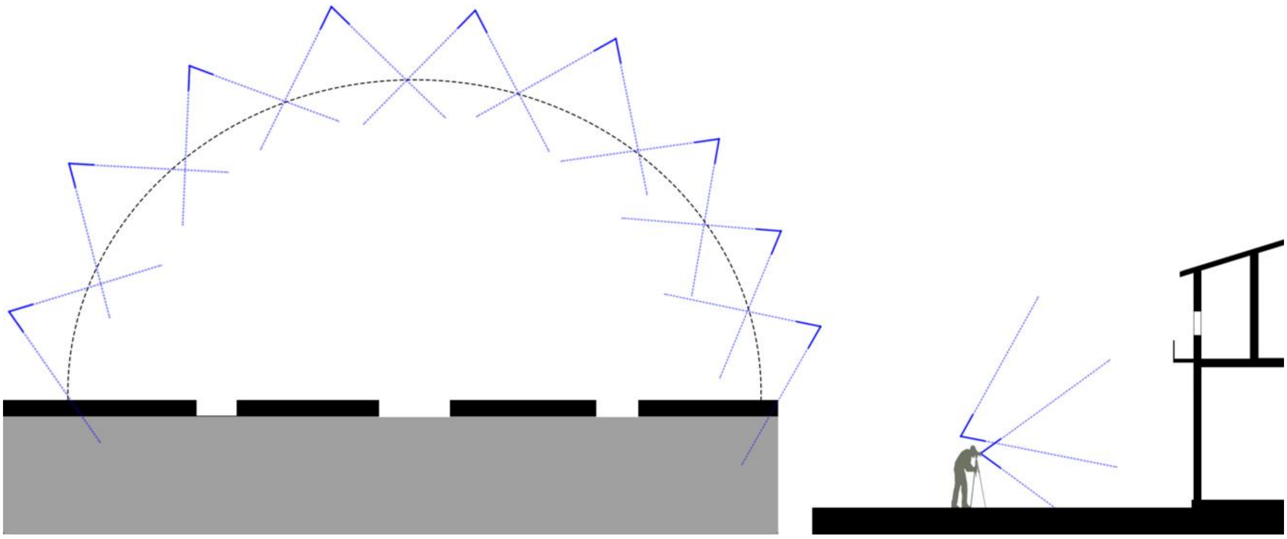

Fig. 10: Shooting with converging axes

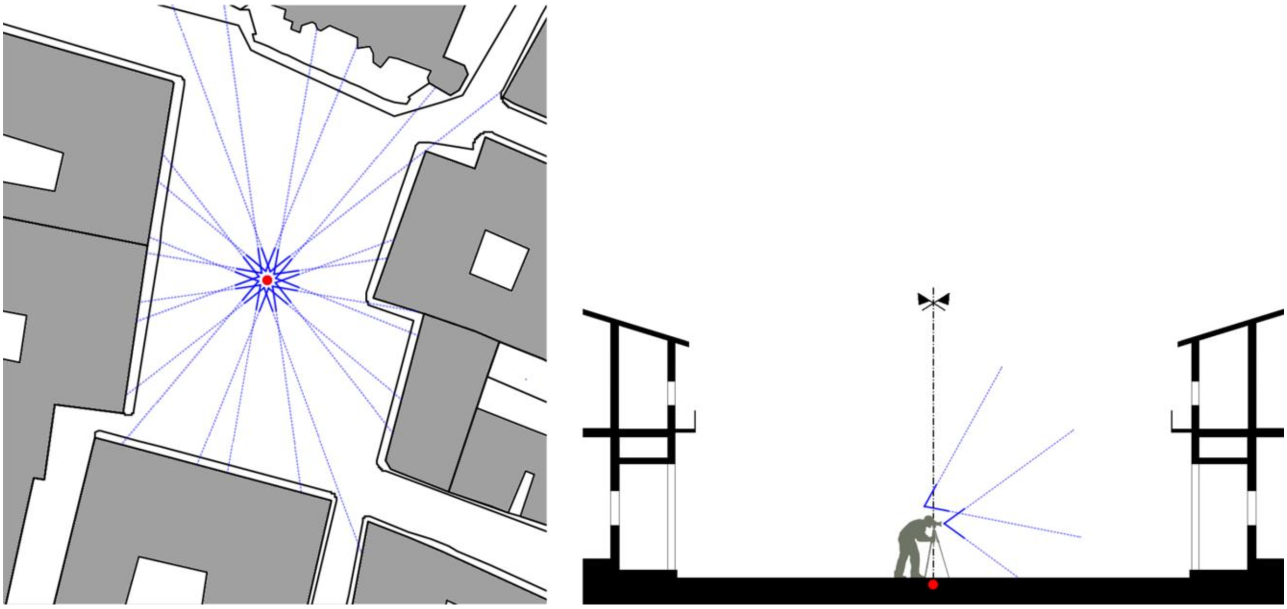

Fig. 11: Panoramic shooting (cylindrical, spherical or partial)

yards and squares in particular, cylindrical shooting technique was implied. This method is performed by taking pictures from a central spot and turning around with the camera taking shots with a 25% images overlap and choosing the proper camera mode between portrait or panoramic. Further additional difficulties were the strategic choice of shooting to define arcades, complex elements with a big amount of components and details, for the orientation of the fronts in every direction, arches, floors and ceilings. The survey of those constituents required a big number of pictures and the combined use of the already mentioned three techniques. The final work consisted in rendering with commercial hardware technologies and dedicated software, in particular Agisoft Photoscan, all the information recollected in order to create a substantial information unit (Fig.12; Fig.13; Fig.14).

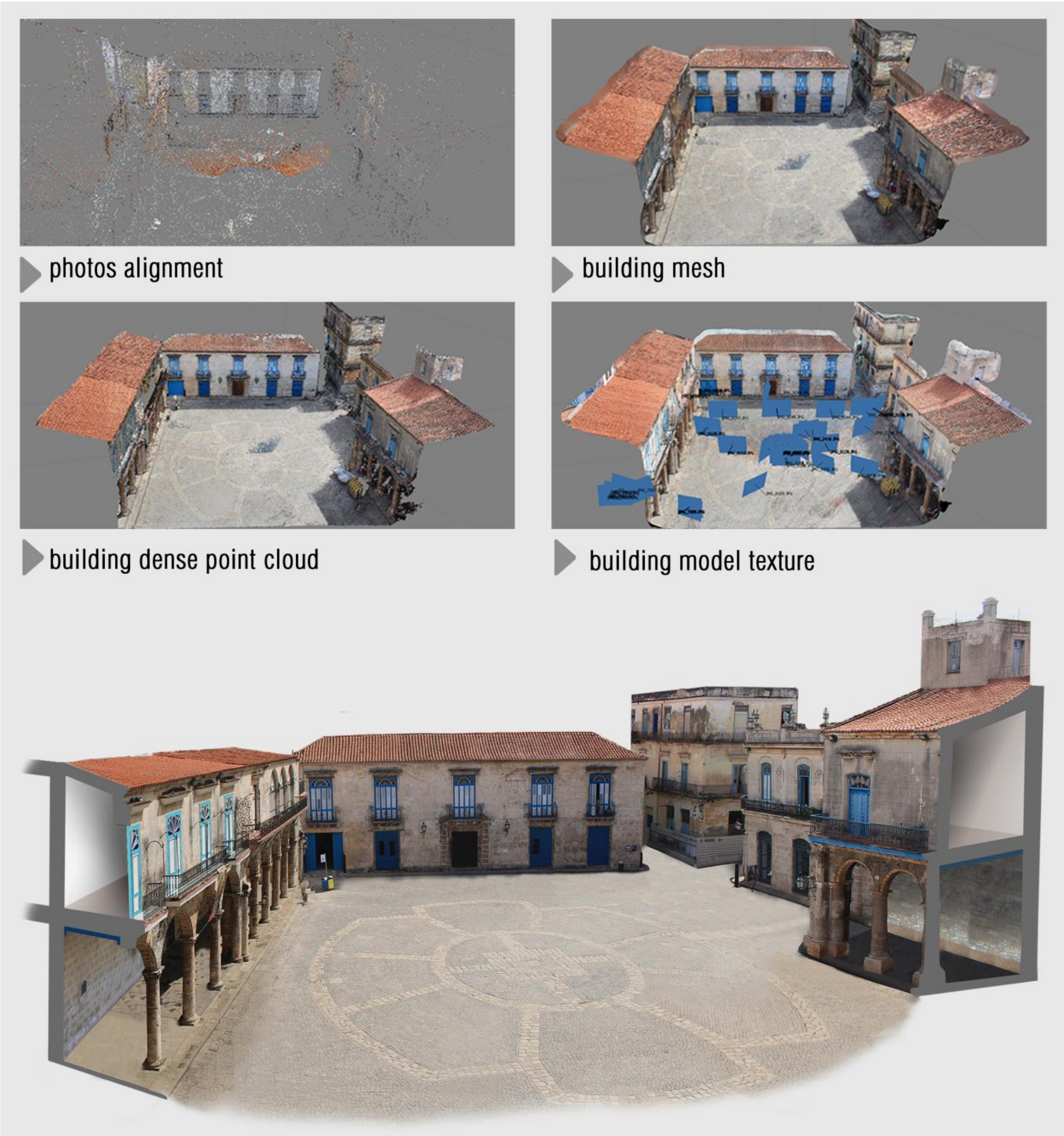

Fig. 12: Plaza de la Catedral: structure for motion

Fig. 13: Plaza de la Catedral

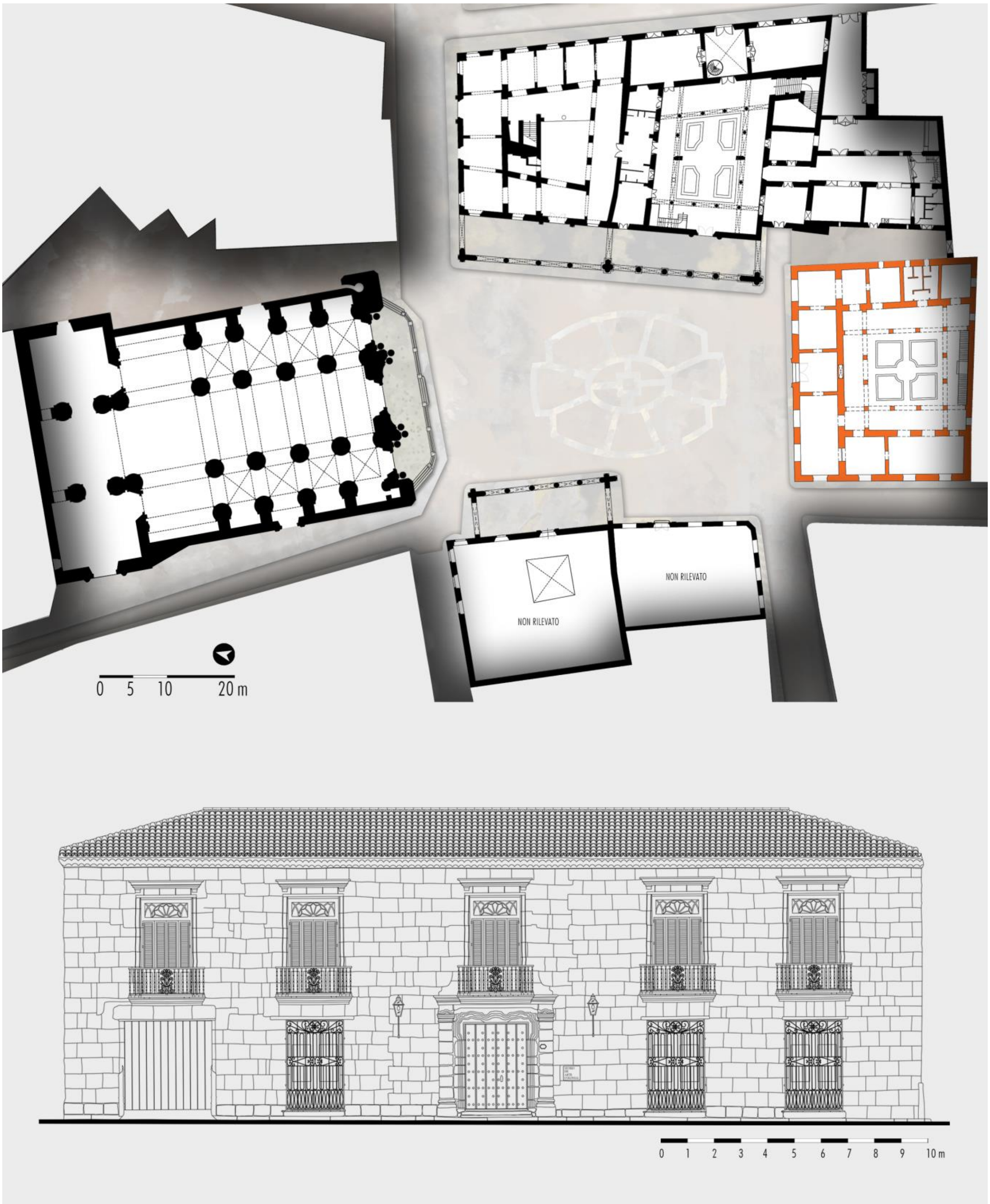

Fig. 14: Plaza de la Catedral: 2D model

A special evaluation needs to be made on measures checking. Absolute mistakes has been certified, those due to camera resolution, settlement of values during the calibration and orientation phase and uncertainty during spots pairing, in addition to those mistakes attributable to direct survey itself. The last one can be valued in 5 mm of tolerance more other 5 mm due to a deformation of the tape measure or its imperfect straightness, even though a great part of measurements was taken more precisely using a laser range marker. To reduce inaccuracies during the survey, a measurement of maximum distances took place for fronts, width, height, depth of the building, considered as a basis for model scaling. Wherever not possible especially for heights the measurement were executed on quotes related to balconies, mouldings and portals. During model scaling step, basis measurement on field were introduced in the program. Taking into consideration those measures affected by an original mistake of 10 mm on a 20 m front (equal to a 0.05%) and comparing measures extracted from the model with other known ones from the survey, it is obtained a medium value of absolute mistake equal to 0.21% on 59 buildings. The range of mistake is from 0.14% to 0.30% with a standard deviation of 0.028%.

6. Conclusion

The study of analyzed subject demonstrated that cognition of architectural and urban scale does not end with identifying its geometric and morphological characteristics, but has to be based on a selective and specialized reading of various aspects. Collecting, interpreting and disseminating a large amount of information helps to define a system we can use to understand our Cultural Heritage. The system has to be based on scientific process used to achieve a dual objective: to document acquisition using a heterogeneous set of data and metadata to guarantee repeatability and to ensure data quality during data capture and processing of 2D and 3D models.

Today there exist integrable methodologies of surveying which ensure surveys of entire cities in a few days taking advantage of photographic acquisition. In this manner models obtained either the most important historical artifacts or entire built-up areas can be obtained at no time at all and at the necessary scale. In the digital age, the concept of model is based on digital techniques now present in all architectural representation tools, techniques which have also invaded the field of architectural survey (Vrubel, A. and Bellon, O.R.P. and Silva, 2009). 2D and 3D models give the possibility to have static and dynamic representation that allows us to move elaborations in a transitive manner around freely and shift from outside to inside the object. Now the concept of models is refined and updated giving more possibilities to study objects thanks to the complex and absolute interactivity between the real object (point clouds and photographs) and virtual system of 2D and 3D digital models.

The use of these models would make it possible to work with more extensive knowledge when securing artifacts of Cultural Heritage. Acting upon more extensive knowledge reduces the costs and in some cases shorten the time necessary to carry out the intervention. 3D models prove to be indispensable for preventions, and for the process of cognizing. Historical architecture documented through the survey with 3D models can always be subjected to analysis or conservation and preservation intervention. It is precisely on the basis of this conception – which considers knowledge and prevention to be the most efficient and long-distance instrument – that we ought to work with our methodologies with the certainty that we can contribute significantly towards our country.

Acknowledgment

2D and 3D model of INPS Building by Martina Ambrogi, Francesco Caparello, Malte Ruths.

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